EcoBalance 2014

The 11th International Conference on EcoBalance

ABSTRACT BOOK

Creating benefit through life cycle thinking

27–30 October 2014, Tsukuba, Japan

Organized by

The Institute of
Life Cycle Assessment, Japan

Abstract Book of the 11th International Conference on EcoBalance

Edited by

Yasushi Kondo
Faculty of Political Science and Economics, Waseda University, Japan

Shinsuke Murakami
Graduate School of Engineering, The University of Tokyo, Japan

Yasuhiro Fukushima
Graduate School of Engineering, Tohoku University, Japan

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Contents

Organizing Committee 4
International Advisory Board 5
Sponsors 6
Financial Supports 6
Cooperating Government Offices 6
Cooperating Organizations 6
Exhibitors 7
Session List 8
Invited Speakers 9

Program 10
Plenary Sessions 10
Oral Sessions 11
October 28, Tuesday 11
October 29, Wednesday 15
October 30, Thursday 20
Poster Session 23

Abstracts 30

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Ministry of the Environment

Exhibitors

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Session List

▶ Plenary Sessions

Opening Plenary
Closing Plenary

▶ Special Sessions

Tsukuba Special Session	28B3
Sustainability in the Chemical Industry	28A3–28A4
Global Food Security and Corporate Practices from Life Cycle Perspectives	
Global Strategies on Agriculture, Food, and Nutrients	28C3
Evaluating Management Practices	28C4
Resource Management in Agriculture	28C5
Green ICT	28D3–28D4
Sustainability of Materials and Industries	
Evaluation of Urban Mining	29F1
State-of-the-Art of Research and Developments in Ecomaterials for Low Carbon Society	29F2
Technologies and Assessments for Recovering Materials from Urban Mining	29F3
The Practical Challenge for Sustainable Industry	
Challenges, Experiences and Lessons	29C1
Organizational LCA (O-LCA): Concepts and Methodologies	29C2
Organizational LCA (O-LCA): Lessons from Application Studies	29C3
Sustainable value chain management by MFCA	30C1
Keys for the breakthrough in business	30C2
Sustainable Resource Management	30A1–30A2

▶ General Sessions

Estimating the Contribution to Avoided Emissions	28A5
Material Flow Analysis	28B4
E-waste	28B5
Driving innovation	28D5
LCA Methodology	29D1
Supply Chain Risk Management	29D2
City & Building	29D3
Behavior & Policy	29E1
Policy & Visualization	29E2
Agriculture & Foods	29E3
Energy	29G1–29G2
Waste Management & Recycling	30B1–30B2
Water	30D1–30D2

Invited Speakers

Keynote 1 **Values of life cycle thinking**
Junko Edahiro (Institute for Studies in Happiness, Economy and Society; Environmental Journalist, Japan)

Keynote 2 **Business strategies and environmental visions in the Hitachi**
Ryuichi Otsuki (Hitachi, Ltd., Japan)

Keynote 3 **Life cycle based sustainability solutions: How successful companies turn sustainability solutions into company benefit and business value**
Martin Baitz (PE International AG, Germany)

Closing **EcoBalance+20**
Matthias Finkbeiner (Technische Universität Berlin, Germany)
Guido Sonnemann (University of Bordeaux, France)
Kohmei Halada (National Institute for Materials Science, Japan)
Atsushi Inaba (Kogakuin University, Japan)

28A3-1 **Decision-support tools for designing sustainable chemical products and processes**
Konrad Hungerbühler (ETH Zurich, Switzerland)

28B3-2 **Hydrocarbon production from microalgae and its potential commercial use**
Makoto M Watanabe (University of Tsukuba, Japan)

28B3-3 **Mobility robot technologies in AIST for green innovation**
Osamu Matsumoto (National Institute of Advanced Industrial Science and Technology, Japan)

28C3-1 **Japanese nitrogen footprint model for the prediction of nitrogen loss to the environment**
Hideaki Shibata (Hokkaido University, Japan)

28C3-3 **Scientific robustness of including indirect land use change into life cycle assessment**
Matthias Finkbeiner (Technische Universität Berlin, Germany)

28C4-2 **Environmental impacts of organic rice farming in Thailand by using life cycle assessment to support policy decision on sustainable agriculture**
Rattanawan Mungkung (Kasetsart University, Thailand)

28C4-3 **Water footprint assessment of crops cultivation in Kurdistan Region, Iraq**
Marlia Mohd Hanafiah (National University of Malaysia, Malaysia)

28C4-4 **Life cycle assessment of biogas production in small-scale household digesters in Vietnam**
Van Thi Khanh Vu (National Institute of Animal Sciences, Viet Nam)

28D3-1 **Analyzing the carbon emissions of cloud computing facilities**
Kendra Tupper (City of Boulder, U.S.A.)

29C2-1 **A new direction for LCA: Organizational LCA**
Matthias Finkbeiner (Technische Universität Berlin, Germany)
Atsushi Inaba (Kogakuin University, Japan)

29F2-2 **Ultra-high temperature materials for higher-efficiency energy conversion of heat engines**
Kyosuke Yoshimi (Tohoku University, Japan)

29F2-3 **Advanced green innovation discovered by self-healing ceramics**
Wataru Nakao (Yokohama National University, Japan)

29F3-1 **Minor rare metals concentration from e-waste by combining novel comminution and physical separation**
Shuji Owada (Waseda University, Japan)

29F3-2 **Metal recovery from urban mines by hydrometallurgical methods**
Mikiya Tanaka (National Institute of Advanced Industrial Science and Technology, Japan)

30C1-1 **Material flow cost accounting: Simple approach, untapped opportunities, upcoming tasks**
Bernd Wagner (University of Augsburg, Germany)

Opening Plenary

Opening Ceremony and Keynote Lectures (Main Convention Hall) 10:00－12:00 October 28, Tuesday

Chair : Y. Fukushima
Vice-chair of EcoBalance 2014

Opening address **10:00–10:05**

Yasushi Kondo
Chair of EcoBalance 2014

Welcome address **10:05–10:10**

Kenichi Ichihara
Mayor, City of Tsukuba

Keynote 1 **10:10–10:50**

Values of life cycle thinking

Junko Edahiro
Institute for Studies in Happiness, Economy and Society; Environmental Journalist, Japan

Keynote 2 **10:50–11:30**

Business strategies and environmental visions in the Hitachi

Ryuichi Otsuki
Chief Strategy Officer, Information & Telecommunication Systems Company, Hitachi, Ltd., Japan

Keynote 3 **11:30–11:50**

Life cycle based sustainability solutions: How successful companies turn sustainability solutions into company benefit and business value

Martin Baitz
Director Content, PE International, Germany

Closing address **11:50–12:00**

Shinsuke Murakami
Vice-chair of EcoBalance 2014

Closing Plenary

Special Panel Discussion and Closing Ceremony (Convention Hall 300) 13:30–16:00 October 30, Thursday

Special panel discussion **13:30–15:00**

Chair : N. Itsubo

EcoBalance+20

Matthias Finkbeiner
Professor, Department of Environmental Technology, Technical University of Berlin; Chairperson, ISO/TC 207/SC 5 Life Cycle Assessment

Guido Sonnemann
Professor, ISM-CyVi, University of Bordeaux; Co-founder and former Programme Officer, the UNEP/SETAC Life Cycle Initiative

Kohmei Halada
NIMS Invited Researcher, Research Center for Strategic Materials, National Institute for Materials Science; President, The Institute of Life Cycle Assessment, Japan

Atsushi Inaba
Professor, Department of Environmental and Energy Chemistry, Kogakuin University; Former President of The Institute of Life Cycle Assessment, Japan

Closing ceremony **15:00–16:00**

Oral Sessions

▶ October 28, Tuesday

28A3 (Room 101) 13:30－14:50 October 28, Tuesday

Sustainability in the Chemical Industry-1

Chair : H. Sugiyama and M. Yoshikiyo

28A3-1 (invited) **13:30–14:10**

Decision-support tools for designing sustainable chemical products and processes

Konrad Hungerbühler, Stavros Papadokonstantakis

ETH Zurich

28A3-3 **14:10–14:30**

Development of the risk-based management system for chemicals throughout the supply chain

Fumiaki Shono, Satoshi Tokushige

Japan Chemical Industry Association

28A3-4 **14:30–14:50**

Chemicals management for sustainability in small and medium-sized enterprises

Emi Kikuchi-Uehara, Yasunori Kikuchi, Masahiko Hirao

The University of Tokyo

28A4 (Room 101) 15:10－16:30 October 28, Tuesday

Sustainability in the Chemical Industry-2

Chair : H. Sugiyama and M. Yoshikiyo

28A4-1 **15:10–15:30**

The use of LCA as a metrics in advancing and scaling up green chemistry research: The case of black liquor

Amandine Foulet, Hervé Deleuze, Philippe Garrigues, Guido Sonnemann

University of Bordeaux

28A4-2 **15:30–15:50**

Sulphur distribution to products in wet biomass gasification

Kenji Koido, Yutaro Watanabe, Kiyoshi Dowaki

Tokyo University of Science

28A4-3 **15:50–16:10**

Estimating reduction of environmental load for resource recovery from plastic waste by LCA methodology and plastic waste processing pathways

Akihiro Izumi, Hajime Munekuni

Plastic Waste Management Institute

28A4-4 **16:10–16:30**

Applying c-LCA for challenges to global warming at Asahi Kasei Corp.

Junichi Nakahashi

Asahi Kasei Corporation

28A5 (Room 101) 16:50－18:10 October 28, Tuesday

Estimating the Contribution to Avoided Emissions

Chair : A. Inaba

28A5-1 **16:50–17:10**

Guideline on quantifying and reporting the avoided emissions of products

Motozo Yoshikiyo, Kiyoshi Kasai

Japan Chemical Industry Association

28A5-2 **17:10–17:30**

Establishment of Kawasaki mechanism, the certification program of avoided emissions outside Kawasaki city

Shoichiro Tsuruta[1)], Masayuki Kanzaki[1)], Akikazu Kobayashi[2)], Toshifumi Takamizawa[2)], Ichiro Daigo[3)]

[1)]Japan Environmental Management Association for Industry, [2)]City of Kawasaki, [3)]The University of Tokyo

28A5-3 **17:30–17:50**

Program for assessing the contribution of business activities to avoided emissions in Shiga Prefecture, Japan

Maki Ogura[1)], Takeshi Matsuda[1)], Ryota Ii[1)], Madoka Kaito[2)], Kazuomi Okuda[2)]

[1)]Pacific Consultants Co., Ltd., [2)]Shiga Prefecture

28A5-4 **17:50–18:10**

Neutralize CO_2 emissions by product contributions

Ryo Yokoyama, Tetsuya Kuwashima, Yasuyuki Fujioka, Masaru Hirose

TDK Corporation

28B3 (Room 102) 13:30－14:50 October 28, Tuesday

Tsukuba Special Session

Chair : K. Okajima

28B3-1 **13:30–13:40**

Introduction: Tsukuba Environmental Style "SMILe"

Tomokazu Ueta

City of Tsukuba

28B3-2 (invited) **13:40–14:10**

Hydrocarbon production from microalgae and its potential commercial use

Makoto M Watanabe

University of Tsukuba

28B3-3 (invited) **14:10–14:40**

Mobility robot technologies in AIST for green innovation

Osamu Matsumoto

National Institute of Advanced Industrial Science and Technology

Discussion **14:40–14:50**

Oral Sessions

28B4 (Room 102) 15:10－16:30 October 28, Tuesday

Material Flow Analysis

Chair : W.R. Poganietz

28B4-1 **15:10–15:30**

Spatial cluster analysis of global metal flows

Shigemi Kagawa[1)], Keisuke Nansai[2)], Yasushi Kondo[3)]

[1)]Kyushu University, [2)]National Institute for Environmental Studies, [3)]Waseda University

28B4-2 **15:30–15:50**

Impact of resource-use intensity of goods and services and demand structure on national resource productivity: Time series analysis for 10 countries

Arata Ito, Seiji Hashimoto

Ritsumeikan University

28B4-3 **15:50–16:10**

Selection of products for remanufacturing based on the designs of end of life products

Aditi D Joshi[1)], Surendra M Gupta[1)], Tetsuo Yamada[2)]

[1)]Northeastern University, [2)]The University of Electro-Communications

28B4-4 **16:10–16:30**

Mathematical formulation of urban mines design problem

Shinsuke Kondoh, Hitoshi Komoto, Keijiro Masui

National Institute of Advanced Industrial Science and Technology

28B5 (Room 102) 16:50－18:10 October 28, Tuesday

E-waste

Chair : G. Sonnemann

28B5-1 **16:50–17:10**

Sorted collection of used batteries and small home appliances by municipalities

Atsushi Terazono[1)], Masahiro Oguchi[1)], Shigenori Iino[2)], Satoshi Mogi[3)]

[1)]National Institute for Environmental Studies, [2)]Tokyo Metropolitan Research Institute for Environmental Protection, [3)]Bureau of Environment, Tokyo Metropolitan Government

28B5-2 **17:10–17:30**

Life cycle assessment of an automotive lithium-ion battery in large-scale commercial production

Hyung Chul Kim, Timothy J. Wallington

Ford Motor Company

28B5-3 **17:30–17:50**

The impact of demographic change in Japan on supply security footprint of critical metals

Yosuke Shigetomi[1,2,3)], Keisuke Nansai[2)], Susumu Tohno[1)]

[1)]Kyoto University, [2)]National Institute for Environmental Studies, [3)]JSPS Research Fellow

28B5-4 **17:50–18:10**

Material flow analysis of heavy metals in contaminated soil: A case study on the polluted sites in Taoyuan County, Taiwan

Rong-Hua Lee, Yuh-Ming Lee

National Taipei University

28C3 (Room 201) 13:30－14:50 October 28, Tuesday

Global Food Security and Corporate Practices from Life Cycle Perspectives-1

Chair : K. Hayashi

28C3-1 (invited) **13:30–13:50**

Japanese nitrogen footprint model for the prediction of nitrogen loss to the environment

Hideaki Shibata[1)], Lia R Cattaneo[2)], Allison M Leach[2)], James N Galloway[2)]

[1)]Hokkaido University, [2)]University of Virginia

28C3-2 **13:50–14:10**

Aggregation of biodiversity impacts across international value chains

Jan Paul Lindner[1,2)], Laura Brethauer[1,2)], Ulrike Bos[1,2)], Rainer Luick[3)], Michael Jäger[2)]

[1)]Fraunhofer IBP, [2)]University of Stuttgart, [3)]University of Applied Forest Sciences Rottenburg

28C3-3 (invited) **14:10–14:30**

Scientific robustness of including indirect land use change into life cycle assessment

Matthias Finkbeiner

Technische Universität Berlin

28C3-4 **14:30–14:50**

Future perspectives on LCA in agriculture: Lessons from the research in Japan

Masanori Saito

Tohoku University

28C4 (Room 201) 15:10－16:30 October 28, Tuesday

Global Food Security and Corporate Practices from Life Cycle Perspectives-2

Chair : M. Saito

28C4-1 **15:10–15:30**

Assessing impacts of land use change and management intensification: A life cycle perspective on agricultural production

Kiyotada Hayashi

National Agriculture and Food Research Organization

Oral Sessions

28C4-2 (invited) **15:30–15:50**

Environmental impacts of organic rice farming in Thailand by using life cycle assessment to support policy decision on sustainable agriculture

Rattanawan Mungkung, Patthra Pengthamkeerati, Ratcha Chaichana, Saranya Watcharothai, Kittiwan Kitpakornsanti, Supachok Tapananont

Kasetsart University

28C4-3 (invited) **15:50–16:10**

Water footprint assessment of crops cultivation in Kurdistan region, Iraq

Marlia Mohd Hanafiah[1)], Hushiar Raheem Hamarash[1)], Muhammad Muaz Aminordin[1)], Shabbir Gheewala[2,3)]

[1)]National University of Malaysia, [2)]The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, [3)]Ministry of Education, Thailand

28C4-4 (invited) **16:10–16:30**

Life cycle assessment of biogas production in small-scale household digesters in Vietnam

Van Thi Khanh Vu, Quynh Duong Vu, Lars S. Jensen, Sven G. Sommer, Sander Brunn

National Institute of Animal Sciences, Vietnam

28C5 (Room 201) 16:50–18:10 October 28, Tuesday

Global Food Security and Corporate Practices from Life Cycle Perspectives-3

Chair : H.Shibata

28C5-1 **16:50–17:10**

Resource logistics for sustainable management of agricultural nutrients

Kazuyo Matsubae[1)], Kenichi Nakajima[2)], Keisuke Nansai[2)], Tetsuya Nagasaka[1)]

[1)]Tohoku University, [2)]National Institute for Environmental Studies

28C5-2 **17:10–17:30**

Monetary and physically flow analyses on products of agriculture

Yuko Oshita[1)], Yasunori Kikuchi[2)]

[1)]Kobe University, [2)]The University of Tokyo

28C5-3 **17:30–17:50**

Evaluation of environmental improvement by introduction of eco-feed

Hongqin Yu, Hiroshi Yagita

Nippon Institute of Technology

28C5-4 **17:50–18:10**

Uncertainty analysis for greenhouse gas impact of feedstuff in Korea

Yoosung Park, Minhyeok Lee, Kunmo Lee

Ajou University

28D3 (Room 202) 13:30–14:50 October 28, Tuesday

Green ICT-1

Chair : M. Hara

28D3-1 (invited) **13:30–13:50**

Analyzing the carbon emissions of cloud computing facilities

Kendra Tupper

City of Boulder

28D3-2 **13:50–14:10**

New key performance indicators for smart sustainable city

Jiro Nakamura, Minako Hara

NTT Energy and Environment Systems Laboratories

28D3-3 **14:10–14:30**

Social impact assessment of ICT services: Case study and tool realization

Julien Boisseau[1)], Tomoko Tanaka[1)], Ahmed Zeddam[1)], Kazue Takahashi[2)], Takashi Sawada[2)]

[1)]Orange Japan, [2)]NTT Energy and Environment Systems Laboratories

28D3-4 **14:30–14:50**

Multiple environmental impact assessment method on biodiversity for industry

Kazue Ichino Takahashi[1)], Eri Matsunaga[1)], Takashi Sawada[1)], Norihiro Itsubo[2)], Masaharu Motoshita[3)], Kayo Murakami[4)]

[1)]NTT Energy and Environment Systems Laboratories, [2)]Tokyo City University, [3)]National Institute of Advanced Industrial Science and Technology, [4)]Kyoto University

28D4 (Room 202) 15:10–16:30 October 28, Tuesday

Green ICT-2

Chair : K. Tupper

28D4-1 **15:10–15:30**

Case study on effect of mechanics development of telecommunication product on material efficiency

Lauri Smalén[1)], Elisabeth Dechenaux[2)], Topi Volkov[1)], Timo Galkin[1)], Timo Junno[1)], Heikki Karvinen[3)], Marc Aubree[2)]

[1)]Nokia Solutions and Networks, [2)]Orange Labs, [3)]Aalto University

28D4-2 **15:30–15:50**

Five IT thoughts from a waste management proof-of-concept project

Yukihisa Yonemochi, Takashi Sakairi, Hiroshi Horii, Tatsuya Ishikawa, Scott Trent, Heather D Achilles

IBM Research

28D4-3 **15:50–16:10**

Environmental footprint for IT equipment

Takaaki Kumazawa, Osamu Namikawa

Hitachi, Ltd.

Oral Sessions

28D4-4 **16:10–16:30**

Analysis of influence of ICT services including application-service and network-service on CO_2 emission

Jiro Nakamura, Tomomi Nagao, Yuichiro Takei, Atsushi Sakurai, Shinsuke Hannoe, Keiichi Saito

NTT Energy and Environment Systems Laboratories

28D5 (Room 202) 16:50－18:10 October 28, Tuesday

Driving innovation

Chair : M. Sagisaka

28D5-1 **16:50–17:10**

Measuring social impacts of products: The Handbook of the Roundtable for Social Metrics

João Fontes, Mark Goedkoop, Anne Gaasbeek

PRé Consultants B.V.

28D5-2 **17:10–17:30**

Policies promoting ecodesign for energy and resource efficiency in Europe: Experiences, barriers and future options

Carl Johan Dalhammar

Lund University

28D5-3 **17:30–17:50**

Reverse flow of knowledge and the development of sustainable energy systems

Harald Ernst Otto

Polytechnic University of Marche

28D5-4 **17:50–18:10**

Canceled

Oral Sessions

▶ October 29, Wednesday

29C1 (Room 201) 9:00－10:20 October 29, Wednesday

The Practical Challenge for Sustainable Industry-1

Chair : M. Motoshita

29C1-1 **9:00–9:20**

Hitachi's CO_2 visualization effort

Tetsuichi Nomiyama, Hitoshi Maekawa

Hitachi, Ltd.

29C1-2 **9:20–9:40**

Challenges to biofuel production enhancing food production: A food and beverage alcohol company perspective

Satoshi Ohara, Akira Sugimoto, Kazutoshi Kitai, Takaomi Yasuhara

Asahi Group Holdings, Ltd.

29C1-3 **9:40–10:00**

Experience of EPD process certification

Lucia Rigamonti[1)], Mario Grosso[1)], Mino Leo Marucci[2)]

[1)]Politecnico di Milano, [2)]Reno De Medici S.p.A.

29C1-4 **10:00–10:20**

Policy options for LCA deployment in automotive industry

Annekatrin Lehmann[1)], Matthias Finkbeiner[1)], Kirana Wolf[1)], Cees ten Broek[2)]

[1)]Technische Universität Berlin, [2)]World Steel Association

29C2 (Room 201) 10:40－12:00 October 29, Wednesday

The Practical Challenge for Sustainable Industry-2

Chair : M. Nakajima

29C2-1 (invited) **10:40–11:00**

A new direction for LCA: Organizational LCA

Matthias Finkbeiner[1)], Julia Martínez-Blanco[1)], Atsushi Inaba[2)]

[1)]Technische Universität Berlin, [2)]Kogakuin University

29C2-2 **11:00–11:20**

Guidance on organizational LCA by the UNEP/SETAC Life Cycle Initiative

Julia Martínez-Blanco[1)], Sonia Valdivia[2)], Ana Quiros[3)], Llorenç Milà i Canals[5)], Atsushi Inaba[4)], Matthias Finkbeiner[1)]

[1)]Technische Universität Berlin, [2)]World Resources Forum, [3)]ECOGLOBAL, [4)]Kogakuin University, [5)]UNEP-SETAC Life Cycle Initiative

29C2-3 **11:20–11:40**

Activity to evaluate a positive impact of an organization

Seiya Yamazaki, Hiroko Ioka, Takafumi Hashitani

Fujitsu limited

29C2-4 **11:40–12:00**

Proposal for a supplementary calculation method for scope 3 emissions

Sachiko Motoike, Hideki Sasaki, Hiroshi Onishi

Panasonic Corporation

29C3 (Room 201) 13:30－14:50 October 29, Wednesday

The Practical Challenge for Sustainable Industry-3

Chair : M. Motoshita

29C3-1 **13:30–13:50**

Estimating multiple changes of GHG emissions on mitsubishi electric group's supply chain; category11-possible variation of GHG during use stage

Chie Uchiyama

Mitsubishi Electric Corporation

29C3-2 **13:50–14:10**

What allocation method should be taken to provide the data for SCOPE3 by supplier to customer? An example of the printing company

Hiromichi Sasaki, Nobuyasu Tanaka

Sun Messe Co., Ltd.

29C3-3 **14:10–14:30**

Water consumption evaluation along the supply chain

Junichi Nakahashi

Asahi Kasei Corporation

29C3-4 **14:30–14:50**

Supply-chain environmental assessment for sustainable procurement

Kenji Ohashi

Shiseido Co., ltd.

29D1 (Room 202) 9:00－10:20 October 29, Wednesday

LCA Methodology

Chair : Y-M. Lee

29D1-1 **9:00–9:20**

GreenGDP study based on life cycle impact assessment of refinery sector in Thailand

Kultida Kunanuntakij[1)], Viganda Varabuntoonvit[1)], Natanee Vorayos[2)], Thumrongrut Mungcharoen[1)]

[1)]Kasetsart University, [2)]ChiangMai University

29D1-2 **9:20–9:40**

Fast screening of alternative life cycles and system optimization using flexibly linkable process subsystems

Bernhard Steubing, Chris Mutel, Florian Suter, Stefanie Hellweg

ETH Zurich

Oral Sessions

29D1-3 **9:40–10:00**

Investigation of the differences between static and probabilistic LCA/LCC results of different floor finishes

Gantner Johannes[1)], William Fawcett[2)], Matthias Fischer[3)]

[1)]University of Stuttgart, [2)]Cambridge Architectural Research Ltd, [3)]Fraunhofer IBP

29D1-4 **10:00–10:20**

Supporting uncertainty evaluation in prospective assessment of innovations: A case on ecological method in shrimp farming

Heng Yi Teah[1)], Yasuhiro Fukushima[1)], Motoharu Onuki[2)]

[1)]National Cheng Kung University, [2)]The University of Tokyo

29D2 (Room 202) 10:40–12:00 October 29, Wednesday

Supply Chain Risk Management

Chair : K. Tahara

29D2-1 **10:40–11:00**

Development of supply-chain matrix database with IDEA aiming for the application to consequential LCA

Kiyotaka Tahara[1)], Masaharu Motoshita[1,3)], Kotaro Kawajiri[1)], Hiroki Hatayama[1)], Chunyoul Baek[1)], Tomohiko Ihara[2)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]The University of Tokyo, [3)]Technische Universität Berlin

29D2-2 **11:00–11:20**

Resolution of nuclear power plant construction conflicts: Argument of tsunami issues through concept mapping and lifecycle thinking

Ting-Fang Hsieh, Yuh-Ming Lee

National Taipei University

29D2-3 **11:20–11:40**

LCA system boundary selection using the industrial clustering analysis

Shunsuke Okamoto

Kyushu University

29D2-4 **11:40–12:00**

Assessing climate impact of industrial symbioses: A dynamic approach

François Dumoulin[1,2)], Tom Wassenaar[1)], Jean-Marie Paillat[1)]

[1)]CIRAD, [2)]ADEME

29D3 (Room 202) 13:30–14:50 October 29, Wednesday

City & Building

Chair : T. Ikaga

29D3-1 **13:30–13:50**

Towards a low-carbon future in China's rural residential sector

Rui Xing, Tatsuya Hanaoka, Yuko Kanamori, Hancheng Dai, Toshihiko Masui

National Institute for Environmental Studies

29D3-2 **13:50–14:10**

Exploring intersection of product lifecycles: GHG emissions associated with vehicles and pavement influenced by pavement maintenance strategies

Yasuhiro Fukushima, Fitria, Shih-Hsien Yang

National Cheng Kung University

29D3-3 **14:10–14:30**

A cradle-to-cradle assessment framework for green building evaluation: Emphases on energy management and resource recovery

Chia-Lin Hsu, Yuh-Ming Lee

National Taipei University

29D3-4 **14:30–14:50**

A life cycle assessment of silica sand: Comparing the beneficiation processes

Anamarija Grbes

Faculty of Mining, Geology and Petroleum Engineering, Zagreb, Croatia

29E1 (Room 303) 9:00–10:20 October 29, Wednesday

Behavior & Policy

Chair : H. Hondo

29E1-1 **9:00–9:20**

A life cycle thinking assessment framework for land reclamation policy in Taiwan

Lih-Ren Liu, Yuh-Ming Lee

National Taipei University

29E1-2 **9:20–9:40**

Constructing a system thinking model for climate policy making based on national GHG inventory

Yu-Tsang Lu, Yuh-Ming Lee

National Taipei University

29E1-3 **9:40–10:00**

Evaluating the change of psychological factors and pro-environmental behaviors through workshop about life cycle thinking and norms

Eri Aoki, Kiyo Kurisu, Keisuke Hanaki

The University of Tokyo

Oral Sessions

29E1-4 **10:00–10:20**

People's environmental consciousness in daily activities

Ai Hiramatsu, Kiyo Kurisu

The University of Tokyo

29E2 (Room 303) 10:40–12:00 October 29, Wednesday

Policy & Visualization

Chair : K. Nansai

29E2-1 **10:40–11:00**

Visualizing core structure of international carbon network associated with household consumption

Yasushi Kondo

Waseda University

29E2-2 **11:00–11:20**

Life cycle inventory database and its applications to support public policy in Thailand

Thumrongrut Mungcharoen[1,2)], Thumrongrut Mungcharoen[1,2)]

[1)]National Science and Technology Development Agency, [2)]Kasetsart University

29E2-3 **11:20–11:40**

Thai CF Pro: A web-based program for evaluating carbon footprint of product

Chantana Yuvaniyama[1)], Wanwisa Thanungkano[1)], Ruthairat Wisansuwannakorn[1)], Athiwatr Jirajariyavech[1)], Thepchai Supnithi[2)], Nattapol Kritsuthikul[2)], Thumrongrut Mungcharoen[3)]

[1)]National Metal and Materials Technology Center, [2)]National Electronics and Computer Technology Center, [3)]National Science and Technology Development Agency

29E2-4 **11:40–12:00**

Visualization of comprehensive environmental impacts

Yoshinori Kobayashi, Kiyoshi Sanehira

Toshiba Corporation

29E3 (Room 303) 13:30–14:50 October 29, Wednesday

Agriculture & Foods

Chair : R. Mungkung

29E3-1 **13:30–13:50**

Life cycle assessment of environmental impacts of crop residue management and manure application in Japanese rice cultivation

Ai Leon, Yasuhito Shirato, Shin-ichi Yoshimatsu, Seiya Tsushima, Kazuyuki Yagi, Kazunori Kohyama

National Institute for Agro-Environmental Sciences

29E3-2 **13:50–14:10**

Total material requirement of food production and related materials in Japan

Eiji Yamasue[1)], Kazuyo Matsubae[2)], Keiichi N Ishihara[1)]

[1)]Kyoto University, [2)]Tohoku University

29E3-3 **14:10–14:30**

Land use change related CO_2 emissions in the LCA of biofuel-based electrification in Mali

Joana Almeida[1)], Jeroen Degerickx[1)], Wouter M J Achten[2)], Bart Muys[1)]

[1)]KU Leuven, [2)]Universite Libre de Bruxelles

29E3-4 **14:30–14:50**

Ecoefficiency analysis of integrated and non-integrated crop, forestry and livestock production systems in the Brazilian Cerrado

Marcela Porto Costa[1,2)], Sueli Aparecida de Oliveira[1)], Gerson Araujo de Medeiros[2)]

[1)]FEE- Espaço ECO Foundation- BASF, [2)]UNESP- Universidade Estadual Paulista Julio de Mesquita Filho -Sorocaba

29F1 (Room 405) 9:00–10:20 October 29, Wednesday

Sustainability of Materials and Industries-1

Chair : Y. Matsuno

29F1-1 **9:00–9:20**

How much does urban mining reduce the environmental burden?

Kohmei Halada

National Institute for Material Science

29F1-2 **9:20–9:40**

Designing strategic urban mining in Japan for criticality mitigation

Hiroki Hatayama[1)], Kiyotaka Tahara[1)], Ichiro Daigo[2)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]The University of Tokyo

29F1-3 **9:40–10:00**

Comparison of end-of-life recycling rates of common metals in Japan

Ichiro Daigo, Kohei Iwata, Yoshikazu Goto

The University of Tokyo

29F1-4 **10:00–10:20**

Framework and applications of time-series material flow and stock analysis

Shotaro Nakanishi, Jun Nakatani, Yuichi Moriguchi

The University of Tokyo

Oral Sessions

29F2 (Room 405) 10:40－12:00 October 29, Wednesday

Sustainability of Materials and Industries-2

Chair : H. Kakisawa

29F2-1 **10:40–11:00**

Value added material flow analysis of NdFeB magnets in Denmark

Komal Habib, Henrik Wenzel

University of Southern Denmark

29F2-2 (invited) **11:00–11:20**

Ultra-high temperature materials for higher-efficiency energy conversion of heat engines

Kyosuke Yoshimi

Tohoku University

29F2-3 (invited) **11:20–11:40**

Advanced green innovation discovered by self-healing ceramics

Wataru Nakao

Yokohama National University

29F2-4 **11:40–12:00**

Environmental barrier coating on SiC fiber-reinforced SiC matrix composites for low pressure turbine in jet engine

Hideki Kakisawa

The University of Tokyo

29F3 (Room 405) 13:30－14:50 October 29, Wednesday

Sustainability of Materials and Industries-3

Chair : K. Halada

29F3-1 (invited) **13:30–13:50**

Minor rare metals concentration from e-waste by combining novel comminution and physical separation

Shuji Owada, Chiharu Tokoro

Waseda University

29F3-2 (invited) **13:50–14:10**

Metal recovery from urban mines by hydrometallurgical methods

Mikiya Tanaka[1)], Hirokazu Narita[1)], Tetsuo Oishi[1)], Takeshi Ogata[1)], Yuiko Tasaki Handa[1)], Kazuya Koyama[1,2)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]Chiba Institute of Technology

29F3-3 **14:10–14:30**

Development of new processes for precious metals recovery using organic aqua regia

Kana Umehara, Akihiro Yoshimura, Yasunari Matsuno

The University of Tokyo

29F3-4 **14:30–14:50**

A recycling system for poly (methyl methacrylate) in Japan

Yasunori Kikuchi[1)], Masahiko Hirao[1)], Hirokazu Sugiyama[1,2)], Stavros Papadokonstantakis[2)], Konrad Hungerbühler[2)], Takashi Ookubo[3)], Akinobu Sasaki[3)]

[1)]The University of Tokyo, [2)]ETH Zurich, [3)]Mitsubishi Rayon, Co., Ltd.

29G1 (Room 406) 9:00－10:20 October 29, Wednesday

Energy-1

Chair : K. Okajima

29G1-1 **9:00–9:20**

Life cycle inventory of energy technologies: Survey and application to energy scenarios

Andrew John Chapman, Benjamin Craig McLellan, Tetsuo Tezuka

Kyoto University

29G1-2 **9:20–9:40**

Network theory integrated life cycle assessment for an electric power system

Heetae Kim, Petter Holme

Sungkyunkwan University

29G1-3 **9:40–10:00**

Life cycle greenhouse gas emission and land use change impact on compressed natural gas as alternative vehicle fuel in Thailand

Worayut Saibuatrong, Viganda Varabuntoonvit, Thumrongrut Mungcharoen

Kasetsart University

29G1-4 **10:00–10:20**

Life cycle assessment of biodiesel in Hong Kong

Ya Hong Dong, S. Thomas Ng

The University of Hong Kong

29G2 (Room 406) 10:40－12:00 October 29, Wednesday

Energy-2

Chair : K. Dowaki

29G2-1 **10:40–11:00**

Ecological effects from operating a biomass power plant

Akito Murano[2)], Satoshi Nakano[3)], Ayu Washizu[1)]

[1)]Waseda University, [2)]Toyo University, [3)]The Japan Institute for Labour Policy and Training

Oral Sessions

29G2-2 **11:00–11:20**

Load flexible power plant concepts: A comparative analysis from a life-cycle perspective

Witold Roger Poganietz[1)], Yasushi Kondo[2)], Hans-Joachim Gehrmann[1)], Shinichiro Nakamura[2)]

[1)]Karlsruhe Institute of Technology, [2)]Waseda University

29G2-3 **11:20–11:40**

An analysis of LCI and fuel cost due to Blue Tower process based on the low power purification system

Rui Ohkubo[1)], Mitsuo Kameyama[2)], Yutaro Watanabe[1)], Kenji Koido[1)], Kiyoshi Dowaki[1)]

[1)]Tokyo University of Science, [2)]Japan Blue Energy Co.,Ltd.

29G2-4 **11:40–12:00**

Small hydro power plants: A modular LCA approach for optimization

Beatrix F. Becker, Liselotte Schebek

Technische Universität Darmstadt

Oral Sessions

▶ October 30, Thursday

30A1 (Room 101) 9:00－10:20 October 30, Thursday

Sustainable Resource Management-1

Chair : B. McLellan

30A1-1 **9:00–9:20**

Global flow of nickel: Identifying its supply chain and implication for sustainable resource management

Kenichi Nakajima[1)], Keisuke Nansai[1)], Hiroya Yamano[1)], Kazuyo Matsubae[2)], Shinsuke MURAKAMI[3)], Yuto OHTSUKA[2)], Yasunori IWATSUKI[3)], Tetsuya NAGASAKA[2)]

[1)]National Institute for Environmental Studies, [2)]Tohoku University, [3)]The University of Tokyo

30A1-2 **9:20–9:40**

Sustainability of rare metal supply chains from unconventional resources

Glen D Corder[1)], Saleem Ali[1,3)], Artem Golev[1)], Benjamin C McLellan[1,2)]

[1)]The University of Queensland, [2)]Kyoto University, [3)]University of Vermont

30A1-3 **9:40–10:00**

Refinement of a simulation model to analyze the formation of urban mines with demonstrative experiments

Hitoshi Komoto, Shinsuke Kondoh, Keijiro Masui

National Institute of Advanced Industrial Science and Technology

30A1-4 **10:00–10:20**

Quality-oriented end-of-life vehicle scrap recycling aimed at efficient utilization of steel alloying elements

Hajime Ohno[1)], Kazuyo Matsubae[1)], Kenichi Nakajima[2)], Yasushi Kondo[3)], Shinichiro Nakamura[3)], Tetsuya Nagasaka[1)]

[1)]Tohoku University, [2)]National Institute for Environmental Studies, [3)]Waseda University

30A2 (Room 101) 10:40－12:00 October 30, Thursday

Sustainable Resource Management-2

Chair : G.D. Corder

30A2-1 **10:40–11:00**

Measuring supply risk footprints of critical metals for Japanese goods and services

Keisuke Nansai[1)], Kenichi Nakajima[1)], Shigemi Kagawa[2)], Yasushi Kondo[3)]

[1)]National Institute for Environmental Studies, [2)]Kyushu University, [3)]Waseda University

30A2-2 **11:00–11:20**

Material flow of cobalt in Taiwan

Lu-Yen Chen, Shun-Tian Huang, Yu-Wen Huang

National United University

30A2-3 **11:20–11:40**

Sustainability and stakeholder interaction in deep ocean mineral resources

Benjamin Craig McLellan[1,2)]

[1)]Kyoto University, [2)]University of Queensland

30A2-4 **11:40–12:00**

Indicators for environmental impacts at mine sites -case studies for large-scale underground mines

Shinsuke Murakami[1)], Tsuyoshi Adachi[2)], Yoshihiko Wada[3)], Satoshi Kojima[4)]

[1)]The University of Tokyo, [2)]Akita University, [3)]Doshisha University, [4)]Institute for Global Environmental Strategies

30B1 (Room 102) 9:00－10:20 October 30, Thursday

Waste Management & Recycling-1

Chair : Y. Oshita

30B1-1 **9:00–9:20**

Repercussion effects of final consumption on production and environmental loads using a China-Japan waste input-output table

Makiko Tsukui[1)], Chen Lin[2)]

[1)]Tokyo International University, [2)]Shandong University

30B1-2 **9:20–9:40**

The implementation of financial incentive on single-use takeout cup source reduction and recycling in Taiwan

Wei-Kai Yang, Ying-Hsuan Lin, Chih-Ku Chen

Sustainable Environmental Technology and Management Co., Ltd.

30B1-3 **9:40–10:00**

Environmental impacts assessment of plastic waste in Thailand

Unchalee Suwanmanee[1)], Thanawadee Leejarkpai[2)], Shinatiphkorn Pongpinyopap[3)], Thumrongrut Mungcharoen[3)]

[1)]Srinakharinwirot University, [2)]National Metal and Materials Technology Center, [3)]Kasetsart University

30B1-4 **10:00–10:20**

Assessing environmental impact of fiber reinforced plastic table top product mixed with non-metallic fraction from printed circuit board waste

Sawanya Jareemit[1)], Suphaphat Kwonpongsagoon[1)], Premrudee Kanchanapiya[2)]

[1)]Mahidol University, [2)]National Metal and Materials Technology Center

Oral Sessions

30B2 (Room 102) 10:40－12:00 October 30, Thursday

Waste Management & Recycling-2

Chair : R. Inaba

30B2-1 **10:40–11:00**

WEEE management in Lombardia region (Italy): An LCA-based evaluation

Laura Biganzoli, Alida Falbo, Federica Forte, Lucia Rigamonti, Mario Grosso

Politecnico di Milano

30B2-2 **11:00–11:20**

Evaluation of environmental effects of recycling of waste from food supply chains using the integrated hybrid analysis

Tamon Maruyama, Jun Nakatani, Yuichi Moriguchi

The University of Tokyo

30B2-3 **11:20–11:40**

Canceled

30B2-4 **11:40–12:00**

Climate co-benefit from improving food waste management: A case of small communities in Thailand

Amornchai Challcharoenwattana, Chanathip Pharino

Chulalongkorn University

30C1 (Room 201) 9:00－10:20 October 30, Thursday

The Practical Challenge for Sustainable Industry-4

Chair : M. Nakajima

30C1-1 (invited) **9:00–9:20**

Material Flow Cost Accounting: Simple approach, untapped opportunities, upcoming tasks

Bernd Wagner

University of Augsburg

30C1-2 **9:20–9:40**

Extending raw material input evaluation in the MFCA framework through implementation of criticality assessments

Christoph Helbig, Christoph Kolotzek, Andrea Thorenz, Axel Tuma

University of Augsburg

30C1-3 **9:40–10:00**

Cost accounting instruments as components in a material flow analysis tool-chain

Andreas Moeller[1)], Martina Prox[2)]

[1)]Leuphana University Lueneburg, [2)]ifu Hamburg GmbH

30C1-4 **10:00–10:20**

New challenge to develop sustainable value chain management by MFCA information

Michiyasu Nakajima, Asako Kimura

Kansai University

30C2 (Room 201) 10:40－12:00 October 30, Thursday

The Practical Challenge for Sustainable Industry-5

Chair : M. Finkbeiner

30C2-1 **10:40–11:00**

Integrating LCA into a design innovation method

Jeremy Faludi

University of California, Berkeley

30C2-2 **11:00–11:20**

Product and organisation environmental footprint: Challenges in theory and practice

Annekatrin Lehmann, Vanessa Bach, Matthias Finkbeiner

Technische Universität Berlin

30C2-3 **11:20–11:40**

20 years of LCA development, have we understood the user needs?

Mark Goedkoop

PRé Consultants B.V.

Discussion **11:40-12:00**

30D1 (Room 202) 9:00－10:20 October 30, Thursday

Water-1

Chair : M. Motoshita

30D1-1 **9:00–9:20**

The significance of land use effects on groundwater resource availability in Japan

Masaharu Motoshita[1,2)], Stephan Pfister[3)], Brad Ridoutt[4)], Yuya Ono[5)], Kiyotaka Tahara[1)], Atsushi Inaba[6)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]Technische Universität Berlin, [3)]ETH Zurich, [4)]The Commonwealth Scientific and Industrial Research Organisation, [5)]Tokyo City University, [6)]Kogakuin University

30D1-2 **9:20–9:40**

Human health impact models from water use: Comparing to better harmonize

Anne-Marie Boulay[1)], Masaharu Motoshita[2)], Stephan Pfister[3)], Cecile Bulle[1)], Manuele Margni[1)]

[1)]CIRAIG, Ecole Polytechnique, [2)]National Institute of Advanced Industrial Science and Technology, [3)]ETH Zurich

30D1-3 **9:40–10:00**

Functional mapping for sustainable consumption: An example through drinking water consumption

Sébastien M.R. Dente, Seiji Hashimoto

Ritsumeikan University

Oral Sessions

30D1-4 **10:00–10:20**

Economic water productivity of polylactic acid (PLA) production chain in Thailand

Shinatiphkorn Pongpinyopap[1)], Unchalee Suwanmanee[2)], Thumrongrut Mungcharoen[1)]

[1)]Kasetsart University, [2)]Srinakharinwirot University

30D2 (Room 202) 10:40 – 12:00 October 30, Thursday

Water-2

Chair : A.-M. Boulay

30D2-1 **10:40–11:00**

Environmental life cycle emissions for vegetable oil microemulsion-based biofuels

Noulkamol Arpornpong[1)], Ampira Charoensaeng[1)], Virin Kittithammavong[1)], David A. Sabatini[2)], Sutha Khaodhiar[1)]

[1)]Chulalongkorn University, [2)]The University of Oklahoma

30D2-2 **11:00–11:20**

Life cycle assessment of biofuels and the issue of indirect land use change

Liselotte Schebek, Yalda Cikovani

Technische Universität Darmstadt

30D2-3 **11:20–11:40**

Evaluation of uncertainty in for- and background systems: A case study of municipal wastewater treatment plant

Hiroko Yoshida, Charlotte Schuetz, Thomas H Christensen

Technical University of Denmark

30D2-4 **11:40–12:00**

Basin-scale multi-objective optimization of water and wastewater systems considering global and regional impacts

Seiya Maki, Jun Nakatani, Kiyo Kurisu, Keisuke Hanaki

The University of Tokyo

Poster Sessions

P-001 Life cycle based sustainability solutions: How successful companies turn sustainability solutions into company benefit and business value

Martin Baitz[1)], Masahiro Osumi[2)], Hatori Yukiyoshi[2)], Harald Florin[1)]

[1)]PE International AG, [2)]PE Asia Corporation

P-002 Guidance to assess avoided emissions of GHGs

Atsushi Inaba[2)], Masaharu Motoshita[1,3)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]Kogakuin University, [3)]Technische Universität Berlin

P-003 Life cycle inventory analysis for environmental footprints: Case study on skin-care and cosmetic products

Hsin-jui Wu, Yuh-Ming Lee

National Taipei University

P-004 Estimation of the workload of calculating GHG emissions of scope 3

Hideki Sasaki, Sachiko Motoike, Hiroshi Onishi

Panasonic Corporation

P-006 Application of life cycle assessment and economic rationality: A cost survey

Tomohiro Tasaki[1)], Koichi Shobatake[2)], Ken-ichi Nakajima[1)], Carl Dalhammar[3)]

[1)]National Institute for Environmental Studies, [2)]TCO2 Co. Ltd., [3)]Lund University

P-007 SCOPE3 of Kogakuin University

Atsushi Inaba[1)], Ko Miyata[1)], Koji Tanaka[2)]

[1)]Kogakuin University, [2)]es.feed

P-008 Life-cycle co-benefit of industrial and regional symbiosis: Environmental input-output analysis on typical resource dependent city in China

Liang Dong[1,2)], Tsuyoshi Fujita[1)], Minoru Fujii[1)], Satoshi Ohnishi[1)], Takuya Togawa[1)], Huijuan Dong[1)]

[1)]National Institute for Environmental Studies, [2)]Nagoya University

P-010 Projection of demand and supply change of first generation biomass

Yuri Hirako, Kenji Koido, Kiyoshi Dowaki

Tokyo University of Science

P-011 Decision supporting tool for sustainable dairy cow system

Chun-Youl Baek[1)], Kiyotaka Tahara[1)], Kun-Mo Lee[2)], Kyu-Hyun Park[3)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]Ajou University, [3)]Kangwon National University

P-012 Domestic consumption and household stock storage media in Japan

Junya Yano, Misuzu Asari, Shin-ichi Sakai

Kyoto University

P-013 Eco-efficiency assessment of ICT product systems: An example of set top box

Jun-Yi Chiang, Yuh-Ming Lee

National Taipei University

P-014 A visualization system for carbon footprint of products on mobile devices

Peijiang Zhao, Gun Suzuki, Koji Nagano, Kazuhiko Sato

Muroran Institute of Technology

P-016 Forecasting electricity consumption of the Japanese information and communications sector toward green of ICT

Yusuke Kishita[1)], Kohei Kuroda[)], Yasushi Umeda[)], Yohei Yamaguchi[)], Yoshiyuki Shimoda[)], Minako Hara[)], Hiroki Oka[)], Jiro Nakamura[)]

[1)]Osaka University, [2)]The University of Tokyo, [3)]NTT Energy and Environment Systems Laboratories

P-017 Testing the FineChem tool

Jan Paul Lindner[1,2)], Ida Masoomi[1,2)], Florian Gehring[1,2)]

[1)]Fraunhofer IBP, [2)]University of Stuttgart

P-019 Life cycle assessment of PVC products based on material flow analysis (MFA) in Thailand

Pomthong Malakul, Thanakorn Rodcharoen, Manit Nithitanakul

Chulalongkorn University

P-020 Sustainability of 3D printing vs. machining: Do machine type and size matter?

Jeremy Faludi, Rishi Ganeriwala, Brett Kelly, Toril Rygg, Chi Yang

University of California, Berkeley

P-021 Life cycle-based exergy analysis and its application to Japanese case

Ryota Ii[1)], Eiji Yamasue[2)], Shinsuke Murakami[3)], Jun Nakatani[3)], Takeshi Matsuda[1)], Ken Horiguchi[1)], Yuusuke Kousaka[1)], Rintarou Terada[1)], Kei Gomi[2)], Makoto Inari[4)]

[1)]Pacific Consultants Co., Ltd., [2)]Kyoto University, [3)]The University of Tokyo, [4)]Inari Consulting Office

P-022 Compilation of embodied CO_2 emission inventory using China's input-output tables: Implication for environmental public utilities

Qian Zhang, Jun Nakatani, Yuichi Moriguchi

The University of Tokyo

Poster Sessions

P-023 Integration of material performance index for a comprehensive change-oriented LCA: The biopolymer case

Bruno De Benedetti, Pierluigi Freni, Paolo Tecchio, Sara Rollino

Politecnico di Torino

P-024 Environmental profile of stonepaper

Atsushi Inaba[1)], Nobuharu Shinozai[1)], Takumi Kawashima[1)], Masaharu Motoshita[2,3)]

[1)]Kogakuin University, [2)]National Institute of Advanced Industrial Science and Technology, [3)]Technische Universität Berlin

P-026 LCA for environmental policy in case of Japanese local governments

Yasuyoshi Taruta, Yoshiteru Nakamori

Japan Advanced Institute of Science and Technology

P-028 Eco-design of tableware from palm fiber bio-composite

Singh Intrachooto, Rattanawan Mungkung, Kanokon Hancharoen, Chiravoot Petchyen

Kasetsart University

P-029 Critical material footprint of household consumption

Stefan Pauliuk

NTNU

P-030 Life cycle assessment (LCA) of the supercritical production of barium titanate nanomaterials

Michael Tsang, Gilles Philippot, Cyril Aymonier, Guido Sonnemann

University of Bordeaux

P-031 Integration of geopolitical related criticality assessment for resources into the life cycle assessment framework

Eskinder Demisse Gemechu[1)], Christoph Helbig[2)], Guido Sonnemann[1)], Andrea Thorenz[2)], Axel Tuma[2)]

[1)]University of Bordeaux, [2)]University of Augsburg

P-032 Exploring potentials of a data-intensive approach for sustainability quantification

Ali Kharrazi, Yarime Masaru

The University of Tokyo

P-033 Toward sustainable energy business using woody biomass in rural communities

Yusuke Kishita, Noriaki Nakatsuka, Yukari Fuchigami, Fumiteru Akamatsu

Osaka University

P-034 Combining product lifetime distribution analysis with multi-regional waste input-output analysis: A case study of automobiles in Japanese prefectures

Daisuke Nishijima[1)], Ryoji Hasegawa[2)], Kenichi Nakajima[3)], Shigemi Kagawa[1)]

[1)]Kyushu University, [2)]Osaka International University, [3)]National Institute for Environmental Studies

P-036 System dynamics model for sustainability assessment of mineral resource consumption considering both environmental and resource constraints

Tatsuhiko Kawamoto, Shinsuke Murakami, Jiro Yamatomi

The University of Tokyo

P-037 Global supply chain analysis for sustainable utilization of nickel

Yuto Ohtsuka[1)], Hajime Ohno[1)], Kazuyo Matsubae[1)], Kenichi Nakajima[2)], Keisuke Nansai[2)], Tetsuya Nagasaka[1)]

[1)]Tohoku University, [2)]National Institute for Environmental Studies

P-038 Mining impact on the changes in land use measured by satellite images analysis

Yasunori Iwatsuki[1)], Kenichi Nakajima[2)], Hiroya Yamano[2)], Shinsuke Murakami[1)]

[1)]The University of Tokyo, [2)]National Institute for Environmental Studies

P-039 Potential self supply of local resources towards regional sustainability: Case study of Shinjo Village in Okayama Prefecture, Japan

Kazutoshi Tsuda[1)], Hirokazu Makino[2)], Keishiro Hara[1)], Michinori Uwasu[1)]

[1)]Osaka University, [2)]Independent

P-041 Anthropogenic earth movement analysis based on geomorphological change by digital elevation model

Keisuke Yoshida, Kenji Sugimoto, Keijiro Okuoka, Hiroki Tanikawa

Nagoya University

P-042 A review of methodology for critical materials evaluation

Lu-Yen Chen[1)], Jia-Huei Huang[1)], Mei-Chiun Chou[2)]

[1)]National United University, [2)]National Taiwan University

Poster Sessions

P-043 Modeling climate effects of biogenic carbon flows from forests and wood products at the national level

Bernhard Steubing[1)], Florian Suter[1)], Stefanie Hellweg[1)], Esther Thurig[2)], Golo Stadelmann[2)]

[1)]ETH Zurich, [2)]Swiss Federal Institute for Forest

P-044 Material flow analysis of the Swiss waste management system

Melanie Haupt, Carl Oskar Vadenbo, Bernhard Steubing, Stefanie Hellweg

ETH Zurich

P-045 Metrics for performance measurement of advanced repair-to-order, disassembly-to-order and refurbishment-to-order

Ammar Yahya Alqahtani[1)], Surendra M. Gupta[2)], Kenichi Nakashima[3)]

[1)]King Abdulaziz University, [2)]Northeastern University, [3)]Kanagawa University

P-047 An estimation of ship waste quantities at port: A case study in Haiphong, Vietnam

Thang Ngoc To, Takaaki Kato

The University of Kitakyushu

P-048 Optimal improvement of waste plastics recycling system in Tianjin based on environmental evaluation and GIS

Richao Cong[1)], Toru Matsumoto[1)], Takamasa Hayashi[2)], Wenchao Li[3)]

[1)]The University of Kitakyushu, [2)]NTT DATA Institute of Management Consulting, Inc., [3)]Nankai University

P-049 Life cycle assessment of reuse system for surgical gowns

Naoki Yoshikawa[1)], Nobumitsu Kitanishi[2,1)], Koji Amano[1)], Koji Shimada[1)]

[1)]Ritsumeikan University, [2)]Takasago Thermal Engineering Co., Ltd.

P-051 Analysis of contamination of impurities in steel recycling

Chihiro Murayama, Ichiro Daigo, Yoshikazu Goto

The University of Tokyo

P-052 Evaluation of the recyclability of concrete rubble using total material requirement index

Keijiro Okuoka, Hiroki Tanikawa

Nagoya University

P-054 Matching reused products with users considering their satisfaction

Yuki Yamamori, Keisuke Nanjo, Hiroyuki Hiraoka

Chuo University

P-058 Review of excessive packaging restriction implementation in Taiwan

Chih-Ku Chen[1)], Hsin-Ying Chuang[1)], Wei-Kai Yang[1)], Chin-Wei Tang[1)]

[1)]Sustainable Environmental Technology and Management Co., Ltd., [2)]International Solid Waste Association, [3)]Taiwan Packaging Design Association

P-060 International interdependencies analysis using detailed Asian international input-output table

Hiroshi Yamaguchi, Hiroshi Yamaguchi, Norihiro Itsubo

Tokyo City University

P-061 Study on framework of life cycle sustainability assessment and social life cycle assessment: As a subject of biorefinery

Tomoko Fuchigami[1)], Xiao-Zheng Sun[2)], Yutaka Genchi[2)]

[1)]The University of Tokyo, [2)]National Institute of Advanced Industrial Science and Technology

P-062 Global scale fate factor of nitrogen for aquatic eutrophication using water circulation model

Masahiaru Motoshita[2,3)], Norihiro Itsubo[1)]

[1)]Tokyo City University, [2)]National Institute of Advanced Industrial Science and Technology, [3)]Technische Universität Berlin

P-063 Methodology to assess sustainability of biomass utilisation in East Asia

Yuki Kudoh[1)], Masayuki Sagisaka[1)], Sau Soon Chen[2)], Jessie C. Elauria[3)], Shabbir H. Gheewala[4)], Udin Hasanudin[5)], Jane Romero[6)], Vinod K. Sharma[7)], Xunpeng Shi[8)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]SIRIM Berhad, [3)]University of the Philippines Los Baños, [4)]The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, [5)]University of Lampung, [6)]Asian Development Bank, [7)]Indira Gandhi Institute of Development Research, [8)]National University of Singapore

P-064 New version of simple LCA software including a comprehensive inventory database (IDEA)

Kuan Jay Bartel, Kiyotaka Tahara

National Institute of Advanced Industrial Science and Technology

P-065 Land use, an important midpoint category indicator in agriculture: How should we deal with it?

Takahiro Nakashima, Shoko Ishikawa

National Agriculture and Food Research Organization

Poster Sessions

P-066 Setting method of the evaluation boundary from the viewpoint of uncertainty management in LCA for transport infrastructure provision

Ryoko Morimoto[4)], Hirokazu Kato[1)], Naoki Shibahara[2)], Yuki Masuda[3)]

[1)]Nagoya University, [2)]Japan Environmental Management Association for Industry, [3)]JR-Central Consultants Company, [4)]Nagoya University (former)

P-067 Uncertainty analysis for infrastructure LCA

Hirokazu Kato[1)], Yuki Masuda[2)], Naoki Shibahara[3)], Ryoko Morimoto[4)], Koh Kanai[1)]

[1)]Nagoya University, [2)]JR-Central Consultants Company, [3)]Japan Environmental Management Association for Industry, [4)]Nagoya University (former)

P-068 Calculation and comparison of weighting factors based on different approaches in LCIA

Ryosuke Yokoi[1)], Jun Nakatani[1)], Masaharu Motoshita[2)], Yuichi Moriguchi[1)]

[1)]The University of Tokyo, [2)]National Institute of Advanced Industrial Science and Technology

P-069 Spatial variation of health damage factors for $PM_{2.5}$ on a continent level

Longlong Tang[1)], Tatsuya Nagashima[1)], Kouichi Hasegawa[2)], Toshimasa Ohara[1)], Kengo Sudo[3)], Norihiro Itsubo[4)]

[1)]National Institute for Environmental Studies, [2)]Chuden CTI Co., Ltd., [3)]Nagoya University, [4)]Tokyo City University

P-070 The role of world structural changes on CO_2 emissions

Kayoko Shironitta, Kayoko Shironitta, Shunsuke Okamoto, Shigemi Kagawa

Kyushu University

P-071 Pedagogical training for environmental education based on life cycle thinking for engineers

Hatsuna Tadaka[1)], Shinya Matsumoto[1)], Reiko Tomaru[2)], Chiake Fukasawa[2)]

[1)]Yokohama National University, [2)]Sanden Kankyo Mirai Zaidan

P-072 Eliminating mottainai product features for our sustainable society

Masatsugu Kitamura, Hidataka Hayashi

EcoDesign Promotion Network

P-073 Environmental performance of biodiesel productions using waste cooking oil

Shogo Eguchi[1)], Shigemi Kagawa[1)], Sangwon Suh[2)], Yuki Kudoh[3)]

[1)]Kyushu University, [2)]University of California, Santa Barbara, [3)]National Institute of Advanced Industrial Science and Technology

P-074 Life cycle CO_2 emission of wind energy at optimum locations in the world

Kotaro Kawajiri

National Institute of Advanced Industrial Science and Technology

P-075 Life cycle environmental impacts of electricity from renewable sources in Turkey

Burcin Atilgan, Adisa Azapagic

The University of Manchester

P-076 Water-based life cycle assessment of power generation and supply in Thailand

Tomohiro Okadera[1)], Shabbir H. Gheewala[2,3)]

[1)]National Institute for Environmental Studies, [2)]The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, [3)]Ministry of Education, Thailand

P-077 The concept of efficiency in the context of sustainable energy consumption: Theoretical considerations and legacy

Harald Ernst Otto

Polytechnic University of Marche

P-078 Life cycle energy and environmental assessment of the production and utilization of compressed biogas (CBG) in Thailand

Pomthong Malakul[1,2)], Seksan Papong[2)], Thawach Chatchupong[3)]

[1)]Chulalongkorn University, [2)]National Metal and Materials Technology Center, [3)]PTT Public Company Limited

P-081 The concept of efficiency in the context of sustainable energy consumption: Current practice and shortcomings

Harald Ernst Otto

Polytechnic University of Marche

P-082 Evaluating the greenhouse gas emissions and the life cycle cost of thermoelectric generators for passenger automobiles

Yusuke Kishita, Yuji Ohishi, Michinori Uwasu, Masashi Kuroda, Hiroyuki Takeda, Keishiro Hara

Osaka University

Poster Sessions

P-083 A proposal of the eco-efficiency of the fuel cell co-generation system of "Ene-Farm" in consideration of LCCO$_2$ emission and metal resources depletion

Yusuke Jinno, Kenji Koido, Kiyoshi Dowki

Tokyo University of Science

P-084 Cost, CO$_2$ emission and energy consumption of bioethanol production from a lignocellulosic energy crop, Erianthus sp. by SRB-CaCCO process

Takahiro Orikasa[1)], Ken Tokuyasu[2)], Masakazu Ike[2)], Rui Zhao[2)], Mitsuru Gau[3)], Shoji Koide[1)], Takeo Shiina[2,4)]

[1)]Iwate University, [2)]National Food Research Institute, NARO, [3)]NARO Kyushu Okinawa Agricultural Research Center, [4)]Chiba University

P-086 Evaluation of power interchange potential and supply-demand balance of distributed generation in Kinki

Daisuke Fukuhara, Naoki Yoshikawa, Koji Amano, Koji Shimada

Ritsumeikan University

P-087 A framework to assess impacts of grid mix changes in Japan using input-output tables

Shunichi Hienuki[1)], Yuki Kudoh[1,2)], Hiroki Hondo[1)]

[1)]Yokohama National University, [2)]National Institute of Advanced Industrial Science and Technology

P-088 Analysis of environmental loads and benefits of a bio-coke production factory: A case study in Osaka

Yukari Fuchigami[1)], Keishiro Hara[1)], Takeo Kita[2)], Michinori Uwasu[1)], Shuji Kurimoto[1)]

[1)]Osaka University, [2)]Osaka Prefecture Forest Owners Association

P-089 Input-output analysis of introducing smart grid systems in Japan

Satoshi Nakano[2)], Ayu Washizu[1)]

[1)]Waseda University, [2)]The Japan Institute for Labour Policy and Training

P-090 Benefits of biogas projects from local and global perspectives

Aya Heiho, Hiroki Hondo, Yue Moriizumi

Yokohama National University

P-091 Carbon footprint labelling certification of railway operating service in Korea

Jae-Young Lee[1)], Woo-Sung Jung[1)], Cheul-Kyu Lee[1)], Hee-Man Kim[2)]

[1)]Korea Railroad Research Institute, [2)]Korea Railroad Corporation

P-092 A review of the life cycle assessment of nearly zero-energy residential buildings

Markus Weißenberger[1)], Werner Jensch[1)], Werner Lang[2)]

[1)]University of Applied Sciences Munich, [2)]Technical University Munich

P-093 An aggregative assessment of environmental impacts on reservoir catchments imposed by public construction projects: A case study on Feitsui Reservoir

Yu-An Lin, Yuh-Ming Lee

National Taipei University

P-094 Environmental impacts of portland cement manufacturing and developed process with alternative technologies in Thailand

Unchalee Suwanmanee[1)], Suthida Authayanun[1)], Worayut Saibuatrong[2)], Viganda Varabuntoonvit[2)], Thumrongrut Mungcharoen[2)]

[1)]Srinakharinwirot University, [2)]Kasetsart University

P-095 Eco-benefit analysis of multifunctional building products

Michael Jäger[1)], Johannes Gantner[1)], Sarah Homolka[2)], Hannes Krieg[1)]

[1)]University of Stuttgart, [2)]Fraunhofer Institute for Building Physics IBP

P-096 Development of a combined LCA and LCC tool for refurbishment measures of districts

Rafael Horn[2)], Johannes Gantner[1)], Michael Baumann[1)]

[1)]University of Stuttgart, [2)]Fraunhofer IBP

P-098 Macro analysis of life cycle CO$_2$ from urban passenger transport systems in Asian developing countries

Kei Ito[1)], Naoki Shibahara[2)], Hirokazu Kato[3)], Koh Kanai[3)]

[1)]Nagoya City Hall, [2)]Japan Environmental Management Association for Industry, [3)]Nagoya University

P-099 Estimation method of the change in life cycle CO$_2$ from mass transit system applying micro-scopic traffic flow simulation

Naoki Shibahara[1)], Ryoko Morimoto[4)], Nozomi Kudo[2)], Hirokazu Kato[3)]

[1)]Japan Environmental Management Association for Industry, [2)]National Traffic Safety and Environment Laboratory, [3)]Nagoya University, [4)]Nagoya University (former)

Poster Sessions

P-100 Net CO_2 emissions by the change of consumption in consequential LCA

Kotaro Kawajiri[1)], Masaharu Motoshita[1,2)], Tomohiko Ihara[3)], Hiroki Hatayama[1)], Kiyotaka Tahara[1)]

[1)]National Institute of Advanced Industrial Science and Technology, [2)]Technische Universität Berlin, [3)]The University of Tokyo

P-101 Modeling consumer's choice and its GHG implication under simultaneous consideration of available income and time

Koji Takase[1)], Yasushi Kondo[2)]

[1)]Shizuoka University, [2)]Waseda University

P-102 Determinants of environment-conscious behavior in eating habits

Tomohiko Ihara[1)], Wakana Zaima[1)], Hideaki Kurishima[2)]

[1)]The University of Tokyo, [2)]Shibaura Institute of Technology

P-103 Product differentiation and eco-behavior by using carbon footprint

Akai Kenju, Haruaki Tamura, Nishino Nariaki

The University of Tokyo

P-104 Analysis of the effects of low-carbon technologies and individual activity schedule on carbon dioxide emissions

Chika Ishida[1)], Hiroyoshi Morita[3)], Yoshimi Kanaoka[2)], Hirokazu Kato[1)]

[1)]Nagoya University, [2)]Urban Renaissance Agency, [3)]Nippon Engineering Consultants Company

P-105 Emission metrics for climate policies and their implications to life cycle assessment

Katsumasa Tanaka

Institute for Advanced Sustainability Studies (IASS)

P-106 Evaluating the relationship between agricultural workers and agricultural residues production: A case study in the Hyogo Prefecture

Tomohiro Tabata, Yukako Sakon

Kobe University

P-107 Land constraints associated with future food and biofuel demands

Kento Tamura, Naoki Yoshikawa, Koji Amano, Seji Hashimoto

Ritsumeikan University

P-108 Web-based system development for GHG emission from livestock sector

Guen-Young Lee[1)], Sung-Mo Yeon[1)], Kun-Mo Lee[2)], Yoo-Sung Park[2)]

[1)]WECOS, [2)]Ajou University

P-109 Greenhouse gas emission of rice production system in the Philippines based upon life cycle inventory analysis

Elmer G. Bautista[2)], Masanori Saito[1)]

[1)]Tohoku University, [2)]Philippine Rice Research Institute

P-110 A proposal of the CF index of rice in consideration of consumer's health condition

Takashi Oi, Kenta Shiokawa, Kenji Koido, Kiyoshi Dowaki

Tokyo University of Science

P-112 Influence of management practices on life cycle greenhouse gas emissions from rice production in Yamagata Prefecture, Japan

Katsushi Yokoyama[1)], Kiyotada Hayashi[2)]

[1)]Yamagata Integrated Agricultural Research Center, [2)]National Agriculture and Food Research Organization

P-113 Potential reductions in life-cycle greenhouse gas emissions from paddy rice production: Assessing the influence of puddling, transplanting density, and irrigation depth

Motoko Shimura[1)], Hidehiro Takahashi[1)], Chiharu Ito[2)], Makoto Shibuya[2)], Kiyotada Hayashi[3)], Kenji Matsumori[1)]

[1)]NARO Western Region Agricultural Research Center, [2)]Akita Prefectural Agricultural Experiment Station, [3)]NARO Agricultural Research Center

P-114 Life cycle CO_2 emission of konjac production via an overwintering methodology in Gunma, Japan

Kenji Koido, Yusuke Akaike, Yousuke Isshi, Keisuke Ide, Shou Ushikubo, Masanori Kou, Kenta Komiya, Katsuya Shimizu, Takumi Minami, Kiyoshi Dowaki

Tokyo University of Science

P-116 Life cycle cost analysis of willow production on small-scale field

Hidetsugu Morimoto[1)], Shigeru Satoh[2)], Kimiharu Ishizawa[3)], Takeshi Arai[1)]

[1)]Tokyo University of Science, [2)]Kyoto Prefectural University, [3)]Miyagi University of Education

Poster Sessions

P-117 Life cycle inventory analysis for small scale trawl fishery in Sendai Bay

Kazuhito Watanabe[1)], Kiyotaka Tahara[2)]
[1)]Miyagi Prefecture Kesennuma Regional Promotion Office, [2)]National Institute of Advanced Industrial Science and Technology

P-118 Improving the environmental efficiency of woody biomass utilization: Focusing on the manufacturing of high value-added products in Maniwa, Japan

Moon Dami, Kitagawa Naomi, Genchi Yutaka, Sagisaka Masayuki
National Institute of Advanced Industrial Science and Technology

P-119 Potential for energy saving of dairy farming system dependent upon land utilization

Tatsuo Hishinuma
Utsunomiya University

P-120 Substance flow analysis on agricultural nutrients focusing on nitrogen and phosphorus

Takashi Yamamoto[1)], Masafumi Mizoguchi[1)], Kazuyo Matsubae[1)], Kenichi Nakajima[2)], Keisuke Nansai[2)], Tetsuya Nagasaka[1)]
[1)]Tohoku University, [2)]National Institute for Environmental Studies

P-122 Water security and socio-economic metabolism in China: Toward an integrated assessment

Tao Wang, Seiji Hashimoto
Ritsumeikan University

P-123 Water footprint assessment of machine tool

Jahau Lewis Chen[1)], Yen-Bou Chen[1)], Hua-Chih Huang[2)]
[1)]National Cheng Kung University, [2)]ITRI

P-124 Evaluation of water use in paddy-rice production on the basis of differential water footprint

Susumu Uchida
Ibaraki University

P-125 Development of water footprint inventory database of Asian countries

Soya Iida, Yuya Ono, Norihiro Itsubo
Tokyo City University

Decision-Support Tools for Designing Sustainable Chemical Products and Processes

Konrad Hungerbühler,* Stavros Papadokonstantakis

Swiss Federal Institute of Technology (ETH), Zurich
*Corresponding author: konrad.hungerbuehler@chem.ethz.ch

1. Introduction

The design of sustainable processes and products has been identified as one of the key research and engineering challenges [1]. In particular, the applicability of sustainability principles can be more advantageous in earlier phases of process design characterized by more degrees of freedom for decision making. To this end, both life cycle impact and hazard assessment affect directly and/or indirectly all three main pillars of sustainability, (i.e., economic, environmental, and social).

One of the rather data intensive methods for promoting environmental sustainability is the systematic procedure of life cycle analysis (LCA, ISO-Norm 14040). However, to be able to assess life cycle impacts at early design stages poses a great challenge. On the other hand, safety, health and environmental hazard assessment extend the analysis from the impacts of the normal to those of the abnormal process operation. Index-based methods are particularly popular in industry and academia for hazard assessment in early to basic design stages, mainly due to their simplicity [2].

In this study we discuss the role of energy related impacts, the availability of short-cut approaches to overcome data gaps for the estimation of life cycle inventories and the challenges of multi-criteria analysis. This is done on the basis of illustrative examples for the energy related impacts of chemical production, evaluating green solvents, and biomass based production.

2. Energy related impacts of chemical production

Energy related impacts have a special place in sustainability assessment. In a recently published taxonomy of sustainability indicators for chemical processes by US-EPA [3], energy related indices are one of the four main classification categories. In quantitative terms, the importance of energy related impacts in chemical production is also highlighted in the work of Wernet et al. [4], summarized in "Table 1" for two widely used life cycle impact assessment metrics, namely Global Warming Potential (GWP) and Ecoindictor-99 (EI99).

Table 1. Environmental impact of energy use in chemical production expressed as % of the total impact.

Type of chemical products	GWP-100a (%)	EI99 H/A (%)
Organic-Ecoinvent	81	43
Organic-Industrial	82	63
Inorganic-Ecoinvent	78	59

Currently, there are a few databases (e.g., Ecoinvent, [5]) for obtaining "cradle-to-gate" data of a substantial number of chemicals based on data standardization techniques for evaluating multiple data sources. However, these databases are far from being complete. The direct impact of these data gaps for any process design project is that assumptions have to be made on the basis of process similarities, which requires expertise on the specific processes, results in time consuming modelling, is often case study specific, and, therefore, almost impossible to automate. Naturally, this phenomenon of data gaps becomes much more intense for new technologies and production concepts such as the biomass based production of chemicals.

To this end, a novel approach for basic and fine chemicals based on fossil resources has already demonstrated that complementary life cycle impact assessment data can be obtained on the basis of molecular structures with satisfactory accuracy for early to basic design stages [6]. Here, we will also present some first efforts towards short-cut models for estimating the CED and GWP of biomass based chemical products based on their molecular structure and minimal process information.

3. Multi-criteria green solvent design for post-combustion CO2 capture

The life cycle impact assessment metrics can be combined with hazard assessment metrics towards a more holistic sustainability assessment of chemical products and processes. Such frameworks have been proposed for the design of green solvents in general [7] and are applied in this case study for the design of solvents for post-combustion CO2 capture within the the FP7-EU CAPSOL project [8]. In a first aspect, the environmental and hazard assessment complement computer-aided molecular design for screening a vast list of potential solvent molecules. In a second aspect, these frameworks are used for comparing the performance of the proposed molecules with benchmark molecules, such as monoethanolamine (MEA), at substance and process level.

4. Sustainability assessment of biomass based production

An illustrating example for the use of such frameworks as decision-support tools in process assessment is the production of lactic acid, a platform chemical for multiple commodity and intermediate chemicals (e.g., acrylic acid, 1,2-propanediol, pyruvic acid, acetaldehyde, 2,3-pentanedione) and biodegradable plastic (i.e., polylactide (PLA). Nowadays, LA is produced via the anaerobic batch fermentation of glucose followed by a series of purification steps. However, due to large waste generation (gypsum), alternative pathways based on chemocatalysis have been proposed, such as the aqueous-phase isomerization of 1,3-dihydroxyacetone (DHA) over Lewis-acid solids, where DHA can be produced from glycerol, an abundant by-product of biodiesel production.

The study and comparison of such innovative production paths should be based on a holistic sustainability assessment. Herein, we demonstrate the synergetic role of the source of raw materials and catalyst performance in determining greenness and economic attractiveness of the different pathways.

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Development of the Risk-based Management System for Chemicals throughout the Supply Chain

Fumiaki Shono,*[1] and Satoshi Tokushige[1]

[1]*Japan Chemical Industry Association, Japan*
*Corresponding author: fshono@jcia-net.or.jp

1. Introduction

"Aiming to achieve, by 2020, that chemicals are used and produced in ways that lead to the minimization of significant adverse effects on human health and the environment" that has been agreed internationally in the Johannesburg Summit in 2002, which was aimed sound management of chemicals.

International Council of Chemical Associations (ICCA) has pledged to run "Global Product Strategy (GPS)" and " Responsible Care (RC) Global Charter" to achieve this goal, in 2006. In accordance with this, the Japan Chemical Industry Association (JCIA) started the voluntary activity "GPS / JIPS" as the new risk-based chemical management system and launched the "SCRUM (Supply chain Chemical Risk management and Useful Mechanism discussion) " project, to deploy its efforts specifically throughout their entire supply chain in cooperation with JAMP (Joint Article Management Promotion-consortium, which has developed and promoted an information transfer scheme for chemicals in article) .

In this session, we will introduce the overview of GPS / JIPS promoted by ICCA and JCIA and SCRUM project aimed at risk management of chemicals throughout the supply chain as an voluntary initiative of the industry.

2. Global current stream of chemical management

Chemicals are used for every personal daily necessities and advanced products and have come to indispensable of our life to improve it. On the other hand, they also have their own risk to adversely affect human health and the environment if not handled appropriately. "The sound management of the chemicals has been taken up in one of the global environmental problems while globalization of the business progressed, and the Plan of Implementation goal that, by 2020, chemicals will be produced and used in ways that minimize significant adverse impacts on the environment and human health" was agreed in the Johannesburg World Summit on Sustainable Development in 2002. You should note here that the paradigm shifts from the hazard-based management to pay only attention to hazard of the chemicals toward more risk-based management.

3. New activities of ICCA and JCIA

ICCA initiated two voluntary, advanced activities as contribution to meet the 2020 goal in 2006. They are the Responsible Care Global Charter and Global Product Strategy (GPS) and the reinforcement of safety of the chemicals in their whole life cycle has been committed through these activities.

GPS is an activity to improve industry's management of chemicals, including completion of risk characterization and recommendation for chemicals in commerce, and communication of chemical hazards and safe handling conditions throughout the supply chain.

JCIA formally decided to promote JIPS (Japan Initiative of Product Stewardship, which is the GPS activity in Japan) in 2009 and has actively developed the GPS/JIPS activities such as the issue of GPS/JIPS guidance document, the construction of IT tool called "BIGDr (the Base of Information Gathering, sharing & Dissemination for risk management of chemical products" to support the member companies in JCIA , the enlightenment to them, the implementation of the risk assessment for the each products by the individual member companies and the disclosure of their results.

4. SCRUM project

JCIA has also set up SCRUM Project in cooperation with JAMP in 2011 to expand GPS/JIPS activity for all industry through the entire supply chain as well as chemical industry located in the upper part of the supply chain.

At first, by the SCRUM project, the following two items were investigated to grasp the actual situation.

① Existing information transfer scheme related the management of chemicals through the supply chain
② The situation of the implementation of risk based assessment and management for the chemicals in each company through the supply chain related chemicals which are chosen.

Some problems to be solved were clarified by these investigations.

Therefore, SCRUM Project will develop "the risk management guidelines on chemical substance in the supply chain" to solve these problems, and explain the risk-based assessment and management of chemicals to companies in the supply chain by using this guideline.

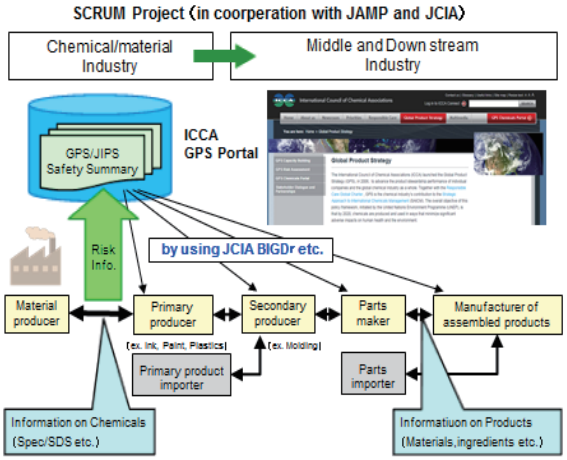


Figure 1. New scheme for sharing chemical risk information throughout Supply chain

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Chemicals Management for Sustainability in Small and Medium-Sized Enterprises

Emi Kikuchi-Uehara*[1], Yasunori Kikuchi[1], and Masahiko Hirao[1]

[1]*The University of Tokyo, Japan*
*Corresponding author: e-uehara@pse.t.u-tokyo.ac.jp

1. Introduction

The appropriate management of chemicals used in manufacturing processes is desired in order to pursue sustainability in industry. Small and medium-sized enterprises (SMEs) have been large emission sources of chemicals, accounting for approximately 60% of the total emissions to the environment from industrial sectors in Japan. The chemicals management system in small and medium-sized enterprises tends to be insufficient due to their lack of funds and skills for management. Many of them have difficulties in process improvement for controlling risks posed on human health and the environment. Strategic approaches are strongly needed so that SMEs can practice appropriate chemicals management in their process design.

In this study, a framework for chemicals management is proposed for decision support in SMEs engaged in process design for environment. Methods for risk analysis and process models are proposed in the framework as supporting mechanisms for process design. A case study is conducted on process improvement for VOC control in metal cleaning.

2. VOC control in metal cleaning

Volatile organic compounds (VOC) can cause health damage and can be causative agents of air pollution. Paints, industrial cleansing agents, ink, and adhesives are major VOC emission sources in industry. In electroplating and thermal treatment of metal parts, solvents are used for removing process oils and dirt on surface. Chlorinated organic solvents, such as dichloromethane and trichloroethylene have been widely used in metal cleaning processes in Japan.

Voluntary efforts have been made in order to control VOC emissions from metal cleaning processes. Aqueous detergents have been substituted for solvents, and devices and operation conditions have been improved. Although those efforts have contributed to VOC emission reductions, the lack of quantitative evaluation of risk reductions associated with process modifications have cause several problems. As presented in Figure 1, chemicals can pose various risks and impacts from local to global scales. The substitution of alternative chemicals can lead to the generation of the countervailing risks. In addition, it is difficult to optimize device and operation conditions, because factors related to physical phenomena inside a process are not clarified.

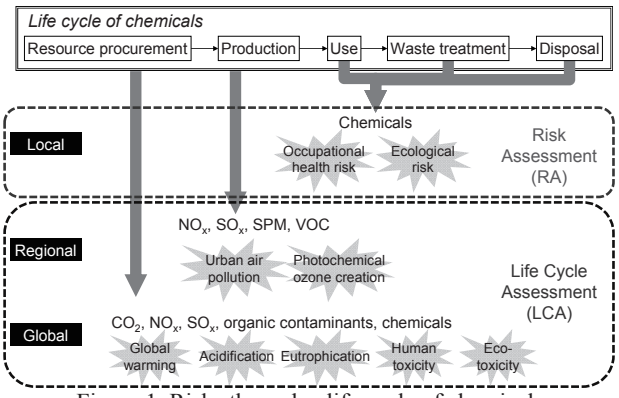


Figure 1. Risks through a life cycle of chemicals

3. Process design based on risk analysis

Figure 2 shows the overview of the chemicals management framework for decision support in process design of SMEs. In order to facilitate process improvement, risk analysis based on the integrated life cycle assessment (LCA) and risk assessment (RA) was proposed. In the case of metal cleaning, life cycle impacts on the regional and global environment (e.g., global warming and photochemical ozone creation) and local risks in and around plants (e.g., workers' health risk and ecological risk in a river where cleaning wastewater is discharged) associated with the use of cleansing agents can be quantified. The effectiveness of process modifications can be analyzed in consideration of trade-off relationships among impacts and risks. Process model to simulate VOC emission from cleaning processes using chlorinated organic solvents was also developed in order to support data collection, which can be an obstacle to practices of LCA and RA in SMEs.

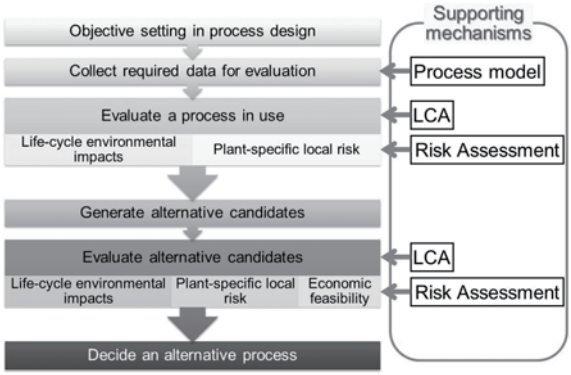


Figure 2. Process design framework based on risk analysis

On the basis of the developed framework which describes process design procedures for chemicals management and the intervention of supporting mechanisms, a software tool was developed for supporting process analysis in industrial cleaning. The tool contains the developed process model and calculation modules for LCA and RA. Engineers in cleaning sites can evaluate a process in use by inputting available data on site to the tool. Some alternatives for process improvement can be also generated and evaluated with the tool. In addition, economic performance of alternatives can be analyzed in order to evaluate their feasibility for SMEs with limited funds for process improvement.

4. Conclusions

The practical framework supporting decision-making of chemicals management in SMEs was proposed. Supporting mechanisms for risk analysis were clarified in order to facilitate process design aimed at risk reductions.

Acknowledgments

Part of this study was financially supported by JSPS KAKENHI Grant Numbers 25740045(Grant-in-Aid for Young Scientists (B), JSPS G8 Research Councils Initiative on Multilateral Research Funding, and the Women Researchers Promotion Program in the University of Tokyo.

The use of LCA as a metrics in advancing and scaling up Green Chemistry research: the case of black liquor

Amandine Foulet[1,2], Hervé Deleuze[1,2], Philippe Garrigues[1,2] and Guido Sonnemann*[1,2]

[1]*Univ. Bordeaux, ISM, UMR 5255, F-33400 Talence, France,* [2]*CNRS, ISM, UMR 5255, F-33400 Talence, France*
*Corresponding author: guido.sonnemann@u-bordeaux.fr

1. Introduction: Green Chemistry and LCA

A key aspect related of Green Chemistry (GC) is the sustainable management of materials, including adequately recycling systems and the substitution of toxic substances. In order to make the GC concept operational, the USEPA developed a set of 12 guiding principles [1], which constitute the backbone of GC and a universal code of practice for the eco-design of chemicals and chemical processes.

However, they have been criticized for their qualitative nature, which can lead to difficulties when trade-offs between principles arise. The scientific community noticed this limitation, and several methods for metrics in GC have been proposed. LCA has been highlighted as a suitable tool in this context by many authors. [2–4],

2. The case of black liquor

Our paper aims at showing how LCA can help evaluating the principles by advancing GC research towards sustainable innovation, using the case of black liquor as an example.

Black liquor, a mixture of water, salts and organic matter, comes from the pulp making process. Its production is up to 1.5 tons for 1 ton of paper pulp. Often, it is used as an energy source in paper mills, however, from a waste hierarchy point of view recycling is preferred to energy recovery.

Therefore we consider options to divert black liquor in other ways as biopolymer, particularly taking benefits of the presence of lignin. A process to prepare porous polymers via medium internal phase emulsion, called polyMIPEs, has been developed [5].

3. Materials and Methods: Comparison of two scenarios

Two scenarios (S1 and S2) are presented here. Scenario 1 (S1) relates to the use of 1,2-dichloroethane (DCE) as the porogen, whereas scenario 2 (S2) is with castor oil. S1 and S2 share the same processing steps and a few common raw materials as shown in Figure 1. The recovery of DCE was successfully carried out with an average yield of 80%.

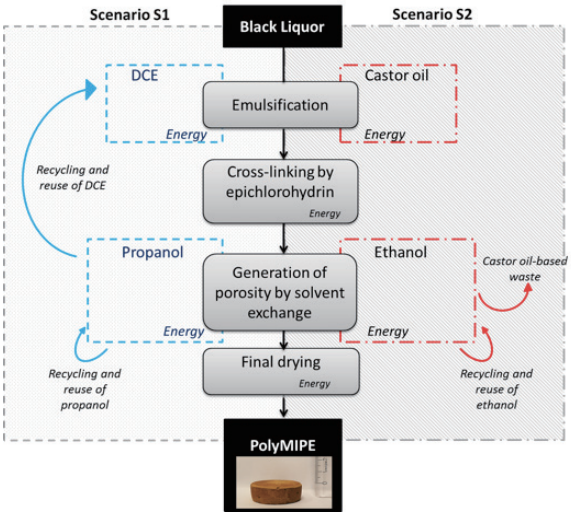


Figure 1. Flowchart of polyMIPE prep. for each scenario

4. LCA – Goal and Scope definition

A comparative LCA of the two scenarios was carried out according to ISO 14040/44. A cylindrical-shaped monolith of 1kg is the functional unit for this study. The organic phase ratio (ϕ) chosen was 0.54, as the maximum castor oil ratio was reached. Life cycle inventory calculations were performed using SimaPro 7.3.3 software with includes databases, of which EcoInvent and ELCD were used.

5. Results and Discussion

Using the calculated life cycle inventory table the LCIA was done using CML 2001 v2.05/West Europe 1995. Comparison of a non-renewable, petrochemical but recyclable solvent with a renewable one was established in order to point out the environmental benefits and burdens of each scenario. The results for each scenario were compared to the highest environmental impact and are presented in Figure 2.

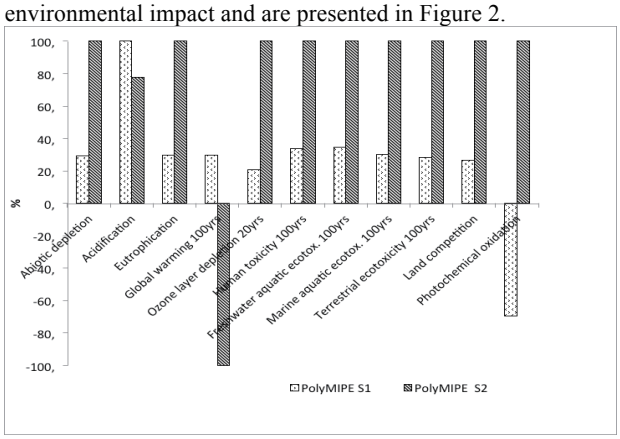


Figure 2. Env. impacts per kg of porous materials of S1 and S2

6. Conclusions

The LCA results showed that the environmental performance of S2 was hindered by the production method of castor oil as well as its in-situ non-recyclability. As for S1, the use of DCE was found to be a better option, as it was part of an efficient recycling loop. We have seen that solvent recovery in line with the GC principle of recycling, should always be considered as a mean to reduce environmental impacts, instead of focusing on the GC principle of renewable resources only.

Acknowledgments

The financial support of the Aquitaine Region for the Chair on LCA at the University of Bordeaux is acknowledged.

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Sulphur distribution to products in wet biomass gasification

Kenji Koido,*[1] Yutaro Watanabe,[1] and Kiyoshi Dowaki[1]

[1]*Tokyo University of Science, Japan*
*Corresponding author: koido@rs.tus.ac.jp

1. Introduction

Biomass gasification is a promising technology to produce synthesis gas for biohydrogen for fuel cell applications. At the same time, the biomass resource is more sustainable than of fossil fuels, and the use of biomass mitigates carbon dioxide emission due to carbon neutrality. Especially, wet biomass such as fermentation residue is sustainable. It usually needs to be dryed to reduce its moisture content for handiness. However, gasification of the biomass with high-moisture content produces more hydrogen-rich product gas and less tar and char in product gas than for dried biomass. Lignin as a model compound of fermentation residue coproduced at ethanol production from ligno-cellulose was gasified for synthesis gas production. The produced gas contained hydrogen sulphide and carbonyl sulphide and the existence of sulphur can cause poisoning of fuel cell catalysts. These facts indicate that the sulphur removal is one of the most important treatments for production of bio-hydrogen and the sulphur distribution to the products (gas, tar, char, water-soluble and catalyst surface) should be clarified to understand the sulphur behaviour in the products from wet biomass gasification.

2. Material and method

Feedstock was prepared by adding water to a sodium lignin-sulphonate (lignin, Kanto Chemical Co., Inc.) until the moisture content (MC) becomes 73–90 wt.%, which is employed as a model compound of ethanol fermentation residue with sulphur compounds [1]. Proximate and ultimate analyses of the lignin are based on JIS-M8812 and JIS-M8813 as presented in Table 1. Catalysts was $NiO/CaO{\cdot}Al_2O_3$ for steam reforming of light hydrocarbons (HiFUEL R110, Alfa Aesar) [1]. The catalyst loading (CL) was 0.17 g-cat./g-feed.

The gasifier was fixed-bed downdraft type, which was suitable for the small-scale gasifier operation. The gasifying agent, Argon gas, was fed to the top of the gasifier by mass flow controller with 200 ml/min. The temperature of the gasifier at T = 700–900°C was attained by the electric furnace. The pressures in the reaction system were measured by a pressure gauge. The liquids containing water soluble products are collected by a liquid collector, while the gas was obtained by gas bag, as shown in Fig. 1. The volume of the gas was measured by the gas meter. The feedstocks with MC = 73–80 wt.% were supplied to the gasifier at 0.5 g/min for T = 750–900°C at a normal pressure for 30–60 mins after reaching the gasifier's setting temperature. The details of the measurement were also described at the previous study [1]. After the measurement, the solid on the grate is considered to be char.

H_2 and H_2S and COS composition in product gas is determined by analysis of the gas chromatograph (GC-8A, Shimadzu Co.) equipped with TCD and that with FPD, respectively. Sulphur element in produced char was determined based on JIS-M8813. Some produced chars were analysed by a scanning electron microscope (SEM, JSM-6500F by JEOL Ltd.) to see the detailed structures of them for understanding reaction order. The detailed analytical methods were described in a literature [1].

Table 1. Feedstock analysis results

Proximate analysis [wt.%]					Ultimate analysis [wt.% dry]			
C	H	N	S	O	VM[a]	FC[b]	Ash	MC
54.0	4.4	0.2	3.5	37.9	43.3	36.1	16.2	4.4

[a]VM is volatile matter; [b]FC is fixed carbon

3. Results and discussion

Yields of sulphur compounds in the products after the gasification reaction was presented in Fig. 1 for different moisture contents. The results showed the sulphur distribution to products in catalytic gasification of lignin at T = 900°C (catalyst: $NiO/CaO{\cdot}Al_2O_3$) was 0.79 for gas, 0.04 for char, 0.003 for water-soluble and 0.378 for catalyst surface in mmol/g-lignin, whereas the sulphur distribution to products in non-catalytic gasification of lignin was 0.95 for gas, 0.11 for char and 0.004 for water-soluble in mmol/g-lignin. With the NiO catalyst, the gaseous sulphur decreased 14.5% sulphur, which showed the possibility of hot-gas cleaning by the catalyst. With the catalyst, the gaseous sulphur decreased 14.5% sulphur, which showed the possibility of hot-gas cleaning by the catalyst. Char played a more active role as adsorbent for the non catalytic gasification (Fig. 2).

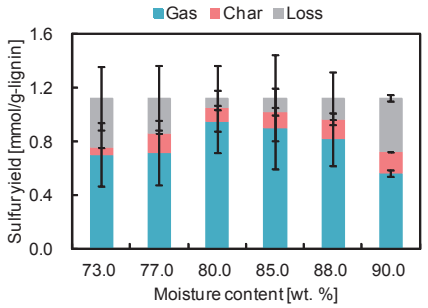


Fig. 1: Sulphur yields after the lignin gasification versus moisture contents

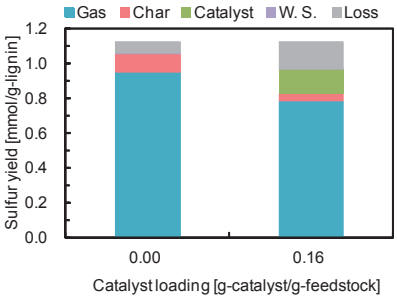


Fig. 2: Sulphur yield after the catalytic or non-catalytic gasification of lignin at MC = 80 wt.% and T = 900°C

4. Conclusion

Sulphur distribution of products from catalytic ($NiO/CaO{\cdot}Al_2O_3$) or non-catalytic gasification of wet lignin with MC = 80 wt.% in fixed-bed downdraft gasifier was investigated. With the catalyst, the gaseous sulphur decreased 14.5% sulphur, which showed the possibility of hot-gas cleaning by the catalyst. Char can act as adsorbent for the non catalytic case.

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Estimating Optimal Environmental Load Reduction for Resource Recovery from Plastic Waste by LCA Methodology and Plastic Waste Processing Pathways

Akihiro Izumi,*[1] Hajime Munekuni[1]

[1]*Plastic Waste Management Institute, Japan*

1. Introduction

The Plastic Waste Management Institute publicly discloses the quantity of plastic production, plastic waste and resource recovery over the course of its plastic production to disposal each year in Japan in an official flowchart. The data in this flowchart indicate that about 10 million tons of plastic is produced in Japan annually and that discarded products are effectively used at a rate of 80%. In 2012, effective use comprised 2.04 million tons of mechanical recycling (MR), 380,000 tons of chemical recovery (CR), and 5.02 million tons of energy recovery (ER). Plastic that is not effectively used is simply incinerated and placed in landfills, with amounts totaling 0.96 million tons of incineration without ER and 0.89 million tons of landfilling.

In the current study, we determined basic conditions such as residue rate and residue pathways successively processed after the effective use of plastic waste as well as the virgin plastic substitution ratio by referencing questionnaires, interviews, and research in relation to plastic waste usage companies and industry associations. We then developed a more accurate method of estimating optimal environmental load reduction.

2. Estimation method for environmental load reduction

If we set the amount of environmental load from production to disposal (energy consumption and CO_2 emission) to (1) and set the environmental load based on the assumption that all plastic waste that should be used effectively is simply incinerated to (2), the amount of reduction in environmental load can be shown as (2) – (1).

3. Introduction of basic conditions

This calculation method specifically uses the figures from the Institute's plastic material flowchart as the processing amount for each effective usage method and applies them to the substitution subtraction (or deduction) method that regards goods obtained from recycling as substitutes for virgin materials and fuel.

4. Results and discussion

We were able to obtain a significantly improved flowchart from resin production through the resource recovery process, including residue recycling. This improved flowchart was then used to develop a new estimating method for much more accurate environmental load reduction.

The proposed method estimated the avoided energy consumption as 229 PJ in 2012 and the ratio of the avoided CO_2 emissions by effective usage versus the total amount of CO_2 emissions in Japan to be around 1%.

As shown in Fig.4, it is easier to lower the energy consumption and CO2 emissions associated with industrial waste than with domestic waste. The avoided energy consumption for domestic mechanical recycling is only about one third that of industrial mechanical recycling.

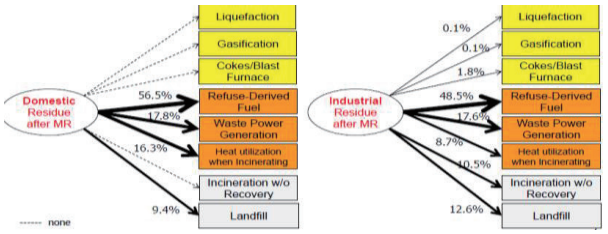


Figure1. Residue destination after MR for energy consumption 2012

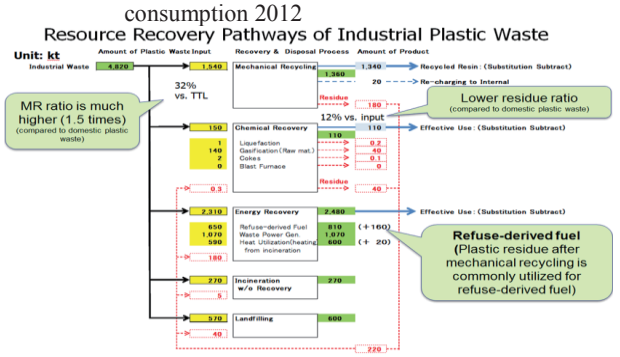


Figure2. Resource recovery pathways

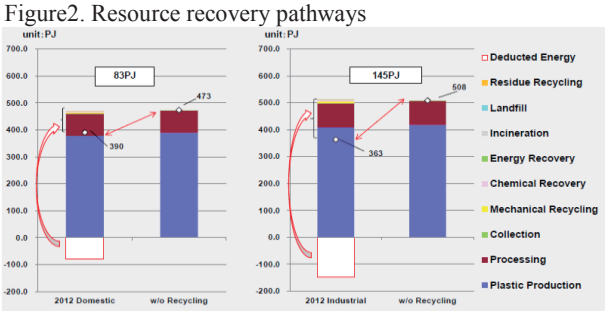


Figure3. Accumulation of energy consumption 2012

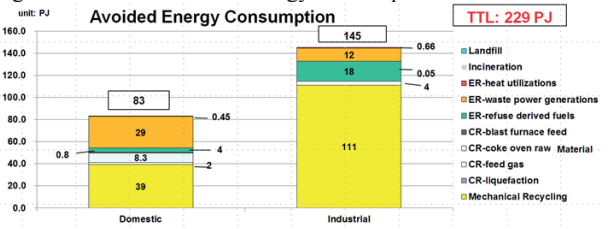


Figure4. Structure of avoided energy consumption 2012

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Applying c-LCA for Challenges to Global Warming at ASAHI KASEI CORP.

Junichi Nakahashi

ASAHI KASEI CORPORATION, Japan

1. Introduction

Human activity has begun to affect significantly to the globe environment. Global warming, water drought, material exhaustion, food shortage etc. are primary issues to be tackled.

ASAHI KASEI CORP. has started to implement the activity for tackling the global warming issue using the c-LCA..

2. Applying c-LCA activities at ASAHI KASEI CORP.

(1) Organization

Global warming Committee whose chairman is the holding company's environmental officer and LCA working group whose leader is the holding company's LCA expertise were settled at 2009. The global warming committee has changed into global environmental committee at 2012.

(2) Vision and Policy on global warming issue

ASAHI KASEI CORP. has released a vision "we live together with environment" at 2011. This means we treat the global warming issues as an important element in the business strategy. Our policy on global warming issues is that we will reduce greenhouse gas (GHG) emissions at our manufacturing facilities and will develop and supply innovative products and technologies which reduce GHG emissions when other industries and consumers use.

(3) Avoided GHG emissions accounting guidance for inner use

We developed an avoided GHG emissions guideline only for inner use at 2008 and uploaded to the intranet.

(4) Decision making tool for new plant investment

We amended the inner use standard for a new business proposal at 2010. The amendment was that the avoided GHG emissions amount shall be mentioned in the new business proposal document. By this amendment, avoided GHG emissions have become one of the elements for decision making in new business generation.

(5) Accounting avoided GHG emissions on actual products and technologies

We have made accounting the avoided GHG emissions using our inner use guideline for more than 40 actual products including products under development.

(6) Indicators and targets for 2020

We settled and published 2 indicators and targets for 2020 at 2011. One indicator is the GHG emissions reduction at our manufacturing facilities and another one is the avoided GHG emissions when our products and technologies are used.

(7) Evaluation by independent 3rd party

We made the independent expertise 3rd parties account the avoided GHG emissions on representative products to increase the credibility.

(8) Activity for chemical industry

I've worked for ICCA (International Council of Chemical Industries) / WBCSD (World Business Council for Sustainable Development) Chemical Sector LCATF in generating the avoided GHG emissions international chemical sector guideline published at 2013 [1]. I've also worked for JCIA (Japan Chemical Industry Association) LCAWG in generating avoided GHG emissions guideline published at 2012 [2]. These activities were intended to increase the credibility of avoided GHG emissions accounting.

3. Conclusion

We have made much GHG emissions reduction and much avoided GHG emissions increasing through 5 year activities on global warming issue since 2009.

Now at 2014 we are challenging to enforce the function of developing new products and new technologies in the field of energy and environment through direct education for employees.

From now we'll continuously challenge towards the target we shall make ASAHI KASEI CORP. the leading company in the field of global environment at 2020.

*note : c-LCA is an abbreviation of "carbon Life Cycle Analysis" and means an accounting method for greenhouse gas emissions along the supply chain.

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Guideline on Quantifying and Reporting the Avoided Emissions of Products

Motozo Yoshikiyo* , Kiyoshi Kasai

Japan Chemical Industry Association
*Corresponding author: myoshikiyo@jcia-net.or.jp

1. Introduction

Chemical Industry contributes reducing greenhouse gas (GHG) emissions through providing goods and services that avoid greenhouse gas emissions – such as fuel-saving tires, LED lamps, insulation materials for buildings and solar cells.

Reducing carbon footprints of product's manufacturing phase is one part of the solution to realize the environmental benefits. But reducing the GHG emissions through the use of the products is another important part to realize the environmental benefit. It is well known that LED lamps contribute to reduce electricity usage. But it is very difficult to quantify the amount of contributions of the products for reducing the GHG emissions. Moreover it is very easy to mislead the amount of contributions through the use of the products. The amount of the reduction of GHG emissions depends on the use conditions by the third party (User) and the choice of the reference products.

International Council of Chemical Associations (ICCA) and World Business Council of Sustainable Development (WBCSD) Chemical Sector project have recognized the importance of establishing the guideline on quantifying and reporting the contributions of the products for reducing GHG emissions through the product life cycle and developed practical guidelines on quantifying and reporting the contributions of the products in October 2013[1].

2. Definition of Avoided Emissions

To evaluate the contributions of the products for reducing GHG emissions through products life cycle, ICCA and WBCSD-Chemical Sector defined the "Avoided Emissions" that is the amount of reduced GHG emissions through the product life cycle enabled by providing the same or similar function as existing products in the marketplace.

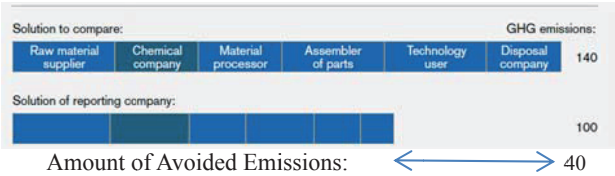


Fig1. Definition of Avoided Emissions

3. Selection of the solution to compare

In order to calculate avoided emissions, the chemical product studied needs to be compared to a specific reference case or baseline, which has to deliver the same function to the user. Additionally, the baseline solution has to be an established product with a high market share (product level studies) or the weighted average based on shares of all currently implemented technologies affording the same user benefit (end-use level studies).

4. Functional unit

4.1 Function of the product/application

As in ISO 14040/44, a functional unit shall be defined to which all inputs and outputs of the product system can be related and which establishes equivalency between the products/applications under study. Companies shall specify and quantify the functional unit taking into account the performance, benefit provided to the customer and relevant quality criteria.

4.2 Quality requirements

The following three quality properties should be used to assess whether compared solutions are truly exchangeable:

1. Functionality, related to the main function of the solution
2. Technical qualities, such as stability, durability, and ease of maintenance
3. Additional benefits rendered during use and disposal

4.3 Service life

The reporting company shall specify the service life of the product or service in the functional unit.

4.4 Time and geographic reference

Companies shall specify the reference period chosen for the study.

If a company wants to study avoided emissions in a future year, the reporting company shall explain the scenarios used to project the future.

Companies shall specify the geographic region chosen for the study.

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5. Calculation Methodology

5.1 Boundary setting

The reporting company shall describe the value chain steps of all solutions being compared. (From cradle to grave)

A flow diagram shall be provided to show the value chain for each of the solutions being compared.

All system boundaries shall be explicitly mentioned in order to clarify what processes are excluded or included.

5.2 Methods/formulas used

The reporting company shall describe the method used to account for emissions at each step. (Methodology, standards chosen)

Simplified calculation methodology is provided in the guideline.

5.3 Key parameters

The reporting company shall specify which activities and parameters drive generation of GHG emissions.

6. Reporting guidelines

The transparency of communication about results of avoided emissions studies is ensured by a number of further reporting requirements. These specify details of the report and include a reporting template.

Acknowledgments

We thank the member of ICCA and WBCSD Chemical sector project who joined the taskforce of preparing this guideline.

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Establishment of Kawasaki Mechanism, The certification program of avoided emissions outside Kawasaki City

Shoichiro TSURUTA,*[1] Masayuki KANZAKI,[1] Akikazu KOBAYASHI,*[2] Toshifumi TAKAMIZAWA,*[2] and Ichiro DAIGO[3]

[1]*Japan Environmental Management Association for Industry, Japan*; [2]*Kawasaki City, Japan*; [3]*The University of Tokyo, Japan*
*Corresponding author: tsuruta@jemai.or.jp

1. Introduction

Local municipalities have been addressing issues on reducing greenhouse gas (GHG) emissions within the administrative district recently. Many of them established the systems of making the reduction plan of GHG emissions whose results will be reported by businesses within the administrative district. Those systems help businesses to reduce GHG emissions voluntary.

Sometimes GHG emissions of new products becomes more increased than existing products even if technical innovations to reduce the energy contributed to the reduction of the whole GHG emissions though the life cycle.

In those cases the whole GHG reductions scheme is used to be negatively evaluated only within the administrative district. Therefore, it is important to evaluate the reduction of GHG emissions when GHG emissions from the final products (e.g. Use phase) is larger than the manufacturing phase. Under the scheme that GHG reduction is evaluated without viewpoint of life cycle, requirement of GHG reductions by the local municipality might cause a risk to lose a chance of overall reduction.

In order to address this issue, Kawasaki City launched the certification program named "Kawasaki Mechanism" in FY2013. The aim is to encourage the businesses to reduce GHG emissions on a global scale, which is taking advantage of many businesses that hold superior environmental technologies in Kawasaki City. Specifically, Kawasaki City certificates avoided GHG emissions outside Kawasaki City (avoided emissions) through a product lifecycle. This paper shows the outline of this program.

2. General scheme of Kawasaki Mechanism

As Figure1 shows the procedure of Kawasaki Mechanism, an application from a business is certificated by Kawasaki city through the review by the independent body and the consultation based on the review results by the evaluation committee.

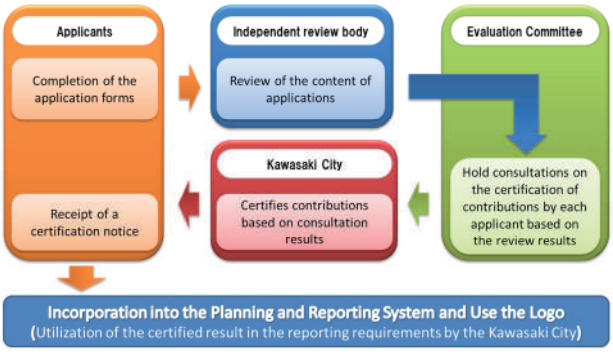


Figure1. Procedure of the Kawasaki Mechanism

Kawasaki City has the ordinance that implements the system of Planning and Reporting of Anti-Global warming Measures in Business Activities. In this system a business's effort toward lifecycle reduction can be reflected on "Adjusted emissions", which is obtained by subtracting the certified avoided emissions from direct emissions.

3. Calculation method of avoided emissions

The calculation guideline for avoided emissions outside Kawasaki City describes this system. The amount of avoided emissions is obtained by multiplying the following three items as shown in Figure2.

(1) The net reduction outside Kawasaki City based on a LCA per unit of product or service is quantified as the difference of emissions between "base-line" and the product or service to be evaluated, where base-line is a scenario in absence of the product or service.
(2) The rate of contribution of applying business entity in Kawasaki City is set, where relevant business part located in Kawasaki City is specified among three candidate phases; R&D, materials processing, and final products processing. Portion of these activities are obtained using any specific parameter, optionally including Kawasaki City input-output tables.
(3) The number of units sold outside Kawasaki City can be calculated by subtracting sales volume inside Kawasaki City from total sales volume. If sales volume is not available, shipped volume is acceptable.

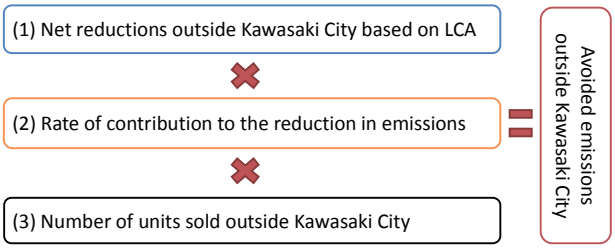


Figure2. Calculation method of avoided emissions

Further improvement of the calculation guideline should be based on accumulation of case studies of applications, in several issues including how to set base-line and rate of contribution.

4. Current status of the Kawasaki Mechanism

Ten applications were certificated and published on the homepage of Kawasaki City in FY2013. The businesses have been making appeals to target markets using the certification results. Kawasaki City intends to operate the system on continuing basis in order to encourage the emergence of new environmental products or services, which is expected to be a trigger for this kind of GHG reduction approach to become widespread among local municipalities.

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Program for Assessing the Contribution of Business Activities to Avoided Emissions in Shiga Prefecture, Japan

Maki Ogura,*[1] Takeshi Matsuda,[1] Ryota Ii,[1] and Kohei Ohnishi[2]

[1]*Pacific Consultants Co., Ltd., Japan*; [2]*Shiga Prefecture, Japan*
*Corresponding author: maki.ogura@tk.pacific.co.jp

1. Introduction

Shiga Prefecture set a long-term goal of a 50% reduction of greenhouse gas emissions from 1990 levels by 2030. To achieve that goal it established "Shiga Prefecture's Ordinance on Promoting the Creation of a Low-Carbon Society." Under the ordinance, businesses that emit above a defined threshold are required to prepare a Business Action Plan to reduce greenhouse gas emissions. This program includes an evaluation of contributions to create a low-carbon society through the development, production, and promotion of energy-efficient products, and other means, as one of the categories to be indicated in the written plans.

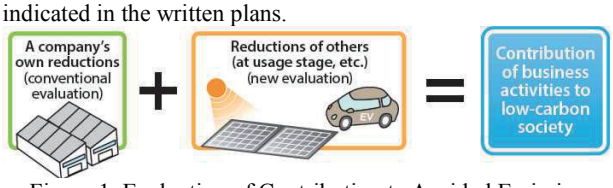


Figure 1. Evaluation of Contribution to Avoided Emission

To help business entities quantify their contribution to avoided emissions, Shiga Prefecture published a "Guideline for quantifying the contribution to avoided emissions" in 2013. In order to develop the Guideline, the Prefecture surveyed the products/services that contribute to avoided emissions, plus challenges in quantifying those contributions. It obtained input about the program through questionnaire surveys, meetings with business entities, and trial calculations, etc. The results were published on the Prefecture's website.

2. Basic Concepts

The Guideline was formulated with these basic concepts:

- ✓ Products and services that contribute to GHG emission reductions in society as a whole by being used are the targets of evaluation.
- ✓ Production and R&D of parts/materials being incorporated into energy-saving products, etc., are recognized as contributing to a low-carbon society.
- ✓ In principle, a lifecycle assessment is required. However, to promote broad use, the Guideline uses the concept of a simplified evaluation process.
- ✓ Amounts of avoided emissions and emissions at the production stage are to be reported and published separately.

3. Calculation methodology

The Guideline identifies the following conditions to be specified for calculations: product/service assessed, product model, time axis, place of use, baseline, life cycle activities, evaluation of parts/materials. Below is an outline of the "baseline" and "evaluation of parts/materials" steps.

3.1. Baseline

Comparative products should be specified (a comparison of the assessed product/service versus a comparison product, to identify GHG emission reductions).

The Guideline offers three concepts for setting baselines: (1) "standard products" now being produced, (2) "past products" (or popular products currently in use), and (3) "the state alternated by products assessed". Each business entity may set the baseline fitted with purpose of evaluation and calculability.

3.2. Evaluation of parts and materials

When parts/materials are evaluated, consideration must be given to how to assess their contributions to avoided emissions. One way is assessing GHG emission reductions of a product using the parts/materials assessed, compared to product made using comparative parts/materials. The other way is calculating the GHG emission reduction of final products made using parts/materials assessed, and distributing it to related business entities. When quantification of the contribution of parts/materials is difficult, business entities may quantify the GHG emission reduction of the final product and describe the role of the parts/materials qualitatively.

4. Characteristics of Shiga Prefecture's Guideline

As shown in Section 3, business entities may choose a evaluation methodology from several options in Shiga Prefecture's Guideline, depending on characteristics of products assessed and difficulties of data collection, calculation, and so on. Shiga Prefecture's aim in providing several options was to encourage as many business entities as possible to evaluate avoided emissions.

5. Aggregate calculation of avoided emissions

In FY 2013, 120 business entities reported their avoided emissions in Business Action Reports submitted. Of them, extracted 16 business entities described CO_2 emission reductions quantitatively. The aggregate calculation of the 16 business entities came to approximately 1.2 million t-CO_2. This figure is approximate and may include individual overestimates and underestimates.

6. Measures to encourage efforts to assess avoided emissions

To encourage business entities to take action to assess avoided emissions, Shiga Prefecture implemented the following measures:

- ➢ Support services to assess avoided emissions
- ➢ Seminars about avoided emissions
- ➢ Created and distributed brochures to broadly spread the word about business entities assessing avoided emissions, and their products and services.

Acknowledgments

We express sincere appreciation to all members of the review meeting for assistance formulating the Guideline.

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Neutralize CO_2 Emissions by Product Contributions

Ryo Yokoyama,* Tetsuya Kuwashima, Yasuyuki Fujioka, Masaru Hirose

TDK Corporation
*Corresponding author : ryoyoko@jp.tdk.com

1. Introduction

In recent years, many organizations and enterprises are focusing on CO_2 emissions reduction by products or services. From the perspective of product lifecycle, they recognize that reducing CO_2 emissions during the use phase is as important as reducing CO_2 emissions during the manufacturing phase.

Especially in the electrical and electronic field, it is expected that applying their products to other industrial fields, office, home, etc. enables these sectors to reduce huge amount of CO_2 emissions. Here, CO_2 emissions reduction during the use phase is called "product contributions", because it is performed by the products which demonstrate excellent effect to reduce negative environmental impact.

CO_2 emissions reduction amount is quantified as the difference of GHG emissions amount in the comparison between target product and baseline.

2. TDK Environmental Action 2020

TDK, electronic components manufacturer, set the ambitious goal of to achieve carbon neutrality by 2020. Carbon neutrality means offset the amount of CO_2 emissions during manufacturing phase by the product contributions.

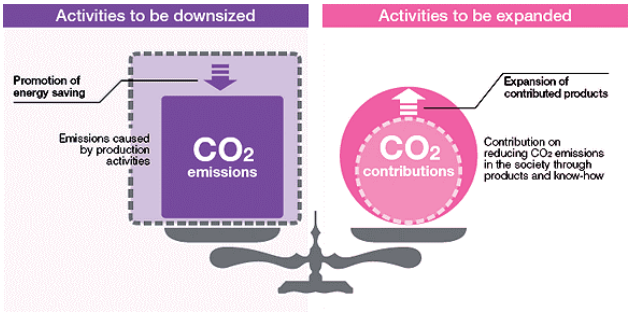


Figure 1. TDK Carbon Neutrality

TDK has made the rational internal standard to calculate the amount of product contributions of electronic components, and offer to the association's working group and academic society.

3. Product contributions of electronic components

For quantifying product contributions of electronic components, existing guidance [1] proposes that a final product should be assessed if a target product is intermediate product. It is considered as an ideal way, but there is a difficulty.

In case only target electronic components was improved, product contributions amount can be quantified by assessing final product in which target product is included. However, usually the design of final product and the characteristic of electronic components are improved at the same time. This is the reason why to quantify product contributions amount of electronic components is very difficult actually. Hence, more interpretation of that guidance which leads to implementation procedure should be given.

As the solution of this problem, two methods have been devised. (a) directly calculate from the energy saving amount by electronic components itself, (b) indirectly estimate by using contribution ratio to the contributions of the final products. Former is for the electronic components used on a transmission route of electric power, and latter is for the others. In other words, (a) is the method which extracts and visualizes the effect of electronic components to the energy consumption of final products. In this method, assessment of electronic components is carried out in the same way for the final product.

4. Calculation formula

Implementation procedure of (b) already has been proposed by some local governments [2, 3] and association in Japan. On the other hand, calculation result by (a) is very few. Because method (a) requires the technical information of actual working conditions of electronic components. But this information is necessary to calculate product contributions of electronic components and also to prevent overestimation.

Calculation formula for (a) is :

$$\text{Product Contributions(a)} = \Delta W_r \times L \times Hop \times Coef \times S \quad (1)$$

ΔW_r : reduced electric power at rated condition,
L : load factor, H_{op} : hours of operation,
$Coef$: CO_2 coefficient, S : sales quantity

and calculation formula for (b) is :

$$\text{Product Contributions(b)} = C_{fp} \times R \times S \quad (2)$$

C_{fp} : product contributions of final product,
R : contribution ratio of electronic components,
S : sales quantity

5. Current status of "TDK Environmental Action 2020"

By using above two calculation formulas, TDK make progress of calculating product contributions. TDK's products are included in a lot of kinds of final products. The number of usage is goes up to 200. These usages are categorized to 26 groups. For each category, detailed calculation formula, L and H_{op} have been decided.

The annual performance result of product contributions in 2013 reached 0.886 Mt-CO_2.

TDK will achieve "Carbon Neutrality" in a couple of years. After that, we are going to build the internal system to promote creation of products which contribute to CO_2 emissions reduction in the society. In addition, we will try to reconsider the scope of "product contributions" of electronic components, from the use phase to lifecycle.

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Impact of resource-use intensity of goods and services and demand structure on national resource productivity: Time series analysis for 10countries

Arata Ito*[1] and Seiji Hashimoto[1]

[1]*Ritsumeikan University, Japan*
*Corresponding author: rv0001rv@ed.ritsumei.ac.jp

1. Introduction

The resource productivity (RP) indicator has been used increasingly in Europe and Japan as a metric of sustainable use of natural resources that is an important and underpinning determinant of sustainable development [1, 2]. The literature reports that the RP value differs widely among countries. Nevertheless, it is difficult to say that the resource use efficiency of a country with higher RP is definitely higher than that of a country with lower RP because the efficiency is affected by diverse factors including material requirements (resource-use intensity, RUI) for producing goods and services and demand shares of goods and services (demand structure, DS). We had estimated the magnitudes of these factors' effects by comparing the RPs of 10 countries, which are importing, exporting, resource extraction and economically developing countries [3]. In this study, we analyzed factors that differentiated resource productivity of 10 countries (Japan, Australia, China, Czech republic, Hungary, Indonesia, India, Netherland, Portugal, and United states) from 1995 through 2010.

2. Methodology

We analyzed the effects of the RUIs and DS of goods and services on national RP by applying index decomposition analysis. It was performed using the following equation: we used national resource-use intensity, i.e., inverse of *RP*, for the left-hand side of the equation because it facilitates the interpretation of factors on the right-hand side.

$$\frac{DMI}{GDP} = \sum_i \frac{DMI_i}{F_i} \times \frac{F_i}{F} \times \frac{F}{GDP}$$

$$= \sum_i \frac{DMI_i}{F_i} \times \left(\frac{F_{id}}{F} + \frac{F_{ie}}{F} \right) \times \frac{F}{GDP}$$

$$= \sum_i RUI_i \times (FDS_{id} + FDS_{ie}) \times (1 + API)$$

where, *DMI* stands for the direct material input (*t*); *GDP* signifies the gross domestic product (PPP-constant 2005 international $); DMI_i denotes *DMI* induced by the final demand for goods and services *i* (t); F_{id} represents the domestic final demand for goods and services *i* (PPP-constant 2005 international $); F_{ie} represents exports for goods and services *i* (PPP-constant 2005 international $); and *F* is the total final demand (PPP-constant 2005 international $).

The first factor, RUI_i ($=DMI_i/F_i$), denotes resource-use intensity per unit of final demand for goods and services *i*. Therefore, lower resource-use intensity of goods and services contributes to lower national resource-use intensity The second factor, FDS_{id}($=F_{id}/F$) and FDS_{ie}($=F_{ie}/F$), shows final demand structures, which respectively denote the ratios of domestic final demand and exports for goods and services *i* to the total final demand. Therefore, lower demand for goods and services which use more materials improves national resource-use intensity. *API* in the last factor is designated as the average propensity to import: it is regarded as representing the condition of international trade and the size of an economy. Lower *API* implies lower national resource-use intensity.

3. Results and Discussion

Figure 1 presents an illustration of the effects of three factors on differences in resource-use intensity in 10 countries. The positive/negative value of a factor denotes its contribution to an increase/decrease in national resource-use intensity of 2000, 2005, or 2010 compared to 1995. *RUI* of goods and services shows negative value for almost all countries, showing that a decrease in *RUI* of goods and services compared to 1995 contributed to a decrease in national resource-use intensity in respective years in those countries. In addition, the *DS* for exports had an impact on resource-exporting countries such as Australia and India, while developing countries such as China and India were affected by the *DS* for domestic as well.

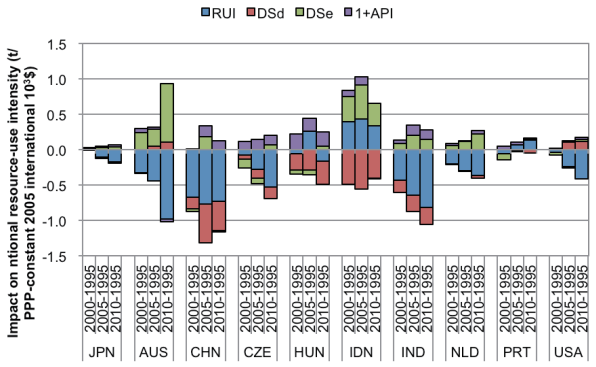


Figure 1. Effects of three factors on differences in resource-use intensity among years in 10 countries.

4. Conclusion

We analyzed the effects of three factors on national resource-use intensity from 1995 through 2010. The changes in national *RP* during the target period were influenced by changes in not only *RUI* of goods and service, but also *DS* for exports and domestic. Therefore, comparison of the *RUIs* of goods and services, rather than just comparing national *RP*, is recommended because national *RP* is affected by difference in other factors examined in this study.

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Selection of Products for Remanufacturing Based on the Designs of End of Life Products

Aditi D. Joshi,*[1] Surendra M. Gupta,[1] and Tetsuo Yamada[2]

[1]*Northeastern University, USA;* [2]*The University of Electro-Communications, Japan*
*Corresponding author: joshi.ad@husky.neu.edu

1. Introduction

This paper addresses the methodology for the selection of used products based on the ease of retrieving its components, their quality level and the total cost of retrieving. A mathematical model using goal programming is developed by considering the goals to minimize the total cost of remanufacturing (total disposal cost, collection cost, labor cost, and recycling revenue), maximize the quality level of the remanufactured products and the material sales revenue and minimize the total disposal weight.

2. Problem formulation

The total cost consists of the total disposal, collection and labor costs minus the total recycling revenue [1].
The remanufacturing system is formulated as follows:

1. The first goal is to minimize the total cost. The total cost is set to be at most TC*. Therefore the first goal can be formulated as follows:
Goal: minimize d_1^+
Subject to: $TC+d_1^- - d_1^+ = TC^*$
Where, $TC= CC_{xj} +DC_x + LC_x - RR_x$

Collection cost: CC_{xj} is the average cost associated with the collection of used product x from the consumers.

Total disposal cost: Disposal cost index, percentage of recyclable contents in each component, the weight of the components, the number of components, the probability of breakage, the probability of missing components and the disposal cost factor affect the total disposal cost.

$$DC_x = \sum_{C_{xj} \in (Root_x)} \{DCI_{xj} * W_{xj} * (1 - PRC_{xj}) * (M_{xj} * (1 - pm_{xj}) - M_{xj} * (1 - pb_{xj} - pm_{xj}) * X_{xj})\} * F_{dc}$$

Labor cost: Disassembly time of the root node of the used product, the disassembly time of each subassembly in the used product and the reprocessing cost per unit time are the factors used in the calculation of the labor cost.

$$LC_x = (T(Root_x) + \sum_{k=1}^{L_x} T(S_{xk})) * C_L$$

Total recycling revenue: Percentage of recyclable contents in each component, the weight of components, the recycling revenue index, the number of components, the probability of breakage, the probability of missing components and recycling revenue factor are the factors that affect this term.

$$RR_x = \sum_{C_{xj} \in (Root_x)} \{PRC_{xj} * W_{xj} * RI_{xj} * (M_{xj} * (1 - pm_{xj}) - M_{xj} (1 - pb_{xj} - pm_{xj}) * X_{xj})\} * F_{rr}$$

2. The second goal is to maximize the quality, to achieve the quality level of at least Q* or more. Therefore the second goal can be formulated as follows:
Goal: minimize d_2^-
Subject to: $Q+d_2^- - d_2^+ = Q^*$

3. The third goal is to maximize the material sales revenue. Therefore, the third goal can be formulated as follows:
Goal: minimize d_3^-
Subject to: $MSR+d_3^- - d_3^+ = MSR^*$

4. The fourth goal is to minimize the total disposal weight. Therefore the fourth goal can be formulated as follows:
Goal: minimize d_4^+
Subject to: $DW+d_4^- - d_4^+ = DW^*$

3. Numerical problem and results

A device-embedded (i.e., sensors and radio frequency identification tags) residential air-conditioner (AC) case is considered here [2]. There are 10 components that the model deals with. The quality level of a component is defined by the remaining life of that component. Larger remaining life signifies better quality. Depending on the remaining life, quality component bins are defined for the remanufacturing system. Three quality component bins are considered here (bin 1 with the lowest quality, bin 2 with the medium quality and bin 3 with the highest quality). The first bin holds components whose remaining life is 2 years or less. The second component bin holds components whose remaining life is between two and three years. The third bin holds components with remaining life of more than 3 years. Repaired product demands are assumed to be 8, 10, and 12 for the remaining life bins 1, 2, and 3, respectively. The mathematical model was solved using CPLEX.

Table 1: Goals and target values using CPLEX

Goal	Target Value	Step 1	Step 2	Step 3	Step 4
Total Cost	7500.00	6704.74	7429.66	7429.66	7429.66
Quality Level	750.00	300.00	723.00	723.00	723.00
Material sales revenue	5000.00	3645.21	4529.82	5291.46	5000.00
Disposal Weight	0.00	31.69	25.89	20.87	13.84

4. Conclusion

Environmental conscious manufacturing and product recovery has gained a lot of attention due to the increasing environmental concerns. Selection of used products can hence be proven to be useful in conserving the environment. But the cost of procuring the used products, their quality level as well as the time and labor cost required to disassemble and assemble the used components can be some of the crucial decision points. A case example was considered to demonstrate the application of the proposed model.

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Mathematical formulation of urban mines design problem

Shinsuke Kondoh,*[1] Hithoshi Komoto,[1] and Keijiro Masui[1]

[1]*National Institute of Advanced Industrial Science and Technology (AIST), Japan*
*Corresponding author: kondou-shinsuke@aist.go.jp

1. Introduction

The amount of metals which has been dumped and accumulated as E-waste to date reaches a scale comparable to natural reserves. For example, according to the calculation of National Institute for Material Science (NIMS) in Japan, the amount of gold, silver, indium, tin, and tantalum reach 16%, 22%, 61%, 11%, and 10% of the world's current reserve, respectively [1]. These metals are called urban mines [2] and collect industrial attentions recently. To make full use of today's urban mines as well as those in future (i.e., electrical and electronic equipment which are currently used but will be available in future), it is necessary to design products and their recycling/reuse processes considering future reverse supply chains in a strategic viewpoint. To this end, this study attempts to mathematically formulate the problem focusing on the interdependency among product structure, recycling/reuse processes, and reverse supply chain network.

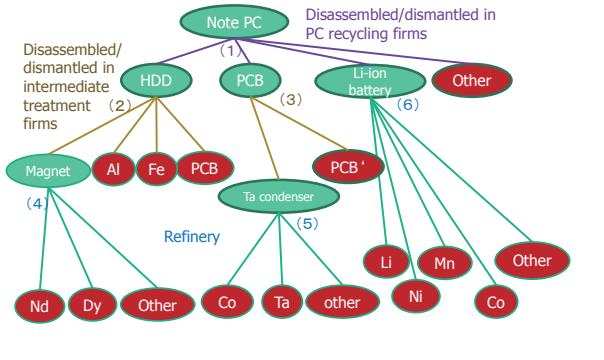


Figure 1. RRT model of PCs

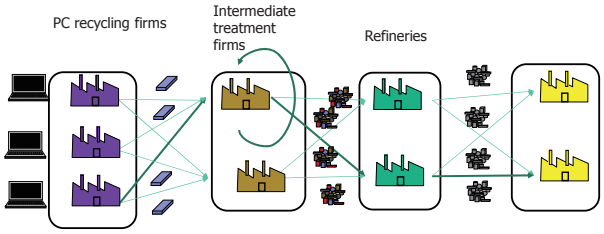


Figure 2. PRN model of PCs

2. Formulation of the model

First, the paper introduces recycling/reuse tree (RRT) model which represents all possible sequences of material recovery (or component reuse) process in addition with their corresponding costs. Figure 1 shows a simplified RRT of a personal computers (PCs). Each node and edge of the graph correspond to either a sub-assembly, component, or material mixture, and either disassembly, dismantling, or refine operations, respectively. For example, the graph shows that a PC can be disassembled in a PC recycling firm to obtain hard disk drive (HDD), print circuit board (PCB), Li-ion battery, and other materials.

Then, the provider and receptor network (PRN) model is introduced to represent all possible assignment of the recycling (or reuse) processes to the firms which are sparsely located in Japan. Figure 2 shows a simplified PRN model of PCs focusing on material recycling. Each node of the graph corresponds to a recycling firm. All operations in RRT model can be assigned to some of the firms included in the PRN model. By correlating these two models, an adequate recycling/reuse sequence as well as corresponding logistic plan among the firms (in terms of a predefined set of goal indicators) are derived considering the cost and revenue of material recovery (or component reuse), which might differ from firm to firm.

3. Urban mines design problem: integrated design of a product and processes

Through a sensitivity analysis of goal indicators (i.e., profit of each firm, overall recycling rate, etc.), (i) most influential RRT and PRN model parameters are identified. Correlating these parameters with product and process design parameters (e.g., assembly structure, material usage in each component, usage conditions of recycling facilities etc.), (ii) a set of key design parameters are identified as shown in Figure 3. A set of design rules for urban mines are derived by interpreting the interrelationship among these parameters in addition with sensitivity analysis results.

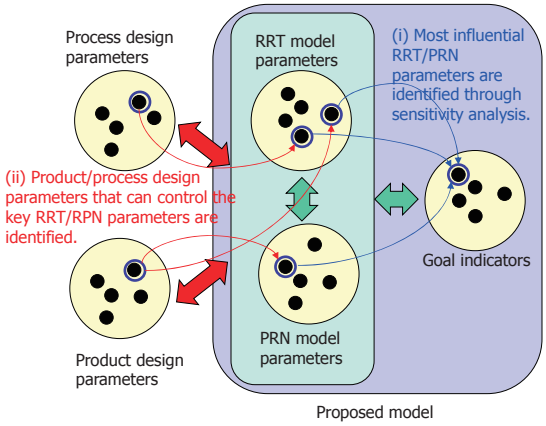


Figure 3. Relationship between parameters

4. Summary

This study attempted to mathematically formulate urban mine design problem by correlating goal indicators with product and process design parameters via an intermediate model consisting of RRT and PRN models. By interpreting the analysis results with referring to the interrelationship among parameters, urban mine design rules can be derived in our future study.

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Sorted Collection of Used Batteries and Small Home Appliances by Municipalities

Atsushi Terazono,*[1] Masahiro Oguchi,[1] Shigenori Iino,[2] and Satoshi Mogi [3]

[1] *National Institute for Environmental Studies, Japan*; [2] *Tokyo Metropolitan Research Institute for Environmental Protection, Japan*; [3] *Bureau of Environment, Tokyo Metropolitan Government, Japan*
*Corresponding author: terazono@nies.go.jp

1. Introduction

In Japan, municipalities collect and dispose of dry batteries, whereas the Japan Portable Rechargeable Battery Recycling Center (JBRC), which is a branch organization of the Battery Association of Japan (BAJ), is responsible for the collection and recycling of small rechargeable batteries. This is a major contrast with the collection procedures of EU member states, where all types of portable batteries are collected together through a designated collection scheme under the EU Battery Directive (2006/66/EC).

The objectives of this study were to clarify current collection rules of waste batteries by municipalities in Tokyo and discuss future challenges for hazardous substance control and safety.

2. Materials and methods

We reviewed the battery collection rules for each ward in the Tokyo Metropolitan Area (23 special wards) in 2013 based on information provided on their websites.

We investigated the characteristics of waste batteries collected through the battery collection scheme in Ward A of Tokyo. In Ward A, waste battery collection boxes are placed at public institutions such as city hall and libraries. The following characteristics were investigated for waste batteries in Ward A: number, weight, shape, size, type, production country, expiration date (month-year) of recommended use, hazardous substance labelling, and insulation.

We also investigated the characteristics of waste batteries collected with small WEEE through the small WEEE collection schemes in Wards A and B and City C. Small WEEE collection schemes began in Ward A, Ward B, and City C in November 2009, October 2013, and July 2013, respectively, using collection boxes located in public institutions. The following characteristics were investigated for the small WEEE: number, weight, category, presence of a battery, and removability of the battery (if used). Removability of batteries was rated on three levels: 1 (manually removable), 2 (easily removable with a screwdriver, no dismantling needed), and 3 (dismantling or destruction needed). We refer to level 1 and 2 batteries as "exchangeable batteries" and level 3 batteries as and "built-in batteries."

3. Results

From the review of battery collection rules, each special ward in Tokyo accepts dry batteries in dedicated collection boxes for batteries (usually regarded as hazardous waste) at public institutions or as non-combustible waste. Consumers need to pay attention to the specific collection rules for each type of battery in each municipality.

Our field survey of collected waste batteries indicated that 6–10% of zinc carbon and alkaline batteries discarded in Japan currently could be regarded as containing mercury. More than 26% of zinc carbon dry batteries currently being discarded may have a lead content above the labelling threshold of the EU Battery Directive (2006/66/EC). Figure 1 shows the expiration dates of alkaline batteries that were collected. Although more than half of the waste zinc carbon batteries had already passed their expiration date, most of the waste alkaline batteries had not expired. The production countries of advanced alkaline batteries are produced in Japan and Thailand. In terms of safety, despite announcements by producers and municipalities about using insulation (tape) on waste batteries to prevent fires, only 2.0% of discarded cylindrical dry batteries were insulated.

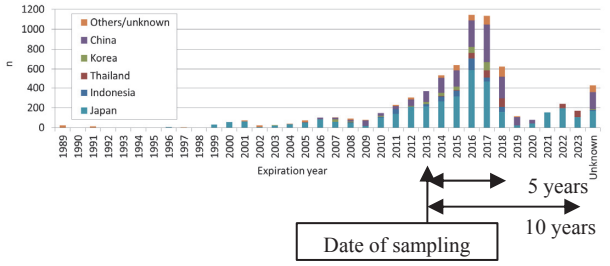


Figure 1. Distribution of expiration dates of cylindrical batteries (from batteries collected in Ward A, on a number basis): Number of alkaline batteries by expiration dates and production countries.

Our field study of small WEEE showed that small WEEE and batteries were combined in the collection boxes. On a weight basis, batteries made up an average of 4.6% of the total collected small WEEE. Exchangeable batteries were used in more than 90% of mobile phones, digital cameras, radios, and remote controls, but the removal rate was as low as 22% for mobile phones.

4. Discussion

In terms of battery collection and recycling, three perspectives are important: control of hazardous substances, safety, and resource recovery. In Japan, button batteries and small rechargeable batteries are required to be disposed of at designated BAJ boxes, primarily to remove Hg and Cd from the waste stream. Because many municipalities in Japan have collection schemes for small WEEE in addition to those for conventional dry batteries, municipalities play a significant role in all three perspectives and in avoiding consumer confusion.

In areas where small WEEE recycling schemes are being operated after the enforcement of the Act on Promotion of Recycling of Small Waste Electrical and Electronic Equipment in Japan in 2013, consumers may be confused about the need for separating batteries from small WEEE (especially mobile phones). Given the safety issues and the rapid changes occurring with mobile phones or other types of small WEEE, discussion is needed among stakeholders to determine how to safely collect and recycle WEEE and waste batteries.

Acknowledgments

This research was supported by the Global Environment Research Fund of the Ministry of the Environment, Japan. We thank the Tokyo Metropolitan Government and the municipalities where we conducted field surveys for their cooperation and support.

Life Cycle Assessment of an Automotive Lithium-Ion Battery In Large-Scale Commercial Production

Hyung Chul Kim*[1], Timothy J. Wallington, Renata Arsenault, and Chulheung Bae

[1]*Ford Motor Company, Dearborn, MI USA*
*Corresponding author: hkim41@ford.com

1. Introduction

Electric vehicles (EVs) including hybrid electric vehicles (HEVs), plug-in hybrid vehicles (PHEVs), and battery electric vehicles (BEVs) provide an opportunity to reduce carbon emissions from the transportation sector. To evaluate the full impacts of EVs requires a Life Cycle Assessment (LCA) perspective. Published LCAs provide greenhouse gas emissions for production of $LiMn_2O_4$ (LMO) and $LiNi_{.33}Mn_{.33}Co_{.33}O_2$ (Li-NCM) chemistry batteries in the ranges 6-8 and 12-51 kg CO_2eq./kg of battery, respectively [1-5].

Primary data are scarce and current LCAs rely on a variety of sources for the inventory analysis of battery materials production and manufacturing stages such as literature values, laboratory scale production data, and estimates based on similar processes or products. While a few studies use data from actual battery design and manufacturing facilities [4, 5], so far no LCAs have been conducted for a commercial lithium-ion battery used in mass produced EVs.

In this study, we will examine the cradle-to-gate greenhouse gas (GHG) emissions for the Ford Focus BEV battery pack. The inventory analysis is based on the actual design and cell manufacturing for a commercial Li-NCM /LMO battery. The results will be compared with the current LCA estimates to understand the effect of production scale and energy mix.

2. Review

Current LCAs focus on the cradle-to-gate emissions of EV batteries. Figure 1 compares the GHG emissions reported in literature for Li-NCM batteries. In these studies the GHG emissions assessed for materials production and battery manufacturing were 9-27 kg CO_2-eq. and 4-24 kg CO_2-eq. per kg of battery, respectively.

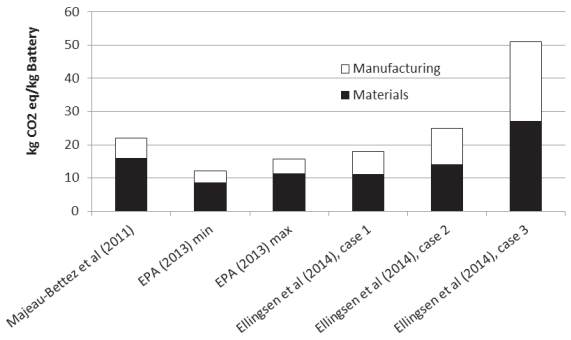


Figure 1. GHG emissions from Li-NCM battery production in literature

The key sources of uncertainties in the studies were the energy demand during cell manufacturing processes including lamination, electrode formation, and assembly along with the materials usages in the battery pack. The manufacturing energy use in the study by Majeau-Bettez (2011) relies on a top-down approach based on industry overall energy requirements while the analysis by the US EPA (2013) uses measured primary data from actual cell production. The study by Ellingsen et al. (2014) is the only study based on data provided by a full battery producer.

3. Results and Future Work

In the screening LCA stage, we estimated cradle-to-gate GHG emissions for the Focus BEV Li-NCM/LMO battery based on the bill of materials (BOM). As shown in Figure 2, cells account for 50% of the battery pack mass with the balance being structural and electronic component materials. Using Gabi and Ecoinvent LCA databases along with literature data for these materials gives GHG emissions of 7-10 kg CO_2-eq./kg of battery. This result falls in the lower bound of the literature estimates shown in Figure 1.

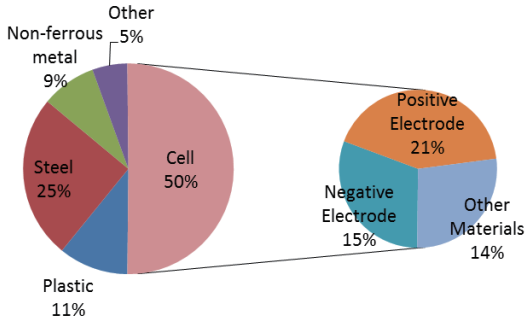


Figure 2. Material breakdown of Focus BEV Li-NCM/LMO battery

A follow-on analysis of the environmental impacts of the battery materials is being conducted and is expected to reduce the current uncertainties for the cradle-to-gate GHG emissions. In parallel, we are analyzing the inventory of cell and battery manufacturing, i.e., the electricity, fuel and water demand, based on primary data from the battery industry.

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The impact of demographic change in Japan on supply security footprint of critical metals

Yosuke Shigetomi,*[1,2,3] Keisuke Nansai,[2] and Susumu Tohno[1]

[1]*Kyoto University, Japan*; [2]*National Institute for Environmental Studies, Japan*; [3]*JSPS Research Fellow, Japan*
*Corresponding author: shigetomi.yosuke.46w@st.kyoto-u.ac.jp

1. Introduction

With expansion of electronics for hybrid vehicle and IT products, the demand for critical metals including rare earth metals has been increasing. These metals are strongly related not only to usefulness for today's our lifestyles but also to new energy technologies such as solar power and wind power to ensure a low carbon society in the future. Reportedly, in terms of life cycle assessment of the entire nation, household consumption is the most important factor related to environmental burdens in economically developed countries. [1] Nevertheless, few studies have analyzed metal consumption from the viewpoint of household consumption similarly to previous studies particularly addressing greenhouse gas (GHG) emissions and energy consumption.

This study calculated material footprints (MFs) [2] of critical metals caused directly and indirectly by Japanese household consumption using a global link input–output model (GLIO) [3] with international material flow data. The target metals here are neodymium, cobalt, and platinum of which the demand is expected to increase along with further expansion of new energy technologies. Additionally, multiplying MFs by the risk factor of each country involved in the MFs yielded mining risk footprints (MRFs) [4] of household consumption. MRF is a key indicator to measure supply security of metals with a focus on mining risk of countries where the metals are mined. We calculated each of the MFs and MRFs in 2005 and then estimated the impact of an aging Japanese society with fewer children in the near future on them.

2. Methods and Data

To examine the effects of the aging and lower birthrate trends on the MFs and MRFs specifically in this study, we defined household attributes (j =1…6) by the age of the head of a household (1=20s, –29; 2=30s, 30–39; 4=40s, 40–49; 4=50s, 50–59; 5=60s, 60–69; 6=70s+, 70–). We estimated respective annual expenditures by disaggregating the household sector defined as a single sector in the 2005 Japanese input–output table (JIOT) into the six household sectors with national household statistics. Then we calibrated them with mathematical programming to be consisted with the annual expenditure of each commodity included in the JIOT.

The most recent JIOT is based on 2005 figures. In this study, we estimated the future household consumption with focuses on changes in the numbers of households and household sizes due to the aging and lower birthrate trends as equations (1) and (2).

$$f_{ij}^{\mathrm{JD}}(t) = f_{ij}^{\mathrm{JD}}(t-1) \times \frac{H_j(t)}{H_j(t-1)} \times \theta_{ij}(t) \quad (1)$$

$$f_{ij}^{\mathrm{JI}}(t) = f_{ij}^{\mathrm{JI}}(t-1) \times \frac{H_j(t)}{H_j(t-1)} \times \theta_{ij}(t) \quad (2)$$

$f_{ij}^{\mathrm{JD}}(t)$ and $f_{ij}^{\mathrm{JI}}(t)$ respectively represent future household consumption expenditures of domestic and import commodities i (i =1...409) by householder age groups j. $H_j(t)$ is number of households by householder age group j according to the National Institute of Population and Social Security Research [5]. Element t denotes target years in this study as follows: 2005 (t=1), 2010 (t=2), 2015 (t=3), 2020 (t=4), 2025 (t=5), 2030 (t=6), and 2035 (t=7), since $H_j(t)$ was predicted for 2035. $\theta_{ij}(t)$ is the influence coefficient on the future household expenditure for commodity sector i reflected by the change in household size. Finally, we obtained each of the MFs and MRFs of neodymium, cobalt, and platinum by multiplying $f_{ij}^{\mathrm{JD}}(t)$ and $f_{ij}^{\mathrm{JI}}(t)$ by their MFs and MRFs per unit expenditure [4], respectively.

The detailed methodology in this study is elaborated in Shigetomi et al. (2014). [6]

3. Results

Here we describe a part of results in terms of the MF and MRF of neodymium. Table 1 shows the 5 commodity sectors with each of the highest MFs and MRFs of neodymium derived from household consumption for 2035, differentiating between domestic products (JD) and imported ones (JI). These 5 commodities dominate in the same rank of largest MFs and MRFs. The value of MRF of the commodity sector means the ratio of mining risk of neodymium induced by Japanese household demand to the global one.

Table 1 Top 5 household commodity sectors and their highest MFs and MRFs of neodymium for 2035

Rank	Commodity No.	Commodity sector	MF [t]	MRF [%]
1	JD252	Passenger motor cars	83	0.20
2	JD381	Repair of motor vehicles	42	0.10
3	JI243	Personal computers	23	0.06
4	JD253	Trucks, buses and other cars	18	0.05
5	JD237	Electric audio equipment	13	0.04

Acknowledgments

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Material Flow Analysis of Heavy Metals in Contaminated Soil – A Case Study on the Polluted Sites in Taoyuan County, Taiwan

Rong-Hua Lee and Yuh-Ming Lee*

National Taipei University, Taiwan
*Corresponding author: yml@mail.ntpu.edu.tw

1. Introduction

Accompanying with Taiwan's industrialization, the industrial wastewater was emitted directly into the irrigation canals around agricultural areas and created serious heavy metal contamination, which is a serious threat to human and animals' health because of bioaccumulation in the food chain. The issue of such contaminated farmlands has emerged as a horrible problem in Taiwan society recently.

Taoyuan County is one of the most seriously contaminated areas in Taiwan. Based on the investigation conducted by local environmental authorities in Taiwan, the agricultural polluted lands were categorized as five grade, and the total area of contaminated farmlands reaching up to fifth grade in Taoyuan County is 319 hectares. Those lands were legally documented as Soil Pollution Control Sites according to the newly enacted law in Taiwan --- the Soil and Groundwater Pollution Remediation Act of 2000 (SGPRA). The amount of control sites in Taoyuan County can be ranked as number one in Taiwan.[1]

2. Methodology

In this study, substance flow analysis and life cycle impact assessment of heavy metal in contaminated farmlands in Taoyuan County will be conducted to fully understand their total quantity, spatial distribution and fate in economic activities and in the environment by using the information of contaminant concentration investigated before.

Udo de Haes *et al*. (1997) define SFA (Substance Flow Analysis) as a specific brand of MFA(Material Flow Analysis), dealing only with the analysis of flows of specific chemicals. In general terms, materials flow studies comprise the following three-step procedure (van der Voet, Kleijn, van Oers, Heijungs, Huele and Mulder 1995): (a) definition of the system, (b) quantification of the overview of stocks and flows, and (c) interpretation of the results. All three steps involve a variety of choices and specifications, each of which depends on the specific goal of the study to be conducted. [2]

The first step in SFA is to define the system, and a number of choices must be made with regard to the following aspects: spatial demarcation, functional demarcation, time horizon and materials to be studied. The various categories of processes, stocks and flows belonging to the system must be specified. Finally, this results in a flow chart: the specification of the *network of nodes*. The quantification of the network is the next step. This involves identifying and collecting the relevant data, on the one hand, and modeling, on the other. Three possible ways of modeling the system are: (a) accounting or bookkeeping, (b) static modeling and (c) dynamic modeling. All three types having their own data requirements, as well as their own potential for policy support. The quantified overview can be regarded as the result of an SFA study. However it is not easy to derive policy relevant conclusions from this. Two types of 'interpretation' are distinguished here: evaluation of the robustness of the overview quantification, and translating the overview into policy-relevant terms.[2]

3. Site Description

Taoyuan County will be chosen as the research scope in this study, which is one of the most seriously contaminated areas in Taiwan. Agricultural land in the county is contaminated by heavy metals such as cadmium (Cd), copper (Cu), chromium (Cr), and zinc (Zn).

The remediation technology for contaminated farmlands in Taoyuan County is generally combined soil turn-over dilution with excavation method to lower the heavy metal concentration to achieve the national standards. Those physical treatment methods (not chemical treatment) could avoid the secondary pollution to the environment and remedial lands could also return for agricultural uses. The government in Taiwan have been devoted to treat the pollution problem in Taoyuan County recently. As a result, the contaminated farmlands in Taoyuan County is a representative area and is a case worth to study.

4. Results and Discussions

(a) There are 1,778 contaminated farmlands, which were legally documented as Soil Pollution Control Sites, at a total area of approximately 232.32 hectares in Taoyuan County, according to the preliminary data collected from Environmental Protection Unit in Taiwan. [1]

(b) Cadmium is a toxic chemical. Taiwan relies on imports to supply the demand of cadmium, because there is no locally produced cadmium in Taiwan. However, due to the change about provisions of the declaration job, there usually exists an inconsistent of the declaration and the actual amount of import. For example, the amount of import declaration of cadmium and its compounds was 174 ton in 1982, and up to 477 ton in 1986. Due to cadmium oxide having not to be declared from 1989, it reduced to 9 ton in 1990. Consequently, the government should strengthen the declaration job for import manufacturers and check the usage and inventory records regularly, in order to really control the amount the heavy metal in Taiwan.[3]

5. Summary and Conclusion

The interpretation of the results of the material flow analysis would be divided into two part: (a) economic part, (b) environmental part. First, this study would conduct the result interpretation about the flow of heavy metal in economic part. On the other hand, the analysis and assessment of the heavy metal released into environment part would also been evaluated simultaneously. Finally, this study would combine these two parts to make a completely interpretation about the flow of heavy metal in Taoyuan County under the concept of life-cycle.

The results of this study could provide proper suggestions to management, policy decision making, and draft strategies for controlling pollution.

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Japanese nitrogen footprint model for the prediction of nitrogen loss to the environment

Hideaki Shibata[1*], Lia R. Cattaneo[2], Allison M. Leach[2] and James N. Galloway[2]

[1]*Hokkaido University, Japan*; [2]*University of Virginia, USA*

*Corresponding author: shiba@fsc.hokudai.ac.jp

1. Introduction

Nitrogen (N) is an essential nutrient, but reactive nitrogen (Nr, defined as all nitrogen compounds except N_2) can cause many environmental problems (e.g., smog, climate change, water pollution) when concentrations exceed certain thresholds. Humans create more Nr than nature, and do so primarily through food and energy production processes. The main sources of Nr are cultivation biological nitrogen fixation (several forms of Nr), fossil fuel combustion (NOx), and fertilizer (NH_3). The Nr application as fertilizer is necessary to sustain a growing population, so it is important to balance the environmental costs and societal benefits of Nr.

The N-Calculator is a tool that allows individuals to calculate their personal N footprint [1]. The "footprint" is a parameter to help determine human impacts on the environment. The N-Calculator takes in information about an individual's resource consumption in the food, housing, transportation, and goods and services sectors, and compares an individual's footprint to the national average. We developed the first Japanese N-Calculator [2].

International trade of food and feed is one of the strongest drivers of global N circulation. Japan relies heavily on imported food and feed which are increasing relative to internal production. Countries produce food differently and with varying nitrogen use efficiencies, so it is important to consider the environmental impact of international trade on the Japanese N footprint.

An individual's N footprint is largely influenced by his/her choices in food, energy, transportation, and goods and services sectors. Individual behaviors may be influenced by a variety of personal, social, and economic factors, including age. Japan is an aging society; a diminishing population of young people is supporting a growing population of older people. Comparing the N footprints of different age groups could provide valuable insight into both current and future Japanese N footprints.

Our primary research questions are: (i) On average, how much Nr is released per capita in Japan? (ii) How does the international trade of food and feed impact the Japanese N footprint? and (iii) How does a consumer's age affect his/her N footprint?

2. Materials and methods

We applied the N-Calculator developed by Leach et al. [1]. The following equation expresses the general concept used to calculate an individual's N footprint:

$$FP_{ind} = FP_{avg} \times AU_{ind} / AU_{avg} \quad (1)$$

where FP_{ind} is the individual footprint for food, energy, transportation, and goods and services, FP_{avg} is the average per capita footprint for the country, AU_{ind} is the individual use in each sector, and AU_{avg} is the average per capita use of each sector for a country. The food N footprint consists of consumption and production. We used food supply data from FAOSTAT to calculate the consumption footprint. The food production N footprint was calculated based on food intake and the amount of N lost during the production of that food, presented as virtual N factors (VNFs). Virtual N includes losses such as fertilizer not incorporated into the plant, crop residues, feed not incorporated into the animal product, processing waste, and household food waste.

Energy consumption from burning fossil fuels produces nitrogen oxides. Energy is primarily used in three areas: housing, transportation and goods and services. We combined bottom-up and top-down approaches to calculate the energy consumption N footprint.

We incorporated the import of foods in VNFs:

$$VNF_{trade} = SSR \times VNF_{in\text{-}country} + (1 - SSR) \times VNF_{import} \quad (2)$$

where VNF_{trade} is the VNF with food trade (import), SSR is the self-sufficiency rate in Japan of each food category, $VNF_{in\text{-}country}$ is the VNF without food trade, and VNF_{import} is the VNF in the exporting country. The further details for the methods are available in Leach et al. [1] and Shibata et al. [2].

3. Results and discussions

We developed the N-Calculator tool for use in Japan in order to determine an individual's current N footprint. Our results indicated that N footprint in Japan including the impact of trade was 28.1 kg N $capita^{-1}$ yr^{-1}. The footprint was dominated by food production. Similar to other countries, energy, transportation, goods and services sectors made minor contributions to the Japanese N footprint.

It was found that the total N footprint in Japan was comparable to European countries and smaller than the US. Virtual N factors (VNFs) for animal products produced in Japan were relatively higher than previous studies.

We also indicated that incorporating international food and feed trade affected most VNFs and the overall food N footprint in Japan. Japan relies heavily on imported food (ca. 61%), so a large portion of the N lost during the food production process is lost to the environment in the exporting country.

The food preferences between different age groups influenced the food N footprint. Younger age groups, who tend to prefer meat, have a higher N footprint than older age groups, who tend to prefer fish and seafood. If younger age groups continue to prefer meats, then Nr losses could increase even with improvements in nutrient use efficiency (NUE). Consumers can affect their N footprints through dietary choices.

It was proposed that some challenges for managing N pollution include limitations in technology for increasing crop NUE, and the effects of trade on global Nr production.

Acknowledgments

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Scientific Robustness of including indirect Land Use Change into Life Cycle Assessment

Matthias Finkbeiner*

Technische Universität Berlin, Germany
*Corresponding author: matthias.finkbeiner@tu-berlin.de

1. Introduction

The 'food versus fuel' debate and the discussion about the environmental performance of biofuels in general have led to the development of the concept of indirect land use change (iLUC) and the proposal to include iLUC factors into environmental assessments of biofuels. There is disagreement about how significant the issue is, what is causing it, and what can or should be done about it.

This controversy is also reflected by the different approaches in sector specific regulations on biofuels. There are so far two biofuel regulations from the United States of America that already require the inclusion of iLUC factors, i.e. the Low Carbon Fuel Standard (LCFS) in California and the Renewable Fuel Standard 2 (RFS2) of the United States federal government. In Europe, the EU Renewable Energy Directive (RED) includes so far only direct land use change greenhouse gas (GHG) emissions, but the future development of a concrete methodology to include iLUC is noted in the RED.

The early life cycle assessments (LCA) and carbon footprints (CF) of biofuels did not address the 'food vs. fuel' issue. Recently, the integration of direct and indirect land use change effects into the LCAs and CFs of biofuels is proposed by several scholars. Since the first paper on the iLUC issue by Searchinger et al. was published in Science [1] a number of different models (economic general equilibrium or partial equilibrium models as well as simplified models often referred to as deterministic or causal-descriptive models) were proposed.

2. Scientific Robustness of LCA and iLUC

A recent paper summarized an analysis of the scientific robustness of the iLUC concept and its consistency with international accounting standards for LCA and CF [2]. The conclusion was that globally agreed accounting standards for LCA and CF do exist, while there are currently no accounting standards for iLUC at all.

The results of assessing the requirements of the leading international standards of LCA (e.g. ISO 14040/44, EU Product Environmental Footprint Methodology, ILCD Handbook) or CF (e.g. ISO TS 14067, GHG Protocol) are presented in Table 1. It is shown that none of them requires the inclusion of iLUC factors. They even contain substantial restrictions for a potential future use of iLUC factors, and with good reason. Fundamentally, LCA and CF focus on real material, energy and emission flows while iLUC is not physically tangible; it is based on theoretical models that rely on hypothetical assumptions and market predictions.

Table 1. Requirements for iLUC in LCA/CF standards [2]

	iLUC inclusion mandatory	iLUC inclusion intended - if methods robust	if iLUC is included, restricted to consequential LCA	if iLUC is included, then also other indirect effects	if iLUC is included, then for all products
Generic LCA standards					
ISO 14040/44	no				
EC PEF Guide	no				
ILCD Handbook	no		yes	yes	yes
French Labelling Scheme	no	yes			yes
Generic CF standards					
ISO DIS 14067	no	yes			yes
GHG Protocol	no		yes		yes
PAS 2050	no	neutral			
Japanese CF Specification	no				
Korean CF Guideline	no				

There is full agreement in the scientific community that iLUC factors are highly uncertain. As shown in Figure 1, the uncertainty and range of iLUC factors goes way beyond levels which are state-of-the art in LCA or CF. The uncertainty leads to the enormous ranges of published iLUC values from 200% below, up to 1700% above the CF of fossil fuels. This uncertainty level of several orders of magnitude is significantly larger than the range of natural science based CFs of all different types of food. With the uncertainty level of iLUC, it would be impossible to differentiate between low CF types of food like lentils or tomatoes and high CF types of food like red meat.

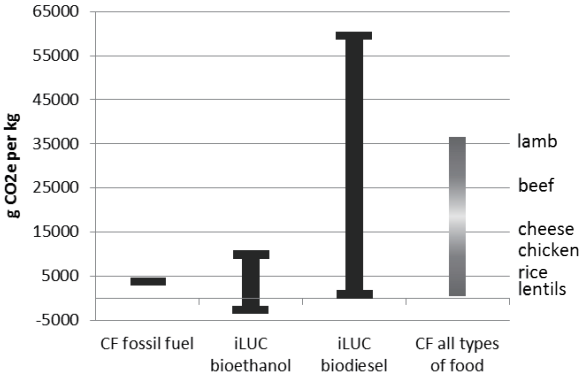


Figure 1. Ranges of iLUC factors [2]

3. Conclusion

LCA and CF have a 'priority for a scientific approach' principle. This is different from iLUC, which is a theoretical, hypothetical value based on market predictions and other assumptions. Therefore, iLUC factors should be reported separately and not be added to the results of LCA and CF.

Scientific contributions to make environmental policy as fact-based as possible are a key lever for sustainable development. However, current iLUC factors are not fact-based. If they are used in the context of LCA and CF, they do not make the policy any better, but damage the reliability, integrity and credibility of LCA and CF. The iLUC concept deserves credit for raising awareness of the important topic of land use change and associated climate change effects. ILUC was good to demonstrate the problem, but will be less effective in solving it - even if further iLUC research makes significant progress.

Zilberman et al. [3] qualified iLUC as "a second-best solution to a first-class problem". Thanks to the iLUC-concept, we understood that there is a problem. It is now time to shift priority from reactive 'penalty factors' to proactive solutions.

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Future perspectives on LCA in agriculture: Lessons from the research in Japan

Masanori Saito

Graduate School of Agricultural Science, Tohoku University, Japan
*Corresponding author: msaito@bios.tohoku.ac.jp

1. Introduction

In this presentation, looking back at two decades of LCA in agricultural sector in Japan, I will discuss some achievements and the future perspectives.

2. LCA Project by MAFF

The national project on "LCA for environmentally sustainable agriculture" was started in 1998 in grant-aid by Ministry of Agriculture, Forestry and Fisheries (MAFF), Japan. This 5 year project was effective to introduce the concept of lifecycle thinking and LCA into agricultural research sector in which these concepts were not well widespread.

In this project, system boundary was set within the production stage of agricultural products. For example, rice production was evaluated from seeding to harvesting. The collected inventory data in the project were of value as actual data from field and have been widely referred [1]. The project unveiled a relatively large impact of Green House Gasses (GHG) emission from natural processes during cultivation such as CH4 emission from paddy soil as well as from ruminant livestock.

Another achievement of the project was publication of manual for LCA in agriculture [2]. Although the manual was preliminary and was only for production stage, it was useful for people who were not familiar with LCA to recognize the significance of LC thinking in agricultural sector.

3. Carbon Foot Print

Since the MAFF national project, the number of the studies on LCA in agriculture increased. However, in the early 2000's studies, most of their system boundaries were limited to only one or two stages in a series of lifecycle from production to disposal through consumption. Not much attention was paid to cooking and eating.

Food Study Group, The Institute of Life Cycle Assessment, Japan, started to work in 2003 on LCI analysis of foods including cooking and disposal [3]. Based upon their studies, looking at total CO2 emission throughout the lifecycle, the following trends are found. (1) A proportion of CO2 emission at production stage is relatively large, (2) a proportion of CO2 emission at transportation stage is relatively small, (3) a proportion of CO2 emission for cooking is not negligible for some foods, and (4) a proportion of non-CO2 GHG from natural processes is large, especially for rice, dairy and beef production.

After the project, food chain system was recognized as a whole. Inventory data in not only production stage but also transportation, consumption and waste stages were collected. Furthermore, Act on Promotion of Global Warming Countermeasures was amended in 2008, so that companies were obligated to pay their effort for visualization of global warming impact of their products. This facilitated companies to start "carbon footprint (CFP)" labelling. In 2009, CFP system was started on a trial base by Ministry of Economy, Trade and Industry (METI), Japan. A number of studies relating to CFP of foods indicated that a large proportion of GHG emission through food chain is from the natural processes and that a relatively small proportion is from transportation process. The latter finding is contrast to the concept of food mileage.

4. Database

For practices of LCA of agriculture and food, it is essential to develop the database for related materials. Ajinomoto Co. first developed the database for foods and their related materials [4]. The database has been developed based on 3EID (Embodied, energy and emission intensity data for Japan) which was developed using input-output table. This database was easy to use so that it was widely used especially for calculation of CFP of foods.

Furthermore, taking the compatibility with other international database such as Ecoinvent into account, more detailed database, JALCA, has been developed [5]. This database comprised of various sources including hearing, literatures, existing database and so on.

5. Perspectives

Numbers of studies on agri-food LCA increased during the last decade not only in Japan but over the world. LC thinking has been reflecting various research topics in agro-environmental studies. Policymakers have been interested in LC thinking in agriculture and food industries.

In MAFF, biodiversity has been emphasized as one of the important environmental policies. Although biodiversity, one of the most important impact categories, has been intensively studied, not much studies among agri-LCA researchers in Japan. We should pay much effort for LCA of biodiversity in agro-environments. Further, integration of various impacts in terms of agricultural sustainability is future challenge for the researchers in agricultural sector.

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Assessing Impacts of Land Use Change and Management Intensification: A Life Cycle Perspective on Agricultural Production

Kiyotada Hayashi*

National Agriculture and Food Research Organization, Japan
*Corresponding author: hayashi@affrc.go.jp

1. Introduction

Increased land use transformation from natural forest to agricultural land for large-scale production of food and energy crops in South East Asia, South America, and East Africa attracts public attention because of the impacts on global climate and biodiversity caused by the transformation. In addition, much interest has been paid to the conversion to sustainable agricultural practices, in which understanding of management intensity plays an important role. There are, however, inconsistencies between the current progress in land use change impact assessment within the framework of life cycle assessment (LCA) and the requirements for conducting the assessment of agricultural production systems.

The purpose of this study is to provide an integrated methodological framework through reviewing earlier studies on land use change in LCA and related studies on land use.

2. Methods

A fundamental research perspective in this study is how agricultural production can be assessed using land use change impact assessment within the framework of LCA. Literature surveys cover the topics such as life cycle impact assessment for land use change with special attention to biodiversity and recent discussions on land sharing and sparing.

3. Results

Global characterization factors developed recently for assessing land use in LCA [1] can be used for assessing agricultural production systems. However, since the characterization factors are prepared for each WWF ecoregion and for limited land use types, it may be difficult to apply the method to comparative LCA of, for example, organic and conventional farming practices in the same region. Although the impact assessment method has been applied to the comparison of organic and conventional milk in Sweden [4], the main difference lies in grass lands for animal feed, which may be classified as a special case, in which diversity in farmlands is worth assessing. In the assessment of agricultural production systems, the distinction between biodiversity inside of farmlands and biodiversity outside of farmlands is crucial.

Three methods to assess land use impacts on biodiversity (including the method mentioned already) have been compared with each other through the case study of forestry plantations in New Zealand [3]. One of the important results is that the impacts are closely related to productivity of the plantations, because of the proximity in characterization factors prepared for the ecoregions. Therefore, if we use the land-oriented expression [2], which was developed for explaining the trade-offs between productivity and environmental impacts per area unit, we will notice that the differences in the calculated biodiversity per area unit among alternative production systems are small.

Modeling management intensity is important in assessing agricultural production systems and management intensity is the cause to change productivity and biodiversity per area unit. However, earlier studies do not necessarily distinguish management intensity and yields [5, 6]. In other words, in explaining the relationship between intensified agriculture and biodiversity, agricultural intensification and yield are not separated [6].

4. Discussion and conclusions

An important implication of this study for LCA of agricultural production systems is that the methodology to integrate site specific and local assessment into global assessment is necessary. This is applicable especially to the assessment of biodiversity and ecosystem services, because the intensity of management practices, which is the decision variable farmers and policy makers can control, is the key to improve sustainability. The development of easy-to-apply techniques for measuring diversity in the site-specific condition is an important research topic.

Acknowledgments

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Environmental Impacts of Organic Rice Farming in Thailand by using Life Cycle Assessment to Support Policy Decision on Sustainable Agriculture

Rattanawan Mungkung[1,2*], Patthra Pengthamkeerati[1], Ratcha Chaichana[1], Saranya Watcharothai[3], Kittiwan Kitpakornsanti[2], and Supachok Tapananont[2]

[1] Department of Environmental Technology and Management, Faculty of Environment, Kasetsart University, 50 Ngamwongwan Road, Chatuchak, BKK 10900 THAILAND; [2] Centre of Excellence on enVironmental strategy for GREEN business (VGREEN), Faculty of Environment; [3] Department of Botany, Faculty of Science, Kasetsart University, 50 Ngamwongwan Road, Chatuchak, BKK 10900 THAILAND

*Corresponding author: fscirwm@ku.ac.th

1. Introduction

Organic farming is seen as an alternative system for sustainable rice production due to lower risks from chemical use, increasing biodiversity [1], lower production costs, and higher price. At present, the proportion of organic rice is only 0.18% of the total area of rice production in Thailand (19,994 ha). However, it is targeted to be increased to 40% in 2016 [2]. In this connection, there is a concern over the environmental implications of such policy which areas should be encouraged to expand more areas for organic rice. This study is then performed to evaluate the potential environmental impacts of organic rice production in Thailand for policy decisions.

2. Methodology

The studied site was a paddy field in Surin province, one of the key areas for organic rice production in Thailand. Life Cycle Assessment (LCA) was used as the analytical tool to assess the potential environmental impacts from cradle-to-gate. The functional unit was set as per kg of paddy rice. Based on the production cycle in 2013, the inputs and outputs of organic rice field and non-organic rice field in the proximity were gathered. The amount of methane and nitrous oxide emitted from the organic rice field were directly measured, whereas that from the non-organic rice was obtained from the previous study. The method of impact assessment was based on ReCiPe 2008.

3. Results

3.1 Inventory data analysis results

The inventory data analysis results showed that the organic rice farming required 0.02 L of diesel, 0.36 kg of organic fertilizer, rain water 4.94 m^3; the direct emissions of methane was 0.16 kg per kg of paddy rice and that of nitrous oxide from organic rice farming was 0.09 g per kg of paddy rice. With respect to the non-organic rice farming, it required 0.098 L of diesel, 0.13 kg of chemical fertilizer, rain water 1.52 m^3; the direct emission of methane was lower (0.16 kg per kg of paddy rice) and that of nitrous oxide was higher (9.9 g per kg of paddy rice) [3].

3.2 Life cycle impact assessment (LCIA) results

The environmental profiles of organic and non-organic paddy rice indicated that the impact on climate change of organic paddy rice was 8% lower than the non-organic paddy rice due mainly to the lower emissions of methane and nitrous oxide (Table 1, Figure 1). The impact on terrestrial acidication was associated with the air emissions of organic fertilizer and SO_2 and NO_2 from the diesel combustion. The impact on water depletion was realetd to the rainwater used during the cultivation period.

Table 1: LCIA results of organic and non-organic paddy rice

Impact	Per kg of organic paddy rice	Per kg of non-organic paddy rice
Climate change (kg CO_2 eq)	3.64E+00	6.59E+00
Terrestrial acidification (kg SO_2 eq)	3.90E-04	2.83E-03
Freshwater eutrophication (kg P eq)	1.00E-06	3.49E-05
Water depletion (m3)	4.94E+00	1.52E+00

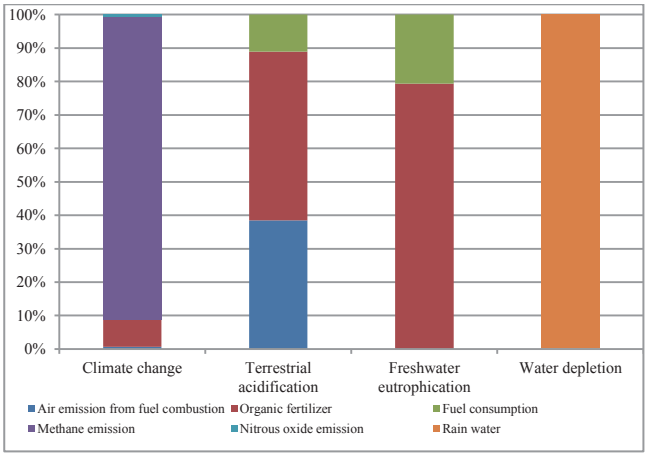


Figure 1: Environmental profiles of organic paddy rice

3.3 Biodiversity assessment results

The biodiversity inventory data in terms of flora and fauna were analysed and found there were more species in organic than in non-organic rice field (Table 2).

Table 2: Biodiversity assessment results

Type of flora	Organic farming	Non-organic farming
Fish	Borapet Rasbosa, Trichopsis vittatus	Flying barb, Blackline rasbora
Phytoplankton	*Phormidium spp.*	Micrasterias foliacea Bailey var. quadrinflata, Spirogyra spp.
Zooplankton	*Arcella bathystoma*	*Difflugia spp.*
Invertebrate	Lanchester's freshwater prawn	Pond snail
Benthos	Tubiflex worm, Blood worm, Mayflies, Common skimmer, Mollusque	Lanchester's freshwater prawn, Mayflies, Blood worm
Macrophytes	*Lophopetalum wallichii Kurz* *Eclipta prostrata L.* *Ipomoea aquatic Forssk.* *Leersia hexandra AW.*	

Acknowledgments

Special thank is given to NSTDA: National Science and Technology Development Agency (Thailand) for funding.

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Water Footprint Assessment of Crops Cultivation in Kurdistan Region, Iraq

Marlia Mohd Hanafiah,*[1] Hushiar Raheem Hamarash,[1] Muhammad Muaz Aminordin,[1] and Shabbir Gheewala[2]

[1]*Universiti Kebangsaan Malaysia, Malaysia;* [2]*King Mongkut's University of Technology Thonburi, Thailand*
*Corresponding author: mhmarlia@ukm.edu.my

1. Introduction

Kurdistan region is located in the Northern Iraq, covering about 28,817 km^2 of area and consists of three provinces namely Sulaymaniyah, Duhok and Erbil. Agriculture is the largest sector in the Kurdistan region, where wheat is the staple food of this region. Other major crops in Kurdistan include barley, sunflower and chickpea. However, irrigation for agriculture is one of the most water-consuming activities and an increasing demand for food has resulted in an increasing demand as well as competition over freshwater [1]. This demand has led to an increased concern of water shortages and water scarcity due to agricultural practices.

Water footprint is a temporally and spatially explicit indicator considering location and timing of the volumes of water used and polluted and can be applied to assess environmental impacts of water consumption [2]. This study estimates the blue and green water footprint of four crops (*i.e.* wheat, barley, sunflower and chickpeas) in Kurdistan, Iraq.

2. Methodology

The water footprint of growing crops were evaluated based on the method of Hoekstra and Chapagain [3] and the CROPWAT 8.0 developed by the Land and Water Development Division of FAO was used to compute the crop water requirement of the four crops grown in the Kurdistan region, Iraq. CROPWAT 8.0 is a decision support system for calculating reference evapotranspiration, crop water requirements and crop irrigation requirements that based on the FAO Penman-Monteith model [4]. Inputs of climatic, crop and soil data were obtained from the Kurdistan Meteorological Department and Ministry of Agriculture and Water Resources. The total water footprint ($WF_{total,grow}$), expressed in m^3/ton was calculated by summing the green and blue components of water footprint.

$$WF_{total,grow} = WF_{green,grow} + WF_{blue,grow} \quad (1)$$

The green water footprint ($WF_{green,grow}$, m^3/ton) of growing crops refers to the volume of rainwater consumed and was calculated by dividing the green component in crop water use ($CWU_{green,grow}$, m^3/ha) by the crop yield (Y, ton/ha). This calculation was also used to derive the blue water footprint ($WF_{blue,grow}$, m^3/ton) and it refers to the volume of surface water and groundwater consumed. The grey water footprint was not considered in the present study.

3. Results and discussion

Figure 1 shows that the green water footprint and blue water footprint for growing wheat, barley, sunflower and chickpeas range between 100 - 550 m^3/ton and 38 – 520 m^3/ton, respectively. Barley has the highest green water footprint (546 m^3/ton), followed by wheat (293 m^3/ton), chickpea (247 m^3/ton) and sunflower (102 m^3/ton). The accuracy of the crop water requirement calculation is strongly determined by modelling parameters, quality and availability of input data as well as assumption made in interpreting the results.

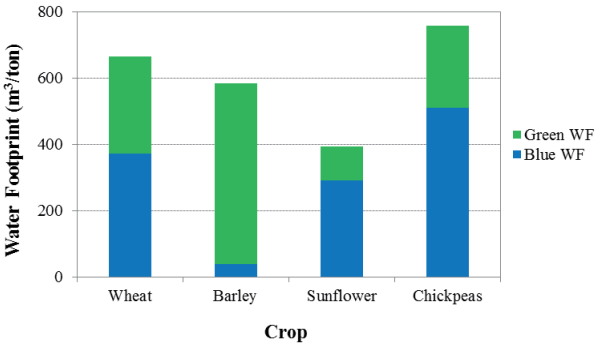


Figure 1. Water footprint of growing wheat, barley, sunflower and chickpeas in Kurdistan region

This study can be used as a starting point to introduce the wise water governance program by developing and implementing good water policy as well as to give a new dimension to the concept of water management in Kurdistan Region. The results of this study also allow the development of recommendations for improved irrigation practices, the planning of irrigation schedules under varying water supply conditions, and the assessment of production under rainfed conditions or deficit irrigation. Besides providing updated status of total water used from the agriculture sector, our results also show that this baseline information helps in identifying which area that need to be conserved and what type of recommendation that should be drawn.

4. Conclusions

In conclusion, we found that the green water footprint and blue water footprint for growing wheat, barley, sunflower and chickpeas range between 100 - 550 m^3/ton and 38 – 520 m^3/ton, respectively. The amount of water required in growing crops can differ depending on the location and climate conditions, therefore the inclusion of local water stress index and evaluation the water footprint of growing crops under different scenarios should be considered in the calculation of water footprint.

Acknowledgments

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Life cycle assessment of biogas production in small-scale household digesters in Vietnam

T. K. V. Vu[1*], D. Q. Vu[2,3], L. S. Jensen[3], S. G. Sommer[4] and S. Bruun[3]

[1]National Institute of Animal Sciences, Thuy Phuong, Tu Liem, Hanoi, Vietnam, [2] Vietnamese Academy of Agricultural Sciences, Thanh Tri, Hanoi, Vietnam, [3]University of Copenhagen, Faculty of Science, Department of Plant and Environmental Sciences, Thorvaldsensvej 40, DK-1871 Frederiksberg C., Denmark, [4]University of Southern Denmark, Faculty of Engineering, Department of Chemical Engineering, Biotechnology and Environmental Technology, Campusvej 55, 5230 Odense, Denmark

**Corresponding author: vukhanhvan2002@yahoo.com*

1. Introduction

Life cycle assessment (LCA) is a tool that can be used to compare the environmental impacts of different products throughout their entire life cycle [2]. LCA has been used to compare different biogas production technologies [3, 4]. Several studies have also focused on technologies for biogas production from manure and different co-substrates for manure [3-6]. However, very few studies have focused on the vast number of small-scale biogas digesters being deployed in developing countries. Only one single study has been identified [7] and this study largely ignores the issues of CH_4 leakage and release and nutrient recycling.

The objective of this study was to use LCA methodology to assess the environmental impacts associated with standard biogas digesters in Vietnam and to compare them with the impacts associated with other standard manure management practices in order to determine whether the current employment of biogas digesters has net positive or negative environmental impacts.

2. Methodology

In this study LCA was used to assess the environmental impacts of pig manure management systems with and without biogas digesters throughout the entire life cycle of manure, from storage to field application.

The functional unit applied was the treatment of 100 kg of solid pig manure and 1000 kg of liquid pig manure collected from animal houses.

The ReCiPe 2008 impact assessment method [8] was applied in this study to assess the impact in four different categories: (i) global warming potential, (ii) marine water eutrophication, (iii) freshwater eutrophication, and (iv) fossil fuel depletion.

Two manure management systems, one with a biogas digester and one without, are compared (Figure 1). The systems were defined to reflect current farm practices on small and medium-scale Vietnamese pig farms with and without biogas, as observed in a contemporary survey [1].

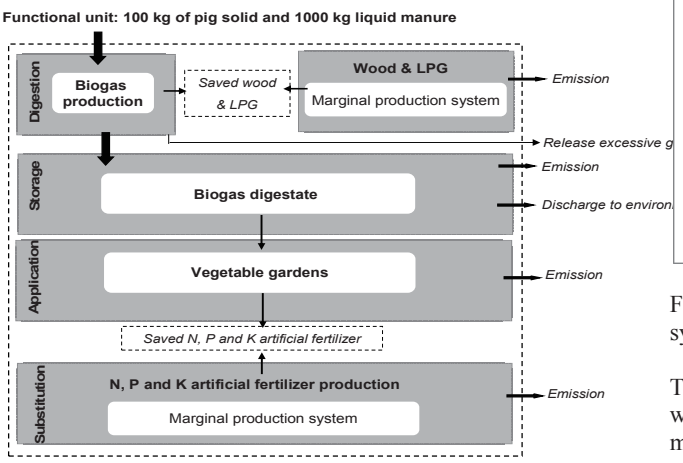


Figure 1a. Manure management system with biogas

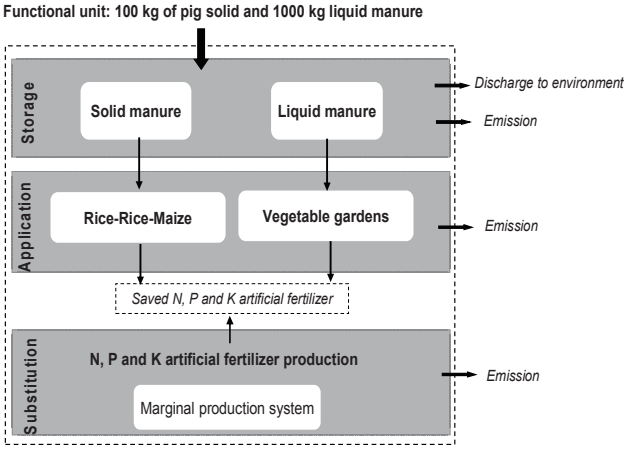


Figure 1b. Manure management system without biogas

3. Results

Global warming potential. When traditional management methods were used, the handling of one functional unit of manure resulted in an impact of 4.4 kg CO_2 equivalents (Figure 2a). The greatest proportions of emissions were methane emissions during solid storage and nitrous oxide emissions after field application. Some emissions could be prevented due to the avoidance of fertilizer production, but not enough to compensate for the emissions during storage and after field application.

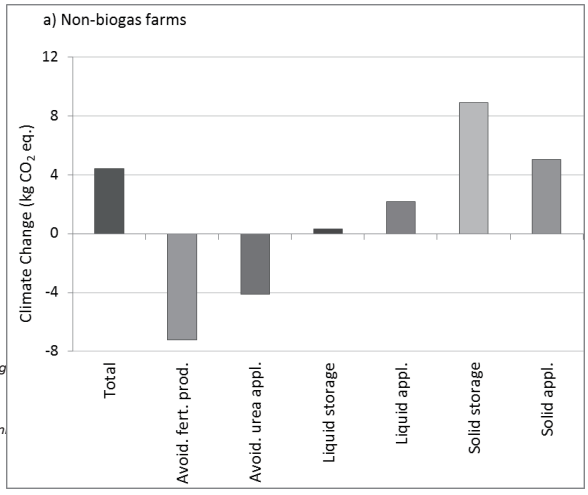


Figure 2a. Contribution of non-biogas manure management systems to global warming potential

The handling of a functional unit of manure resulted in a global warming potential (GWP) of 3.2 kg CO_2 equivalents in a manure management system with biogas (Figure 2b).

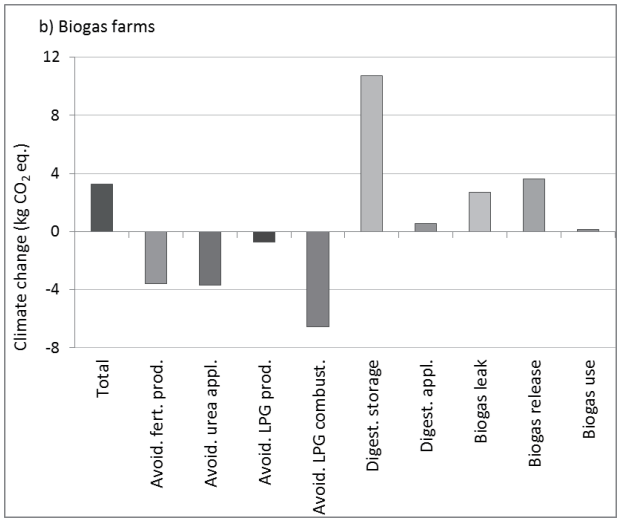


Figure 2b. Contribution of biogas manure management systems to global warming potential

The greatest emissions in this system are associated with CH_4 from digestate storage. In addition, the loss of CH_4 through leaks and the intentional release of biogas has a considerable impact. The results clearly show that emissions of CH_4, mainly from digestate storage and the intentional release of biogas when production exceeds consumption, may seriously compromise any benefits in terms of global warming by outweighing any savings made by replacing alternative fuels with biogas.

Fossil fuel depletion potential. Figure 3 shows that both manure handling systems represent net reductions in fossil fuel depletion potential. The reason for this is that manure is a useful resource that can be used to replace fuels and fertilizers. The non-biogas management system resulted in greater savings than the biogas management system. Although the biogas replaces LPG production, non-biogas farms saved more fossil resources since this system features a greater recycling of nutrients and thus leads to replacement of more chemical fertilizers whose production requires considerable energy. These results are obviously highly dependent on the assumptions regarding the substitution of mineral fertilizer and the fact that these substitutions actually happen. However, despite this uncertainty, the result clearly shows that the substitution of fertilizers is also important in terms of fossil fuel depletion potential.

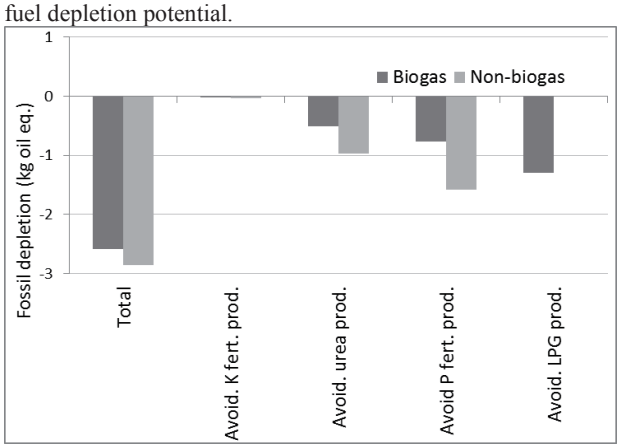


Figure 3. Contribution of biogas farms and non-biogas manure management systems to fossil fuel depletion potential

Freshwater eutrophication potential. The ReCipe method assumed that biological production in fresh water ecosystems is limited by P availability. Therefore, there is no effect of emissions from other nutrients in this category. The biggest environmental burden on fresh water eutrophication comes from the discharge of liquid manure and digestate in both manure management systems (Table 1). The level of P discharged from the biogas system was five times higher than that from non-biogas systems. This is mainly caused by the discharge of digestate, which is harder to recycle because of its high water content. As a result, the impact potential in this category from biogas systems was 0.551 kg P eq. per FU, while it was only 0.128 kg P eq. per FU from the non-biogas system.

Table 1. Contribution of biogas farms and non-biogas farms to freshwater eutrophication potential, in kg P eq.

Farm types	Total P	Avoided fertilizer	Liquid discharge	Solid discharge
Non-biogas farms	0.128	-0.003	0.115	0.027
Biogas farms	0.551	-0.001	0.552	

Marine water eutrophication potential. The ReCipe method assumes that the marine environment is N limited and therefore that only emissions of N-containing compounds can contribute to marine water eutrophication.

The non-biogas management system contributed 0.33 kg N eq. per FU to marine water eutrophication potential (Fig. 4a). The N content in the discharged liquid manure as well as emissions during and after application of solid manure are the largest contributors to marine water eutrophication in this system. The emission associated with liquid and solid manure application on agricultural land was 0.24 kg N eq. per FU, which is similar to the emissions saved by not using urea fertilizer.

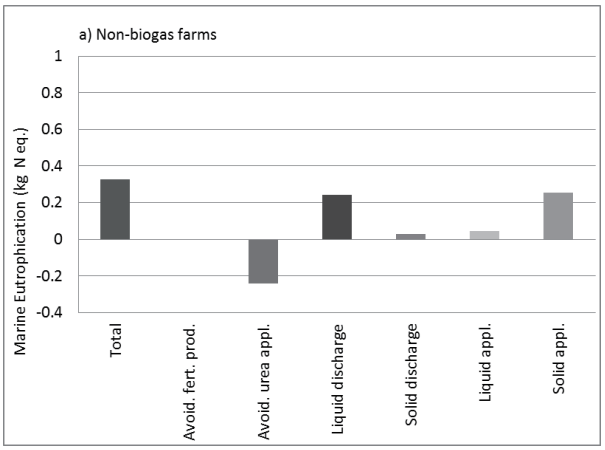


Figure 4a. Contribution of non-biogas manure management systems to marine water eutrophication potential

The biogas manure management system contributed 0.82 kg N eq. per FU to marine eutrophication (Fig.4b). The main contribution to this is through the discharged digestate. Again the emissions saved by not using urea prevent an impact similar in size to the one associated with digestate application. As with the non-biogas management system, the two processes of digestate storage and digestate application made a negligible contribution to marine water eutrophication.

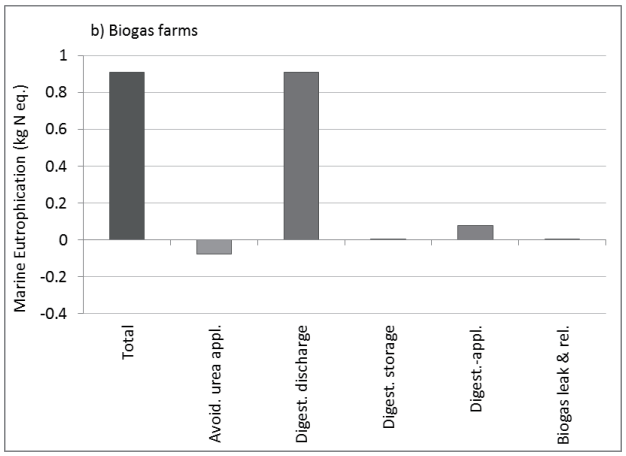


Figure 4b. Contribution of biogas manure management systems to marine water eutrophication potential

4. Implications

The results clearly indicated that losses of biogas from digesters as well as the intentional release of biogas and emissions of methane from manure storage compromise the beneficial effects in terms of global warming brought about by using the biogas produced to replace other fuels. Although the current results still indicate that there is an overall advantage, it is clearly diminished by these losses. However, biogas digesters can become a means of reducing global warming impacts relatively easily if CH_4 emissions can be kept low. This knowledge will be helpful for proposing interventions for efficient manure management through improved biogas systems.

Furthermore the current analysis clearly demonstrates that biogas digesters are exacerbating matters with the low recycling of nutrients from animal waste. The environmental costs associated with reduced nutrient recycling caused by the digesters means that in order to make the digesters more sustainable it is pertinent to develop better methods and technologies to ensure the recycling of nutrients contained in the digestate.

Acknowledgments

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Resource Logistics for sustainable management of agricultural nutrients

Kazuyo Matsubae,*[1] Keisuke Nansai[2], Kenichi Nakajima[2], Tetsuya Nagasaka[1]

[1]*Tohoku University, Japan* [2]*National Institute of Environmental Studies, Japan*
*Corresponding author: matsubae@m.tohoku.ac.jp

1. Introduction

Agricultural nutrients including phosphorus, potassium, and nitrogen are essential elements for food production. The global population is predicted to exceed 9 billion by 2050, and furthermore, bioethanol production has increased by about three times over the past ten years. As a result, the resources for agricultural production including water, land and fertilizer will be of increasing importance in next few decades [1]. However, there are growing concerns over supply strategies for essential resources because of environmental problems, such as eutrophication (N, P), acidification (N), resource depletion and price increases (P) [2]. For the sustainable resource governance, we proposed resource logistics analysis, based on material flow analysis and input output analysis, and discuss the strategic management of the flow of resources through the supply chain in our society.

2. Method

This paper incorporates the agricultural nutrient flows into the 2005 input-output model of the Japanese economy, and integrates international trade statistics on the basis of Global Linkage Input Output (GLIO) model [3].

3. Results and conclusion

Our results shows that the nitrogen and phosphorus flows which caused by Japanese final demand were 1,601kt-N and 242kt-P, in which 39% of N (629kt-N) and 46% of P (126kt-P) from USA (Fig.1-2). Regarding with N flows, direct flows to Japan was originated from Australia, USA, and China. On the other hand, indirect flows have been originated from USA, UAE, Saudi Arabia, and Russia.

Looking at the P flows, direct flows to Japan was originated from USA, China, and Australia, where are agricultural production countries. On the other hand, indirect flows have been originated from USA, Morocco, and China, where are the P rock mining countries, and fertilizer production countries.

Considering the economic structure and geopolitical problems, it was found that special attention should be paid to maintaining a stable supply of agricultural nutrients resources to ensure stability in agricultural production as well as in the many industries which use phosphoric acid (P) and ammonia (N) as an essential chemical material.

Acknowledgments

This study has been partly supported by research funds from the Research Institute of Science and Technology for Society of Japan Science and Technology Agency, (JST-RISTEX) as a research program on Science of Science, Technology and Innovation Policy.

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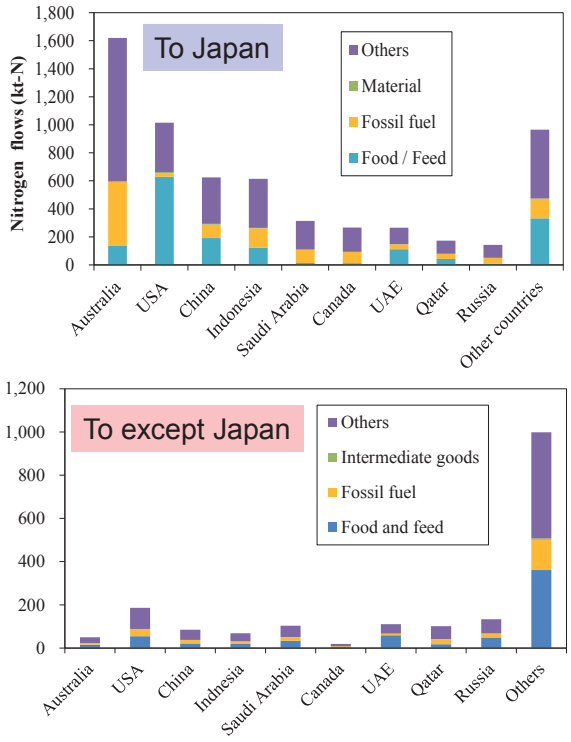


Fig. 1 Direct and indirect nitrogen flows related with Japanese final demand

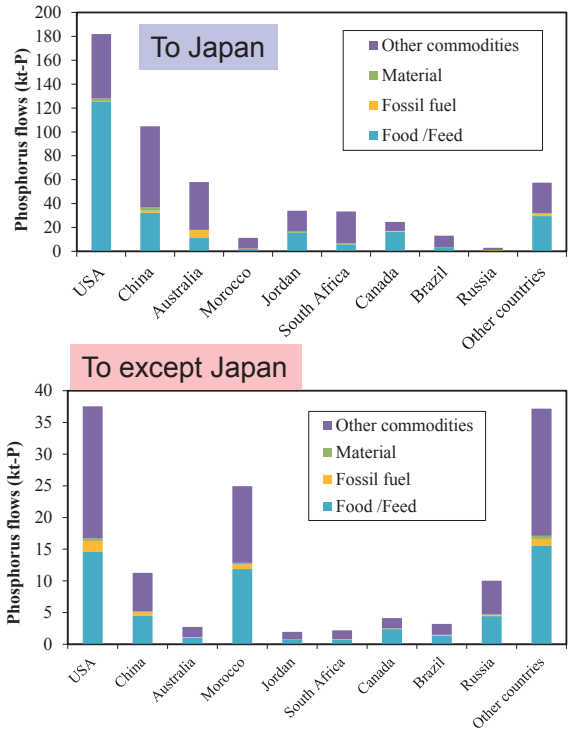


Fig. 2 Direct and indirect phosphorus flows related with Japanese final demand

Monetary and Physical Flow Analyses on Products of Agriculture

Yuko Oshita,*[1] and Yasunori Kikuchi[2]

[1] *Kobe University, Japan*; [2] *The University of Tokyo, Japan*
*Corresponding author: y_oshita@maritime.kobe-u.ac.jp

1. Introduction

Agriculture industry of Japan is facing many critical issue, e.g., aging workers, lack of young workers, climate change, using biomass resources, food safety, stabilization of income and free trade restrictions of products. As well as main products (foods and wood material etc.), by-products (e.g., bagasse, chaff and timber offcuts) have become important products as biomass renewable resources, regarding agriculture industry. To build robust domestic-supply chains, we need innovation in consideration of process of agriculture, system of using by-products, social system and supply and demand structure. However the flows from agriculture to final consumers through other industries are still unclear.

This paper analyze not only monetary flows but also physically flows of products of agriculture and outlines present structure. Then we propose a new design for robust supply chains by introducing new biomass conversion technology or suggestion of the products which they should focus etc.

We apply technique of structural path analysis (Defourny and Thorbecke, 1984; Lenzen, 2002; Oshita, 2012) to extract the monetary and physically flows. In this study, we analyze the flows of 6 products, rice, potatoes, vegetables, fruits, sugar crops, and logs which cover 90% of their total domestic output.

2. Methodology

Using input-output model, the domestic output of each industry can be estimated with the following eq. (1):

$$\mathbf{x} = \left(\mathbf{I} - \mathbf{A}\right)^{-1}\mathbf{y} \tag{1}$$

where **x** is a matrix representing the domestic output, **I** is an identity matrix, **A** is an input coefficient matrix and **y** is a matrix representing the final demand. $\left(\mathbf{I} - \mathbf{A}\right)^{-1}$ is the Leontief inverse matrix (**L**), where the elements of the matrix represent the demand for each commodity input directly and indirectly to produce one unit of each commodity. In other words, eq. (1) represents the direct and indirect production of each commodity induced by each final demand.

The Leontief inverse matrix **L** can be converted into a series expansion. Eq. (1) can be converted as eq. (2):

$$\mathbf{x} = \mathbf{y} + \mathbf{A}\mathbf{y} + \mathbf{A}^2\mathbf{y} + \mathbf{A}^3\mathbf{y} + \cdots \tag{2}$$

Each term of the right hand of eq. (2) can be decomposed to element, which express supply chains. For example, the third term ($\mathbf{A}^2\mathbf{y}$) can be expressed by $a_{ij}a_{jk}y_{if}$, which represents a supply chain: industry i (intermediate product) → industry j (intermediate product) → industry k (final product) →final demand f.

Applying the structural path analysis method, we extract supply chains which start from target products as eq. (3).

$$\mathbf{F}_i = \sum_{f;j;k;l;\cdots} \left(y_{if} + a_{ij}y_{jf} + a_{ij}a_{jk}y_{kf} + a_{ij}a_{jk}a_{kl}y_{lf} + \cdots \right)$$
$$\left(i = \text{target products}\right) \tag{3}$$

The data used in this paper is extracted from the 1990-1995-2000-2005 Linked Environmental Input-Output Table at the four-digit commodity classification level compiled by Japan's National Institute for Environmental Studies.

3. Results and discussion

From the results, it became clear that the structures of flow are different on each agricultural products. Rice, vegetables and fruits have relatively simple flows, most of them go to final consumer directly or secondarily. On the other hand, sugar crops and logs have complex flows, and they go to final consumer through many industries, not only food industry but also chemical industry. Many agricultural products produce by-products, and the by-products go to agriculture and dairy farming as compost and feed etc., some by-products from logs go to energy industry.

According to results of monetary flows, rice are supplied to grain milling (86%), 60% of domestic output of rice are demanded by household as grain milling. In short, such supply chain: rice → grain milling → household occupy 60% of all supply chain. Other rice (grain milling) are supplied to eating and drinking services or foods manufacturing. Also more than 60% of all vegetables and fruits are supplied directly to final consumers, and most of them are household. Rest of direct consumption are supplied to industries which are like flow of rice. However it is a noteworthy that by-product of rice: rice straw and chaff, supplied to livestock sector and vegetables as fermentation feed and compost. On the other hand, the ratio of sugar which is supplied to household directly is only 9.5% of total output of sugar crops. The most of them are supplied to eating and drinking services and food manufacturing. By-products of sugar crops, bagasse and filter cake etc., also supplied to livestock sector and vegetables. Potatoes is used for not only food, but also industrial starch. Therefore the flow diagram is relatively complex and has many industrial sectors. Flow of logs is most complex, and their by-products are used by agriculture and livestock sectors and power generation. However physically flows of the by-products are large, monetary flows of them are so small because of low price of themselves.

4. Conclusion

It is necessary for sustainability of agriculture that main products (foods and logs) which have highly-added value even in small quantities are produced and also flows of by-products in large quantities make economically feasible. To build a more "benign" process and supply systems, the technology roadmaps containing future development should be carefully taken into account within the physical and monetary flow analyses, which can facilitate the involvement of related stakeholders.

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Evaluation of environmental improvement by introduction of Eco-feed

Hongqin Yu ,*[1] and Hiroshi [2]

[1] *Graduate School of Nippon Institute of Technology*; [2] *Nippon Institute of Technology*
* yukoukinn@yahoo.co.jp

1. Introduction

90% livestock feed is imported from abroad in Japan[1]. Arable land area required for the imported livestock feed production is estimated as 3.63 million ha, which corresponds to 77% of the agricultural land area of Japan[2].

This study focuses on eco-feed which is made by food waste[3]. The introduction of eco-feed is possible to solve the problem of waste disposal, to solve the problem of livestock management, and to suppress the resource depletion. Recycling of food residue has been attracting attention from the point of view of environmental protection, but it can not be said that environmental aspects of eco-feed has been fully elucidated yet.

2. Purpose

The purpose of this study is to assess the environmental impact by the introduction of eco-feed. Specifically, beer lees which occurres from Sapporo beer factory in Hokkaido was ensiled. Beer lees is made it into eco-feed and it is used to livestock of Tokachi. Environmental load and economic aspects were considered on eco-feed.

3. Research methods

During the consideration of environmental evaluation of eco-feed, the model of silage of Sapporo beer lees on Hokkaido is assumed (Figure 1).

The target of this study is livestock feed combined system of food waste (Figure 2). The environmental impact of the eco feed is quantitatively evaluated. GHG emissions is estimated by JEMAI-LCA Pro and the environmental impact of beer lees is evaluated. The economics of eco-feed is also considered (Figure 3).

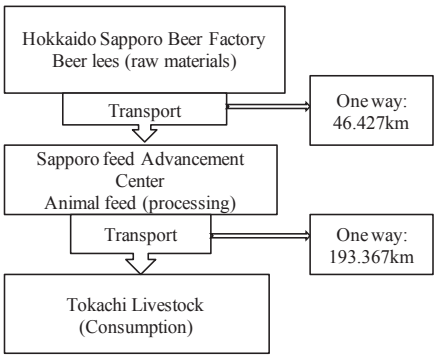


Figure 1. the model of silage of Sapporo beer lees

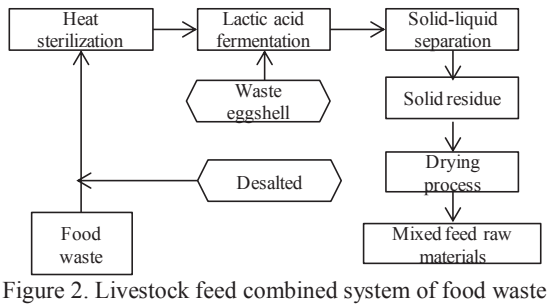


Figure 2. Livestock feed combined system of food waste

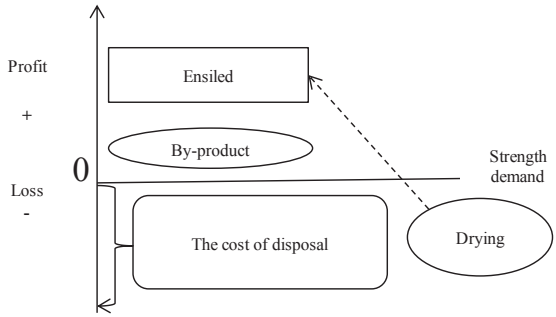


Figure 3. the economics of eco-feed

4. Result

Table 1 shows the energy of making eco-feed. Table 2 shows the results of the environmental impact of collecting beer lees, manufacturing, transportation, up to use. Table 3 shows the results of comparison of the environmental impact and economic of formula feed and eco-feed

Table 1. the energy of making eco-feed[3]

Fermentation	Drying
Beer lees: 100kg	70kg / batch
Desalted solution: 100kg	Banner fuel: 58kW
Ph for eggshell: 6kg	Gas: 10.8 m^3 / batch
	Electrical: 3kW

Table 2. the results of the environmental impact

Section	Emissions of the entire CO_2
Eco-feed(14kg)	29.5kg

Table 3.Comparison of the environmental impact and economic of formula feed and eco-feed

Section	Feed unit price: yen / kg	Environmental Impact: kg-CO_2
Formula feed	50	0.32
Eco-feed	43.25	0.52

5. Summary

Both of Environmental and economic aspects impact were evaluated of silage of beer lees that occurred in the Sapporo beer factory located in Hokkaido.

Unit price of 1kg eco-feed is 6.75 yen cheaper than formula feed, but it is 0.2kg CO_2 emissions more than formula feed. It is necessary to improve the environmental technology of silage of beer lees.

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Uncertainty analysis for greenhouse gas impact of feedstuff in Korea

Yoo-Sung Park, Min-Hyuk Lee and Kun-Mo Lee*

Eco-product Research Institute, Ajou University, Suwon, Korea
*Corresponding author: kunlee@ajou.ac.kr

1. Introduction

The aim of this study is to assess the uncertainty of the greenhouse gas (GHG) emission of the feedstuff for the livestock industry using the linear GHG model equation, and to compare the model results between the single point estimation method and the range estimation method.

2. Method

System boundary of this study is the cultivation of feedstuff in an agricultural farm. The system includes fertilization, chemicals, mechanical treatment and harvest. Figure 1 shows the system boundary of the feedstuff cultivation.

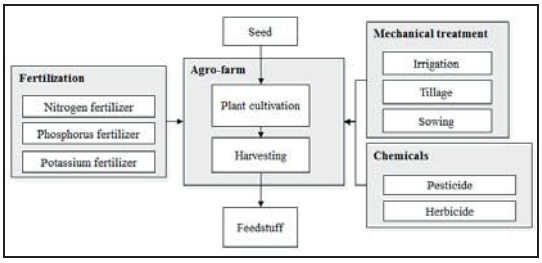


Figure 1. System boundary of the feedstuff cultivation

Functional unit is 1kg of each target feedstuff. The target feedstuff includes straw, corn, wheat, alfalfa and rapeseed.

Input/output data of the feedstuff cultivation and activity data were collected from the on-site investigation, and background data were collected from the statistics Korea, Ecoinvent and Korean LCI DB Information Network [1-4]. GHG emission from soil was calculated by Greenhouse Gas Inventory & Research Center of Korea [5].

In this paper two different types of the GHG emission results of the feedstuff were generated: one is the point estimation result and the other the range estimation result. Comparing two different types of the results, one can identify how they affect decision about the environmental issues around the feedstuff cultivation.

3. Result

GHG emissions of the target feedstuffs based on the point estimation method and the range estimation method are shown in Tables 1 and 2, respectively. From Table 1, one can identify clearly the order of the magnitude (rank) of GHG emission of the feedstuffs. However, Table 2 shows that GHG emission range of wheat overlaps with that of alfalfa. Figure 1 shows the overlapped area between wheat and alfalfa.

Table 1. Point estimation result

Feedstuff	Values	Rank
Rice Straw	0.169 $kgCO_{2\text{-}eq}/kg$	5
Rapeseed	0.737 $kgCO_{2\text{-}eq}/kg$	2
Wheat	0.552 $kgCO_{2\text{-}eq}/kg$	3
Alfalfa	0.441 $kgCO_{2\text{-}eq}/kg$	4
Corn	1.216 $kgCO_{2\text{-}eq}/kg$	1

Grey area in Figure 1 shows that 95% confidence interval of GHG emission of wheat and alfalfa overlaps. Furthermore, the point estimation results of both feedstuffs are located inside the overlapped area. This is a clear indication that there is no difference in both GHG emissions as such one cannot sure be which feedstuff is more environmentally significant in this case.

Table 2. Range estimation result

Feedstuff	Values (min.)	Values (max.)
Rice Straw	0.152 $kgCO_{2\text{-}eq}/kg$	0.184 $kgCO_{2\text{-}eq}/kg$
Rapeseed	0.623 $kgCO_{2\text{-}eq}/kg$	0.894 $kgCO_{2\text{-}eq}/kg$
Wheat	0.481 $kgCO_{2\text{-}eq}/kg$	0.624 $kgCO_{2\text{-}eq}/kg$
Alfalfa	0.361 $kgCO_{2\text{-}eq}/kg$	0.521 $kgCO_{2\text{-}eq}/kg$
Corn	1.090 $kgCO_{2\text{-}eq}/kg$	1.369 $kgCO_{2\text{-}eq}/kg$

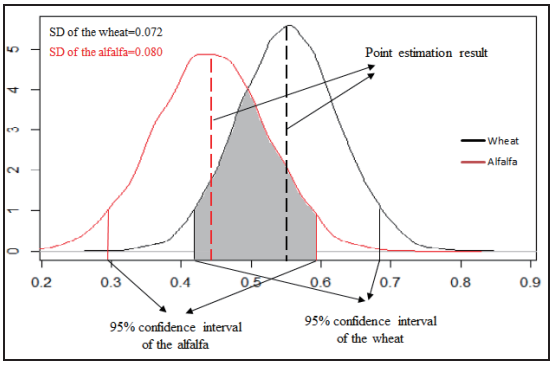


Figure 1. GHG emission result of the wheat and alfalfa

4. Conclusion

The range estimation result indicates that single point estimation result cannot be a good indicator for identifying key environmental issues in some cases.

For identifying the environmental key issues, one must pay attention to the uncertainty of the data and the impact model results from the data. At the same time, every effort must be given to reduce the error of the data and the model results.

Acknowledgments

This work was supported by the Korean National Institute of Animal Science and was performed as part of a project entitled 'Development of an estimation method and tool for accounting CH_4 and N_2O emissions from livestock'.

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Analyzing the Carbon Emissions of Cloud Computing Facilities

Kendra Tupper[1]

[1]*City of Boulder (Community Planning and Sustainability), United States*

1. Introduction

In 2020, experts predict that the world's data centers will use about 285 TWh/year of electricity. With the growing shift to private and public cloud computing facilities, it is important to understand the key drivers for efficiency and emissions reductions in these type of data centers.

In addition to large private cloud facilities and public hyperscale cloud providers (e.g., Google, Salesforce), there is a rapidly growing marketplace referred to as Multi-Tenant Data Center (MTDC) providers, also known as colocation providers. Multi-tenant data centers are shared data centers where customers lease space and power to run their computing equipment rather than managing their own data center. By 2016, more than a quarter of all data center capacity will be delivered by MTDC service providers, rather than being managed in-house by small, medium and large organizations.

The main drivers of operational efficiency and sustainability for cloud computing facilities are:

- Power Usage Effectiveness (PUE): The efficiency of the facility housing the servers, including cooling, power distribution, and lighting
- Hardware efficiency: The efficiency of the servers, data storage, and networking equipment
- Server utilization factor: How much of the server's total processing capacity is effectively utilized
- Electricity carbon emissions factor (kg CO_2eq per kWh): carbon footprint of electricity powering the data center

2. Efficiency Potential of Cloud Computing

Cloud computing holds great potential to reduce data center energy demand due to both large reductions in total servers through consolidation and large increases in facility efficiencies compared to local, smaller counterparts. While studies have shown that large, internal implementations can be as efficient as cloud providers, the vast majority of enterprise or small/medium businesses cannot compete with the cost or efficiency of large aggregated cloud providers.[1] Further, many cloud providers, including Google, Microsoft, and Salesforce, have compared the carbon footprint per user of their services versus on premise data centers, reporting carbon emissions savings between 50-95%.

However, not all clouds are created equal; there are "green" clouds and "brown" clouds. And while the average PUE of large cloud facilities is typically at least 35% better than on premise facilities, a highly efficient and virtualized on premise facility can have a comparable carbon footprint to an average cloud facility.

3. Strategies to Reduce Emissions from Cloud Computing

While there are many ways to increase efficiency and reduce carbon emissions in data centers, I will highlight six:

1. Increase Server Utilization: Average server utilization is very low in most data centers and this has a big impact on energy use. A McKinsey study [2] noted that as much as 30% of servers are utilized less than 10% of the time.
2. Improve Airflow Management: By isolating the flows of cold and hot air, you can decrease the amount of cold air required and increase the efficiency of the HVAC systems.
3. Increase Data Center Temperatures: It is common practice in data centers is to set air conditioning set points between 68°F and 72°F. Most IT equipment purchased since 2006 can easily operate at temperatures up to 95°F.
4. Better IT System Efficiency: More efficient IT equipment (servers, power supplies, etc.) can produce more work per watt, and significantly reduce energy use when idle.
5. Improve Software Efficiency: New software can shift where loads are processed when an outage is detected. With this, the facilities don't have to be built so redundantly, leading to more efficient operation.
6. Power the Data Center with Clean, Renewable Energy

4. Relative Impact of Key Variables

While the impacts of improving PUE and the carbon content of the electricity source is clear, the importance of utilization is often overlooked. Recent analysis shows that increasing the utilization of a data center has a far more significant impact on energy and carbon emissions than decreasing the PUE.

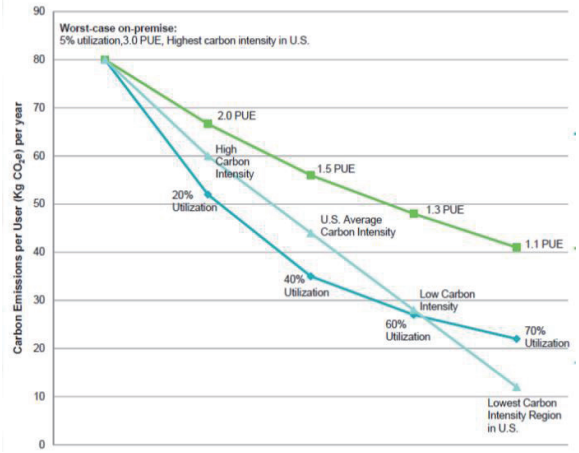


Figure 1. Relative Importance of Data Center Efficiency Variables [1]

6. Barriers in MTDCs

There are four primary reasons why MTDCs have not been able to achieve best-practice energy efficiency performance to date and they cover the spectrum from behavioral, to contractual, and policy-oriented. Specifically, they include:

1. De-prioritization of energy efficiency vs. competing priorities due to contractual relationship
2. The split incentive and behavioral challenges between customers and the provider
3. A lack of clear, robust and available incentives and financing from policy makers to apply within the MTDC environment
4. Customer concerns over sharing application instance and server infrastructure to increase utilization

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New Key Performance Indicators for Smart Sustainable City

Jiro Nakamura and Minako Hara*[1]

[1]*NTT Energy and Environment Systems Laboratories, Japan*
*Corresponding author: hara.minako@lab.ntt.co.jp

We propose key performance indicators (KPIs) based on the Gross Social Feel-good (GSF) Index [1] to evaluate a Smart Sustainable City and report the results of a city field trial conducted in the center of the Tokyo Metropolitan Area.

We developed new KPIs based on the following concepts:

1. The triple bottom line forms the basis of the evaluation criteria.
2. The same unit is used for every evaluation criterion.
3. The KPIs can be used to measure a diverse range of Smart Sustainable Cities with different goals.

The GSF Index is used as the basis of the proposed KPIs, which are aligned with 1, 2, and 3 listed above. Six indicators ("environment", "economy", "comfort", "health", "safety", and "happiness") are proposed for the GSF Index. These indicators along with the proposed KPIs of the Smart Sustainable City are divided into four layers for simplicity, and the triple bottom line and "satisfaction" constitute the first layer. Since the notion of "society" is broad, this layer is further split into "safety", "health", and "comfort," and then positioned in the second layer. The third layer includes indicators such as "information security" and "ubiquity" from an ICT perspective.

Each KPI was evaluated for one year using the following procedures.

(1) Environment: Life cycle CO_2 emission of the ICT system and reduced CO_2 emission realized by reducing the movement of helpers by car were calculated based on L.1410 [2]. An improved KPI value was obtained by comparison of both scenarios
(2) Economy: The construction cost of the ICT system, the operating expense (electric charge) and the increase in shop sales were calculated.
(3) Society: The reduction in traffic accidents and the reduction in time spent in a refuge at the time of a disaster were calculated.
(4) Satisfaction: The willingness to pay for each ICT service was obtained by asking users to complete a questionnaire.

We undertook a trial evaluation using the proposed KPI in a Smart Sustainable City where ICT systems including 'IP announcement', 'Wi-Fi around the station' and 'information transmission and control' are introduced.

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Social Impact Assessment of ICT Services: Case Study and Tool Realization

Julien Boisseau,*[1] Tomoko Tanaka,[1] Ahmed Zeddam,[1] Kazue Takahashi,[2] and Takashi Sawada[2]

[1]*Orange Japan, Japan*; [2]*NTT Energy and Environment Systems Laboratories, Japan*
*Corresponding author: julien.boisseau@orange.com

1. Introduction

Information and Communication Technology (ICT) products and services know a worldwide exponential growth, with notably over two billion people connected to the Internet. The benefit of telecommunications on the development of countries and their people, not only from an economic point of view, is enormous. This is especially true for emerging countries where ICT services often compensate for a lack of infrastructures such as banks or health centers.

Today, several economic indicators are at our disposal to measure part of this benefit. The environmental aspects are also more and more precisely described through life cycle assessments. However, the quantitative evaluation of impacts related to the third pillar of sustainable development – society - is still lagging behind, at least at the scale of a service.

2. Social impact assessment principle

NTT and Orange have been working on solving this issue by co-developing an original tool that considers all impacts of an ICT service or product and translates them into monetary values for an easy understanding of results [1-2]. It is composed of several indexes, with the notion of "society" - too broad and vague - being subdivided into different notions: economy, environment, health, comfort, safety, education. Whether the value of the indexes is positive or negative, small or high, enables to check to what extent a service contributes or not to the realization of a sustainable society.

3. Assessment example: solar charger for off-grid areas

To illustrate the concept of social impact assessment, the example of a portable solar charger, to refill mobile phone batteries and power LEDs, is chosen. Such products target off-grid rural populations of emerging countries. They normally have to walk several kilometers in order to find a store providing a mobile phone battery charging service for a fee, and to purchase the kerosene that fuel the lamps in their houses at night.

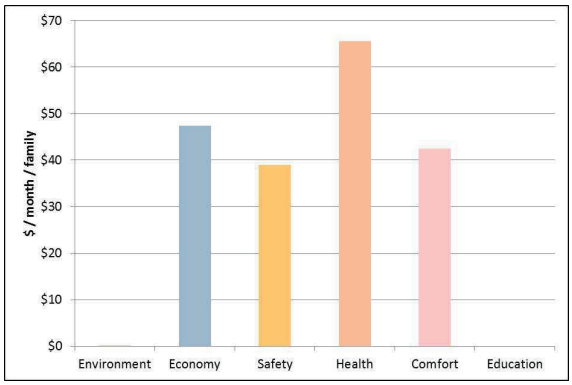


Figure 2. Social impact assessment results for solar charger

If the environmental impact of solar charger can already be evaluated [3] and the return on investment easily calculated, bringing to light the numerous social benefits is new. "Figure 1" shows the results of the comparative study, a positive graph value meaning that the solar charger is more beneficial than the current situation. For instance, the safety index translates the advantage of eliminating the risk of burn, of house fire and of kerosene ingestion by children, related to the use of traditional lamps. The health index deals with the problems of indoor pollution and respiratory diseases and the comfort index with the transportation time saved and the increase of human relationships if the family uses the solar charger to create its own charging business.

4. Social impact assessment tool

Use cases conducted in various countries on ICT services with different profiles (videoconference service, m-health services…) proved the relevance of the approach adopted, by giving results consistent with reality. They also helped clarifying the definition of each index.

Realizing quantitative assessments based on realistic scenarios is however quite time-consuming and sometimes controversial. Monetizing the impacts of ICT services requires indeed putting figures on notions that can be abstract and hard to quantify or hard to find in the literature, such as the value of life, the value of time or the value of human relationships.

In order that those obstacles do not slow down the widespread adoption of social impact evaluation, Orange and NTT have been working on a tool that would integrate monetization equations and a database to automatically generate results. After selecting the category of the service to evaluate, the tool user still needs to input a few data describing the evaluation boundaries and scenario. But the purpose is to develop an interface as user-friendly as possible to familiarize people with the notion of quantitative social impact assessment, still quite new. Transparency is also an important aspect, data and monetization equations being visible to enable a critical understanding of the results.

There is of course a trade-off between user-friendliness and accuracy / degrees of freedom of the evaluation. However, realizing a working version of a social impact assessment tool still represents an important step for the promotion of such evaluations.

5. Conclusion

To continue the development and promotion of social impact assessment tools, additional use cases need to be conducted to confront the progress made with the tool realization and its result consistency. Discussions among actors with different points of view are also essential to improve the methodology and find consensuses, in order to one have at our disposal social impact assessment tools as sophisticated and widely used as those for environmental impacts.

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Multiple Environmental Impact Assessment Method on Biodiversity for Industry

Kazue I. Takahashi[*1], Eri Matsunaga[1], Takashi Sawada[1], Norihiro Itsubo[2],
Masaharu Motoshita[3], and Kayo Murakami[4]

[1] *NTT Energy and Environment Systems Laboratories, NTT Corporation;* [2]*Tokyo City University;*
[3]*National Institute of Advanced Industrial Science and Technology;* [4]*Kyoto University*

[*] takahashi.kazue@lab.ntt.co.jp

1. Introduction

People enjoy various benefits from ecosystems. Therefore, biodiversity has become as important an environmental issue as global warming. To promote environmental management, the total effect on an biodiversity should be understood quantitatively and objectively. The ultimate goal of our study is to establish a biodiversity impact assessment method for evaluating industrial activities. We proposed a hybrid impact assessment method consisting of Environmental Economic Analysis (EEA), Life Cycle Assessment (LCA) and Ecosystem Service Loss Index (ESLI) on land use [1]. Our integrated method quantifies both negative and positive effects. If the method is to be implemented, a single indicator is essential. The results of EEA are initially shown in terms of the same monetary value. And the LCA results can be converted to a monetary value if we use the Lifecycle Impact assessment Method based on Endpoint modeling (LIME) 2. On the other hand, the ESLI results have a physical value, such as volume (m^3) and weight (kg) [2]. Therefore, we developed new conversion coefficients for transforming a physical value to a monetary value and reported the impact of typical Japanese corporate activity as a case study.

2. Method

To obtain the conversion coefficients, we selected an alternative cost method and a preference assessment method. As the former method we referred to the coefficients used for evaluating the functions of agriculture and forests [3] concerning the ecosystem services of carbon storage, flood adjustment and water preservation. The weight coefficient of LIME was substituted in relation to Net Primary Production (NPP). As the latter method, we used the results of a conjoint analysis of green space to evaluate willingness-to-pay (WTP) [4]. As a case study, we evaluated the loss to the ecosystem caused by companies' land use by modeling a real Japanese group company that occupies 30 million m^2 of land throughout the country.

3. Results and Discussion

The evaluation results are shown in Figure 1. Carbon storage had the greatest impact on ecosystem service. The ecosystem service losses obtained with the alternative cost method were greater than those obtained with the preference assessment method. The total ecosystem service loss was 57 billion yen with the alternative cost method and 9 billion yen with the preference assessment method. The total impact of material and energy use by the same group company was about 1 billion yen from the LCA evaluation. The land use impact was greater than that of the material and energy use and so the impact of land use is very important. We examined the consistency and found the preference assessment method to be preferable for an integrated evaluation.

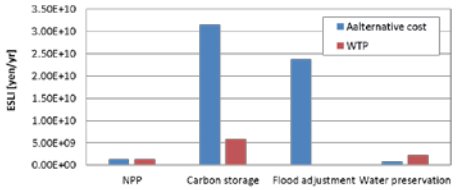


Figure 1. ESLI results shown as monetary values.

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Case study on effect of mechanics development of telecommunication product on material efficiency

Lauri Smalen,[1] Timo Junno,[1] Topi Volkov,[1] Timo Galkin,*[1] Elisabeth Dechenaux,[2] Marc Aubree,[2] Tomoko Tanaka,[3] Heikki Karvinen[4]

[1]*Nokia Networks, Finland*; [2]*Orange, France*; [3]*Orange, Japan;* [4]*Aalto University, Finland*
*Corresponding author: timo.galkin@nsn.com

1. Introduction

The Europe 2020 strategy recognizes the global challenges and opportunities presented, interpreting sustainable growth as "building a resource-efficient, sustainable and competitive economy, exploiting Europe's leadership in the race to develop new processes and technologies".

This study is linked to this strategy by being part of ongoing Opera-Net 2 project activities in Eureka Celtic Plus program. Aim of this project is to reduce the environmental impact of mobile radio networks, and focuses on power, material and resource efficiency improvements.

2. Resource efficiency and sustainability

Recently Design for Resource Efficiency (DfRE) has received an increasing interest. The definition of Resource Efficiency varies. Sometimes it covers raw material consumption only, sometimes also pollution of natural resources and ecosystem is included. In addition to material efficiency, in this study resource efficiency covers natural resources (fossil fuels). In general, DfRE has three objectives: reducing the environmental impacts, improving resource supply security including lowering import dependency for example for metals, and saving the production costs.

The sustainable use of raw materials is widely accepted but there is no consensus yet how "resource use" should be measured. The measurement can be made based on definition of physical indices like mass and material input per service unit or impact assessment indicators of LCA, like Resource Depletion (fossil fuel or minerals). From the life cycle based sustainability assessment point of view, DfRE approaches are not always suitable, because they only look at the output side of a product and try to make it easy to deal with the scrap at the end of life, which enables the reusability of the raw material for future products. From the sustainability perspective it is necessary to look at the input side, for example recycled material content, which means how much used materials actually replace primary materials.

3. Changes in radio access product mounting kit

The life cycle of the Flexi mounting kit was divided into 4 life cycle stages: raw material acquisition, production, use, and end-of-life treatment. The production stage includes die casting of aluminum in versions 104-105 and 206. Kits in this study were manufactured in China, and then transported to the use place. The amount of materials used was reduced from 6.7kg to 2.8kg, and the stainless steel was replaced by die cast aluminum. In this comparative LCA product packaging and use phase were cut-off because there is no difference between each version.

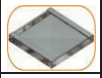
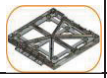
4. Evaluation of new material possibilities

Materials with low environmental impacts, light weight and stiffness were searched with CES Selector software. Study showed that cast aluminum is the optimum choice. Other materials with suitable properties exist like galvanized and stainless steel, magnesium and PC. But, those materials might not be practical or cost-effective to be processed into products.

4. Impact of changes on environmental parameters

According to LCA methodology results (Table 1), kit version 206 has the smallest environmental impact due to the high percentage of recycled material (100%) and an optimized structure which allows reducing the amount of used material.

Table 1: Improvement history of mounting kit

Version of Mounting kit	101-102 	103 	104-105 	206 
Main Change		Material	Manuf. tech.	Design optimizing
Manufacturing technology	Stainless steel (SS) sheet	Al and SS sheet parts	Al die cast	Al die cast
Stainless steel	6720	1550	110	110
Aluminum	0	3071	4120	2720
Polymeric mat.	9	9	0	0
Total [g]	6729	4630	4230	2830
Recycled Al content [w %]		0%	100%	100%
Climate Change [kgCO2eq]	20,56	30,15	16,27	10,85
Resource Depletion (fossil fuels)[MJ]	253,4	362,2	295,7	196,6

6. Conclusions

Our goal was to minimize the impacts on the environment of the materials used for a mounting kit. The results showed that cast aluminum is the optimum choice. There are materials with smaller density (magnesium, engineering thermoplastics) or smaller environmental impacts (galvanized steel) but aluminum provides a good combination of properties.

The design of the new kit allows the use of a smaller quantity of metal and mainly of recycled aluminium. When metals are recycled, there is a clear reduction in environmental impacts, especially because the recycling of metals decreases the demand for primary metals as raw materials.

Acknowledgments

The French Ministry of Industry and the Finnish Funding Agency for Technology and Innovation (Tekes) have partially funded this study through Opera-net 2 project.

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Five IT Thoughts from a Waste Management Proof-of-Concept Project

Yukihisa Yonemochi,*[1] Takashi Sakairi,[1] Hiroshi Horii,[1] Scott Trent,[1] Tatsuya Ishikawa,[1] and Heather D. Achilles[2]

[1]*IBM Research - Tokyo*; [2]*IBM T. J. Watson Research Center*
*Corresponding author: pandrbox@jp.ibm.com

1. Introduction

Intelligent Waste Management is a research effort based on the Smarter Planet and Smarter Cities strategy of IBM Research. To promote the sustainability ideals of reduce, reuse, and recycle, sophisticated cities and companies in developed countries like Japan are efficiently managing recycling with reduced cost and zero-landfill methods.

This Proof of Concept project was a joint effort between IBM Research, the IBM Corporate Environment Office and the city of Dubuque, Iowa [1], USA. We had implemented and deployed Waste Management software. Data monitoring, integration, and analysis are key to achieving these goals. However, today, most systems collect only one type of waste related data (ex: weight), they do not include other waste data such as cost, container sizes, etc. To yield meanful results, all of these waste related data must be integrated and analyzed together.

Our team identified five information technology issues related to data integration and analysis. We will show and explain concrete methods to resolve these issues based on our IT experience along with associated examples. We will also briefly introduce a software solution which can be used to manage and analyze waste data.

2. Integration into usable information systems

Relevant data include not only weight but also waste type, time stamp, location, process method, etc. However, the data format for waste related data is not standardized. Hence data integration is not trivial, and sophisticated data management techniques are required.

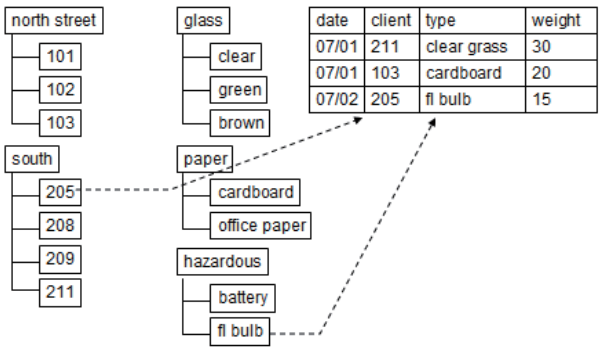


Figure 1. Data structure for waste management

3. Visualization and Interactive Reporting of Data

There are many reporting methods and tools. Data presentation (e.g, graph selection) must be discussed. Our tool can easily display this chart by simply selecting the name of a town, type of waste, or demographic of customer. Figure 2 shows selecting two types of waste.

4. Adoption of data mining methodologies

Many approaches and graphs will be used to understand the data. The exact method depends on the question-at-hand. Hence, data mining tools enable us to choose from a wide variety of options for time range, waste type, process method, customer demographic, etc. Thus our reporting tool includes data selection functionality.

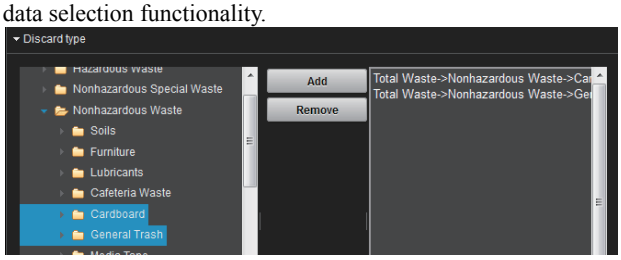


Figure 2. Selecting types of waste to be reported

5. Prediction of waste trends

Importing data from six prefectures that the Japan government published on their web[2] into our reporting tools, we can see a report of that data. In addition, We can predict goal achievement with forecasting as lines. We can use simulation to understand the effect of various scenarios for planning purposes. (Figure 3)

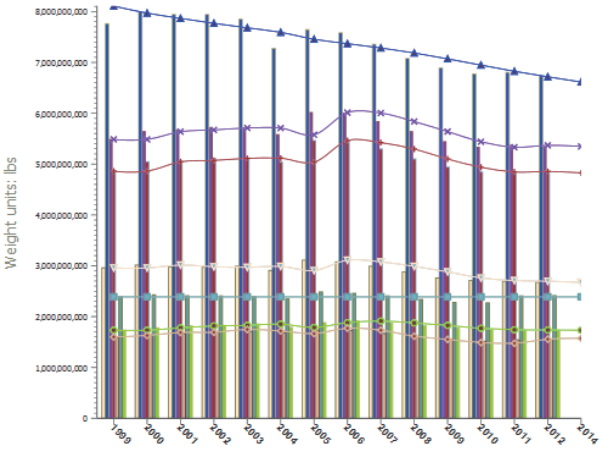


Figure 3. Reporting tool for weight of waste

6. Including data which may appear unrelated to waste

The goal is to understand and include useful data. For example, data such as rainfall, temperature, humidity, event plans, population changes, etc. Integrating this kind of data will produce a valuable perspective for identifying relationships.

Conclusion

We had implemented the solution software through these experiences and provided some clients. The software is continuously updated for new enhancements.

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Environmental Footprint for IT Equipment

Takaaki Kumazawa,*[1] Osamu Namikawa,[1] and Yasushi Furushima[2]

[1]*Hitachi, Ltd.*; [2]*Mizuho Information & Research Institute, Inc.*
*Corresponding author: takaaki.kumazawa.sa@hitachi.com

1. Introduction

IT equipment such as a server or a storage system runs continuously as a data center equipment for enterprise. Therefore, we have focused on climate change as the impact category of IT equipment and reduced the power consumption in use. The Product Environmental Footprint (PEF) [1] in EU, which is still in pilot phase, will increase the need to consider more impact categories on product development.

We have used LIME2[2] as an impact assessment method and IDEA[3] as LCA(Life Cycle Assessment) database developed in Japan. However, another method is recommended in PEF guide. Thus, it is important to understand how the difference of the method affects product development.

The present work discusses the necessary activities of manufacturer based on two results of LCIA(Life Cycle Impact Assessment). One is result of our conventional method and the other is preliminary result in PEF pilot test.

2. Scope of LCIA

LCIA of the storage system[4] was carried out on this work. The function of storage system is to records data and support retrieval. Storage system is an integration of controllers, storage devices such as HDD, and software as in Figure 1.

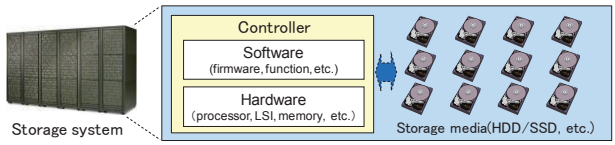


Figure 1. Configuration of storage system

The system boundary of LCIA includes production and transportation of purchase parts, those of the product, use of the product, and recovery of the used product. Most environmental loads are included in these processes. Recycling processes were not taken into account because the evaluation model had not been decided in pilot test yet.

3. Evaluation

The breakdown of LCIA results were calculated in order to find the difference of significant design parameter. Figure 2 shows results of using LIME2 and IDEA1.1.0. We selected categories which can be calculated and are relevant to categories designated in PEF guide.

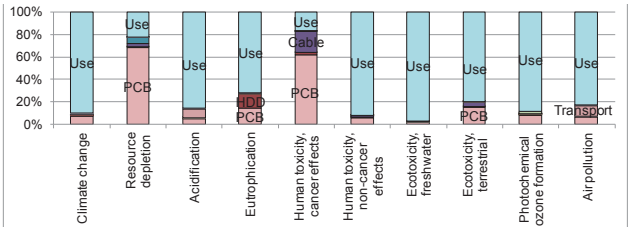


Figure 2. Impact Assessment using LIME2 and IDEA

The power consumption during in use of product, shown as Use in this figure, has significant impact on the climate change, eutrophication, etc. This result presents the effectiveness of conventional approach.

The impact of printed circuit board, shown as PCB, also have a major impact on resource depletion and human toxicity. The effects of HDD and the cable can't be neglected on eutrophication and human toxicity. On the air pollution, the effect of transportation is observed, which shows ship is assumed to be used for overseas transportation.

Figure 3 shows the preliminary calculations in PEF pilot test. The impact assessment method is designated in PEF guide. ELCD 3.0[5] and ecoinvent3.01[6] were used for LCA database to take the overseas environmental load into account.

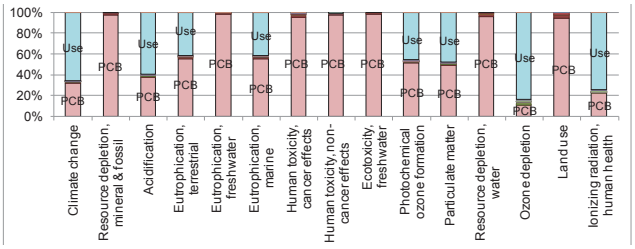


Figure 3. Preliminary calculation in PEF pilot test

The impact of Use and PCB are significant on climate change and resource depletion of mineral & fossil in common with Figure 2. However, the impact of PCB is much larger than Figure 2 on eutrophication and human toxicity. On the other hand, the impact of HDD and cable are not observed here. The effect of transportation is not observed, either.

These results indicate a significant design parameter can be changed in accordance with LCA methodology, that is an impact assessment method and LCA database. Since these results are under discussion so far, we will focus on significant categories and improve the quality of calculation.

4. Conclusion

The results of LCIA indicate the requirement for product design depends on LCA methodology. This means the requirements for manufacturer will expand if the countries or regions where they dispatch their products adopt their own LCA method. This leads to cost issue.

In order to harmonize economy and ecology, the global standardization of LCA methodology should be driven forward as an academic activity. Manufacturers should work together with them and build the flexible system to meet the requirements from customers.

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Analysis of Influence of ICT Services Including Application-Service and Network-Service on CO2 Emission

Jiro Nakamura, Tomomi Nagao, Yuichiro Takei, Atsushi Sakurai, Shinsuke Hannoe, and Keiichi Saito [3]

NTT Energy and Environment Systems Laboratories
*Corresponding author: hannoe.shinsuke@lab.ntt.co.jp

NTT (Nippon Telegraph and Telephone Corporation) Group formulated THE GREEN VISION 2020, which composed of three approaches on Information and Communication Technology (ICT) : “Green of ICT”, “Green by ICT”, and “Green with Team NTT” [1]. ICT services are expected to mitigate CO2 emissions through the use of ICTs in other sectors because their features include the improvement of work efficiency and the digitalisation of information. “Green by ICT” means the contributing to the reduction of CO2 emissions of society as a whole through promoting the increasing utilization of ICT services.

To assess our activities in relation to “Green by ICT”, We investigated an environmental impact assessment methodology based on a two-level model consisting of application-service and network-service levels [2][3].

For our evaluation of application services, we calculated the reduction in CO2 emission realized for individual services by comparing the lifecycle CO2 emission before and after introducing the application services and calculating the total values for individual services.

We calculated the reduction in the amount of CO2 emitted per user, and then obtained the total value for all the network services by multiplying the number of users by the CO2 emission reduction per user.

Using our developed method, we estimated the CO2 emission reduction for NTT Group network services and obtained a value of about 10 million tons. This corresponds to more than double the value of the CO2 emissions generated by NTT Group business activities.

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Measuring social impacts of products: the Handbook of the Roundtable for Product Social Metrics

João Fontes*, Mark Goedkoop and Anne Gaasbeek

PRé Sustainability, Netherlands
*Corresponding author: fontes@pre-sustainability.com

1. Introduction

Measuring and managing social impacts at product level is a driver for companies to innovate and to differentiate in the market. Companies have started to develop in-house approaches based on guidance at global level. These include the UNEP SETAC Guidelines for Social Life Cycle Assessment of Products [1] and corporate level standards including GRI, UNGC and ISO 26000 [2–4]. However, a complete methodology to measure the social impacts of products was still missing. In response to this, a group of experts from large companies[1] joined forces at the Roundtable for Product Social Metrics to advance this area. This work presents the Handbook for Product Social Impact Assessment, which is the result of the first two phases of this collaboration.

2. Content of the Handbook

The Handbook proposes a complete framework for organisations to measure social impacts of products and services on three stakeholder groups as shown in Figure 1: workers, consumers and local communities. These three groups include those who are directly impacted by the product, or live close to its production, use or disposal.

	Life cycle stages		
	Supply chain (raw material extraction, manufacturing and retail)	Use phase	End of life
Stakeholders addressed	Workers	Consumers	Workers
	Local communities		

Figure 1. Stakeholder groups covered in the Handbook

The Handbook includes social topics, performance indicators and impact assessment method. Besides assessing working conditions in the supply chain, there was need for a balanced framework, enabling objective and unbiased assessment. Therefore, in addition to topics such as health and safety, the Handbook also includes topics such as experienced well-being, work-life balance and local capacity building.

The impact assessment method allows assessment of overall performance since the social topics and the respective performance indicators proposed make both positive and negative impacts visible. The stages of the method are listed in Figure 2.



Figure 2. Stages of the impact assessment method

The method supports use of both quantitative and qualitative data. In the referencing stage, quantitative data is compared with reference values, while qualitative data is converted to numbers using reference scales. Reference values and reference scales for each one of the social topics are also provided in the Handbook (see example in Figure 3).

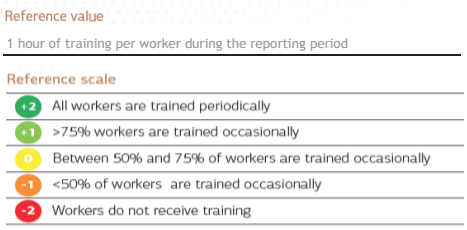


Figure 3. Reference value and scale for training and education

3. Discussion

The methodology allows identification of points of excellence, improvement opportunities and risks. It can be used to support decision-making and communications in numerous applications, from empowering supply chain management, to steering product development and social investment.

During the 2nd Phase of the Roundtable the methodology was tested by the participant companies, confirming that it is applicable to companies in different sectors and with global operations. However, the handbook presents limitations, including i) the performance indicators are not fully applicable to small farmers, small companies and the self-employed, ii) the handbook does not provide guidance on possible data sources, neither has it mapped the performance indicators with data that may be available on public or private databases, and iii) the described methodology is not yet fully aligned with other ongoing global initiatives. The Roundtable will continue to develop in a way to address these issues in the future.

Acknowledgments

The authors would like to thank the members of the Roundtable for Product Social Metrics: Andrea Bolhuis (Ahold), Peter Saling (BASF), Marzia Traverso (BMW Group), Jacobine Das Gupta (DSM), Dave Woodyard and Lynn Bell (Goodyear), Markus Laubscher and Marcel Jacobs (Philips), Dave Challis (RB), Carmen Alvarado (AkzoNobel), Charles Duclaux (L'Oréal), Hazel Culley (Marks & Spencer) and Sébastien Zinck (Steelcase). The authors also would like to thank the external organisations that provided feedback during the 1st Phase of the Roundtable.

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Policies promoting ecodesign for energy and resource efficiency in Europe: experiences, barriers and future options

Carl Dalhammar*[1]

[1]*Lund University, Sweden*
*Corresponding author: Carl.Dalhammar@iiiee.lu.se

1. Introduction

In the European Union (EU), numerous policies and regulations are used to regulate the life cycle environmental performance of products, at both the EU and member state levels., cf. figure 1.

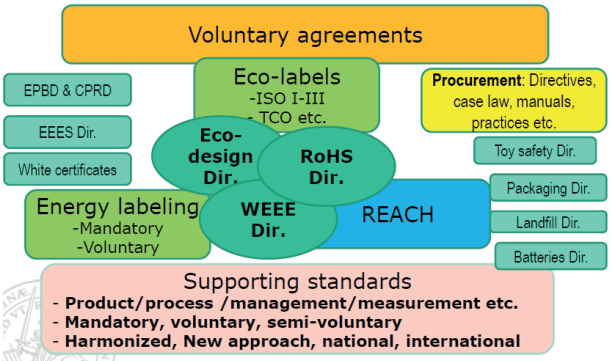


Figure 1. European Union environmental product policies

2. The product policy mix for promoting energy efficiency

The Ecodesign Directive is an EU framework Directive: under the Directive, Ecodesign criteria are set for various product groups. The Directive promotes a life cycle perspective but so far, it has mainly been used to regulate the energy efficiency of product groups, including electric motors, dishwashers, TVs and boilers. In order for the Directive to reach full effect, it should interact well with other policies (cf. figure 2) [1]. Minimum environmental performance standards (MEPS) set under the Directive should remove the worst-performing products from the market. The application of labeling, subsidies and public procurement, helps to diffuse the best performers, and provide continuous ecodesign incentives for manufacturers

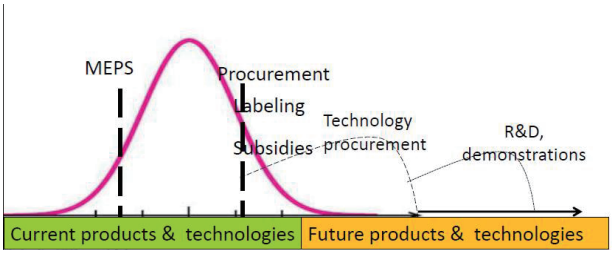


Figure 2. Product energy efficiency policy mix.

In the best case scenario, criteria in both mandatory and voluntary instruments are continuously strengthened, and the products on the market become more and more energy efficient. Over time, the interactions of policies for energy efficiency have been improved. For instance, the European Union increasingly coordinates the review of MEPS and energy labeling to ensure that there is a dynamic.

3. Ecodesign standards for resource efficiency

There is now much interest in using the Ecodesign Directive also to promote resource efficiency and increased recycling levels. Potential mandatory ecodesign standards include requirements that increase product durability; modular design to facilitate repair and up-grade; ban substances, or the mixing of certain materials in the product design to allow cost-effective future recyling; provide information about certain critical materials and where they are located; the setting of maximum time limits allowed for disassembly; and requirements on recycled content in new products [2, 3]. Such standards could support other waste rules. Ecodesign standards will be part of a policy mix, which includes eco-labels, and public procurement. Main research tasks include: 1) how is resource efficiency criteria applied in voluntary policy instruments, and what can we learn from this in relation to mandatory standards?; 2) how can mandatory standards best interact with voluntary standards?; 3) when should we apply mandatrosy standards, and when are they unsuitable?

4. Learning from voluntary policies

A review of different policy instruments showed that many different requirements related to resource efficiency already exist in the Eco-labels, EU Green Public Procurement (GPP) practices, and the business driven scheme EPEAT (a rating scheme for electronics). Criteria relate to issues like recyclability, recycled content, hazardous substances, durability and recycled content. When setting mandatory standards we can learn from the voluntary instruments [2]. But the compliance mechanisms are different, and this should be considered.

5. The policy mix

A review showed that mandatory and voluntary policies can interact in various ways [2]; e.g., voluntary policies can address product life cycle impacts that are not possible to regulate through mandatory standards. In some cases, mandatory and voluntary standards can be mutually supportive.

6. When to apply mandatory standards

Interviews with industry and policymakers outline main criteria that influence when mandatory standards make sense [2]. These include: product life span, whether voluntary approaches are effective, user behavior, and the potential to set quantifiable targets and prove compliance. Further, there will be a need to make a market analysis to examine the need for mandatory standards and their projected costs and benefits.

Acknowledgments

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Reverse Flow of Knowledge and the Development of Sustainable Energy Systems

Harald E. Otto

Polytechnic University of Marche, Italy
h.e.otto@univpm.it

1. Introduction

At present, over three-quarters of the world's primary energy comes from fossil fuels. Energy is vital to all kinds of social and economic processes and to human activity per se. However, as fossil fuel resources are not endlessly abundant, and their use is associated with a number of negative environmental effects, energy has become an increasingly socio-economic and geo-political issue. As a result, society worldwide is facing challenges and pressure to shift from fossil fuel-based energy technologies to green technologies based on renewable and low-polluting clean energy resources, while also restructuring processes, lifestyles, and social structures in order to both use energy more efficiently and considerably curtail total energy consumption. The latter reflects not only on sustainable development and energy systems, but also on current pressing global issues such as climate change and mitigation of carbon emissions.

2. Scope and outline

This represents a global move, which is likely to spur the development of and encourage a transition towards sustainable energy systems and a reduced and more efficient use of energy in both developing and developed countries. Recent studies have led to an increased promotion and implementation in developed nations of innovations originating in developing countries. This demonstrates that developing countries can generate effective solutions for today's challenges (cf. [1,2]). However, innovations produced in developing countries do not automatically transfer effectively to developed countries and translate into viable solutions. To tap into the potential of knowledge and insight generated through technology transfer, research collaboration, and innovation to advance sustainable energy systems, we need a better understanding of the generation and flow not of technology and hardware artifacts, but of knowledge and expertise. This includes combining the learning processes of developing and developed countries [3]. Knowledge, expertise, and innovation emerge from and develop within and together with societies, technologies, and economies, and these evolve and interact with each other in response to many and various internal and external forces.

3. Conceptualization and approach

To provide solutions within the context outlined above, knowledge and inventions at different levels and directions within the socio-technological and economic system need to be realized and implemented. This must be achieved in the form of innovations that are in turn feasible from a social, technological, and economic point of view. For quite some time, starting in the 1950s, innovation was viewed as a sequential linear process where investment in research and development would lead almost automatically to new products or services. This is a view which has been severely criticized, and which has gradually changed. Newly introduced paradigms and work on innovation systems focus more on the interaction of the participants, and the sharing and use of knowledge.

In various fields, studies on innovation as an organizational phenomenon have a long tradition and have brought about conceptualizations in a variety of ways. Innovation can be abstracted as a process or an outcome. The former views innovation as a series of interrelated activities from idea to invention, and finally to commercialization, with new knowledge being created and employed through these activities, while the latter relates to an idea, product, process, organizational structure, etc. [4]. Knowledge is complex, abstract, multifaceted and context-dependent. It is considered to be one major key element in all forms of innovation, with knowledge creation having a high impact on innovation. However, even though knowledge is essential for innovation, it is the exposure to and subsequent recognition of a problem, which is considered to be the initiator of the innovation process.

The study presented in this paper provides an analysis from a knowledge-based viewpoint, looking at knowledge creation and flows within international research collaboration and within different forms of innovation. It examines, for example, product and process innovation, social innovation, and various forms of learning, such as learning-by-using (user innovation), and learning-by-doing. This in turn is related to key energy areas, to provide insight and pointers to facilitate and support efforts to address impediments, remove barriers and employ in a systematic and consistent manner the potential of reverse knowledge flow to support a new generation of effective solutions for sustainable energy systems.

4. Conclusion

As the study examines both dynamic and static concepts of the knowledge-based view in order to shed some light on reverse knowledge flow, it soon becomes apparent that various barriers have been overlooked or ignored. Moreover, there remains considerable potential which is still neither enabled nor supported, and which is thus rendered unused. Empirical data on international research and development cooperation between developed and developing countries, and notably innovation in the latter, are still fragmented and scarce. Therefore, insight into and understanding of knowledge-based processes and knowledge flows are still elusive. This is reflected in our current inability to form an integrated theoretical base that can be employed to better guide planning and policy-making and to establish conditions that will stimulate the generation and deployment of effective and efficient solutions aimed at making sustainable energy systems become a global reality.

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Hitachi's CO_2 visualization effort

Tetsuichi Nomiyama,*[1] and Hitoshi Maekawa[2]

[1]*Hitachi, Ltd., Japan*; [2]*Hitachi, Ltd., Japan*
*Corresponding author: tetsuichi.nomiyama.hf@hitachi.com

1. Introduction

Product assessment has been carried out in Hitachi from the past and from 1991 Design for Environment was introduced and LCA was dealt to confirm product enhancement point or to feedback for next product development. In 1999 "A assessment guide of Design for Environment" was published and Eco-Product, which is assessed using the guide, have been disclosed to public.[1]

Hitachi have tackled environmental issue and have disclosed environmental information as part of CSR from the past. Furthermore, this effort will be developed and LCA will be able to be used to create business activities.

2. Challenge of LCA on business using

To contribute to business activities, it is required to be interesting for customer, to be easy to understand and not to give false impression. And LCA is required for practitioner to conduct with not too much load.

Effects of CO_2 emission reduction was attracted attention because business can be streamlined by introducing ICT solution. So, in 2003 SI-LCA, which assess ICT solution environmental effect, was developed to compare the effect before and after system introduction focusing on global warming as environmental effect.

Furthermore, for customer to have reliability for quantified results and comparison results, in 2009 Hitachi participated in "Japan CFP pilot project", which was propelled by METI and related ministries, and after shifting to private operation "Carbon Footprint Communication Program" to disclose information with high reliability by acquiring third party certification. But at the beginning, there was a challenge not to be allowed to compare because there was p principal to express amount of emission in sales unit in pilot project.[2]

3. Effort of IT equipment at Japanese CFP pilot project

Comparing is effective to express a effectiveness of CO_2 emission reduction. But IT equipments, which are used by many people in being concentrated, like server computer or RAID or something, have flexibility of construction. So effective comparing could not be conducted in sales unit. So we proposed "per function", which make even function unit, of every IT equipment and it was approved. As a result, with using same assessment rule (Product Category Rule, PCR), displaying of CO_2 reduction rate compared with previous model by "per function" was allowed.

Lifecycle stage of every IT equipment except usage (raw material procurement, production, distribution, disposal & recycle) is common regardless of equipment type. So, PCR for every equipment was not published but PCR for common IT equipment was published and PCR was composed to be added individual matter, which is usage and so on, of every equipment when PCR is revised.

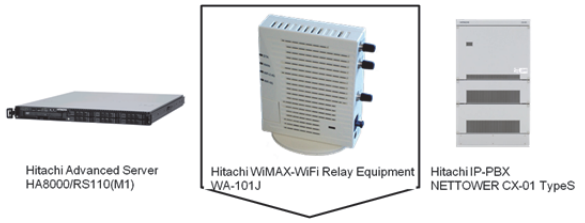
4. Effort of IT solution at Japanese CFP pilot project

About ICT solution, CO_2 reduction rate was considered like IT equipment. But quantification of reduction rate was given up because comparing target is before and after ICT solution introduction and assessment using same PCR is difficult.

And "per function" of CO_2 emission amount also intended to be considered about ICT solution. In approved PCR of "Teleconference Systems" as ICT solution, "per function" was determined to be CO_2 emission amount of 1 hour meeting.

5. Effort after Japanese CFP pilot project

Hitachi have acquired CFP declaration certification of IT equipment such as server computer, auto teller machine, data storage, network equipment, IP-PBX and WiFi relay equipment and system product such as teleconference system. In 2011, we got LCA Japan forum chairman award of 8th LCA Japan forum award LCA section for "Effort and Business Using of CFP in Hitachi Group".



※自社比

-57%

CO_2

CO_2を削減
カーボンフットプリント
1M bit/s ・1年あたり
http://www.cfp-japan.jp
登録番号：CR-CI05-14009

		対象製品	従来製品
製品名		WiMAX-WiFi中継装置	WiMAX-WiFi中継装置
型式		WA-101J	WIFI-AP-A
CO2排出量	製品あたり	160 kg-CO_2e	130 kg-CO_2e
	1M bit/s・1年あたり※	0.28 kg-CO_2e/(M bit/s・年)	0.66 kg-CO_2e/(M bit/s・年)
主な製品仕様	ダウンリンクの最大スループット(規格上の最大値)※1	110 M bit/s	40 M bit/s
	見備するWAN側の通信方式	WiMAX,WiMAX2+	WiMAX
	同時に接続可能な無線LAN端末台数	200 台	200 台
	想定使用期間※2	5 年	5 年
測定条件		使用時電力は、無線LAN端末は未接続の端末サーチ状態で、WAN側の無線回線は接続状態(アクティブモード)で測定する。	

※ この製品の販売単位のCFP値は、CO_2排出量(1M bit/s・年あたり)にダウンリンク側スループット(M bit/s)、及び想定使用年数(年)を乗じ算出されます。
※1 ダウンリンク側スループットについて、WA-101JはWiMAX2+、WIFI-AP-AはWiMAXの規格上の最大値です。
※2 想定使用年数は、設計寿命5年間として計算しております。

Figure 1. Approved CFP products in 2014

6. Development from now on

We continue to promote expanding approved CFP product. And for more contribution to business activities, we will tackle EPEAT registration and will propose to premium standard of Green Purchasing Law and so on and we aim advantage of public procurement and we solve challenge of communication or quantification method which will be out there.

Acknowledgments

I would like to express my very great appreciation to Mr. Maekawa for his patient guidance, enthusiastic encouragement and useful critiques of this work.

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Challenges to Biofuel Production Enhancing Food Production: A Food and Beverage Alcohol Company Perspective

Satoshi Ohara,* Akira Sugimoto, Kazutoshi Kitai and Takaomi Yasuhara

Asahi Group Holdings, Ltd., Japan
*Corresponding author: satoshi.ohara@asahigroup-holdings.com

1. Introduction

The global demand of food and energy is increasing with the world population growth and a rise in living standards. On the other hand, the usable land area has become increasingly limited on the crowded earth. This trend is creating concerns in serious deficit of food and energy in the near future.

From a perspective of a food and beverage company, finding solutions to these issues not only creates a new business, but also contributes to an ongoing business by secure and sustainable procurement of raw materials. In other words, in the highly-globalized market environment, food and beverage companies will be increasingly needed to tackle global challenges and local challenges such as the economic sustainability of farmers, simultaneously.

In this context, the combined production of sugar and ethanol from sugarcane, practiced in many countries, has a high affinity with the technical background and culture of Asahi Group Holdings (Asahi) because Asahi's core competence is in the production of ethanol from carbohydrates (i.e., sugars, etc.). In addition, given that the energy cost is expected to increase in the future, this business is particularly attractive because bagasses, fibrous residue from pressing of sugarcane, can be utilized as fuel.

In the sugarcane industry, agricultural and industrial (sugar, ethanol) technologies are independently developed. Without departure from this paradigm, sugar and ethanol productivity is in a competing relationship - ethanol production compromises the production of sugar. Although efforts to modify cultivar to increase yield per hectare have been made, they usually lead to increase reducing sugars (glucose and fructose) in the sugarcane juice, which inhibit the crystallization of sucrose, thereby negatively influence the sugar productivity. Therefore, it is the common practice to utilize cultivars with high sucrose and low reducing sugars content with low input of fertilizer, water and labor. This approach is referred to as unsustainable agricultural practice in both the global and local context.

2. Shifting paradigm with life cycle thinking

Asahi has been tackling the simultaneous increase in sugar and ethanol production in a sustainable manner, applying life cycle thinking. The life cycle thinking allows re-defining the system-wide objective in optimization of technologies. In Asahi's case, it meant that sugarcane breeders, process engineers and bio-scientists communicate and work together.

Firstly, a new cultivar KY01-2044 was developed by Kyusyu Okinawa Agricultural Research Center, as a result of joint research with Asahi [1]. This cultivar has relatively low content of sugar, but has excellent biomass-productivity with low input of fertilizer, water and labor. As this cultivar has high fiber content, it is possible not only to supply the total energy for producing sugar and ethanol, but also to generate surplus electricity. In Japan, this energy self-sufficiency in the mill is particularly meaningful, as sugarcane is grown mainly on southwestern islands, where they are disconnected from power grid with large-scale (and thus efficient) power plant.

KY01-2044 has greater sugar productivity in total. However, as described above, increased proportion of reducing sugars makes sucrose-crystallization difficult. Asahi and their colleagues have developed a new process called "inversion process" to deal with this problem [2]. Asahi's technologies and experiences in fermentation were the key to develop this process - that utilizes yeasts that ferment only reducing sugars and leave sucrose untouched [3]. By the selective fermentation of reducing sugars before sugar production, the sugarcane juice with high reducing sugar contents turns into high sucrose content juice with ethanol.

With the two innovations in the product's life cycle system, now it is made possible to increase productivity of sugar and ethanol simultaneously without increasing the input to the farm, in the form of fertilizer, water and labor. Currently, the pilot scale experiments of the inversion process are being conducted in cooperation with the operating sugar mill. With these experiments, lots of detailed challenges in technological aspects are being identified and solved.

3. Remaining challenges

Communication among different players in technological aspect has been successful. As a result, the cross-industrial innovation is made technically possible. However, there still remains non-technical challenges to be dealt with.

In order to assure the economic sustainability of the proposed system, the merits created by the life cycle wide optimization and multiple innovations must be appropriately shared among the stakeholders. As the envisioned system involves lots of stakeholders, it is very challenging for a company like Asahi to make a proposal to all of them. A platform to foster the understanding of farmers, policy makers and other industries that may create symbiotic relation with the sugar mills via heat and power sharing must be established. On this platform, to achieve a system-wide transformation towards a sustainable state reflecting the local conditions, participation of all the stakeholders must be achieved under the leadership of local stakeholders.

The collaboration with academia and government is also necessary. We hope that the researchers in the field of EcoBalance, together with industry, shed light on the function of LCA and other associated tools to communicate and arrange the merits, beyond merely working out the envisioned system-wide merits.

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Experience of EPD Process Certification

Lucia Rigamonti,*[1] Mario Grosso,[1] and Mino Leo Marucci[2]

[1]*Politecnico di Milano, Italy*
[2]*Reno De Medici S.p.A., Milan, Italy*
*Corresponding author: lucia.rigamonti@polimi.it

1. Introduction

An environmental declaration is defined, in the ISO 14025 standard, as quantified environmental data for a product with pre-set categories of parameters based on the ISO 14040 series, but not excluding additional environmental information. It is created and registered in the framework of a type III environmental declarations program, such as the International EPD® (Environmental Product Declaration) System.

The Reno de Medici SpA Group is the first Italian and the second European producer of cartonboard based mainly on recycled material. Its production capacity is spread across various plants in Italy, Spain, France and Germany.

In 2010 Reno de Medici decided to promote activities for improving the environmental sustainability of its products. In particular, it started some Life Cycle Assessment (LCA) studies to register under the EPD® system some types of chipboards produced in its Italian facilities. Currently three products are certified.

As a wide number of different chipboards are produced in each facility, according to the same overall production process, the traditional approach for the EPD® certification of each of them would turn out in a time consuming and expensive activity. In order to overcome such limitation, Reno de Medici has recently decided to work in getting the so-called "EPD process certification" (The International EPD® System, 2013). This is a possibility that the International EPD® System gives the organisations to simplify the verification process. In this way the organisation handles internally the management of EPD data involved in the verification procedure and issues individual EPDs without a third party certifier being involved in each case.

2. Material and methods

The development of the EPD process has followed the pattern of Figure 1.

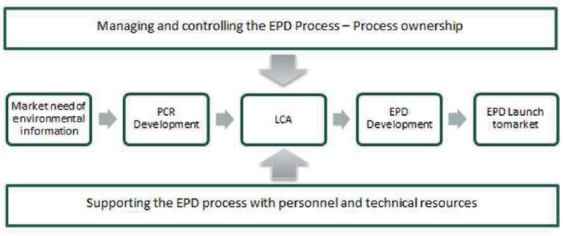


Figure 1. Pattern of the development of the EPD process

First of all, Reno de Medici has defined the following roles needed to implement and maintain the EPD process and continually improve its effectiveness:

- EPD process owner, i.e. personnel having authority and responsibility in managing the overall EPD process;
- EPD responsible publisher, i.e. personnel having authority and responsibility regarding when to publish EPDs to external parties;
- EPD independent internal verifier, i.e. a verifier assuring the reliability, relevance and independence in the handling of the EPD process, and assessing the EPD process to certify its appropriateness;
- EPD independent external verifier, i.e. a third party who verifies the internal EPD process assurance.

Then, the organisation has developed the EPD process. It includes the following main steps:

- EPDs preparation, i.e. determination of the Central Product Classification code of the product, of the corresponding Product Category Rules to be used, of the General Programme Instructions (GPI) to be followed; performing of the LCA studies and development of the EPDs; publication of the EPDs;
- EPD process assurance, i.e. internal assessments conducted by the internal verifier at planned intervals to determine whether the EPD process conforms to the planned arrangements, to the requirements of the GPI and to the EPD process requirements established by the organisation, and whether the EPD process is effectively implemented and maintained;
- EPD management review, i.e. review of the EPD process conducted by the EPD process owner at planned intervals, to ensure its ongoing suitability, adequacy and effectiveness. This review includes assessing opportunities for improvement and the need for changes to the EPD process;
- EPD process certification, i.e. verification done by an independent third party verifier during the time of validity of EPDs following the EPD process, as a complement to the internal assurance activity.

The EPD process implies that the organisation shall have internal competences and skills to conduct the prescribed LCA calculations and to create EPDs according to the reference rules, and to have regular follow-up routines in place to accurately check the relevance of the current information in registered EPDs. Reno de Medici has chosen to outsource the LCA studies to LCA experts of Politecnico di Milano. Anyway, the organisation is in charge to ensure control over this very important step of the process.

3. Conclusions

Reno de Medici has decided to develop an EPD process for the products manufactured in its facilities. This will give the organisation the possibility to simplify the achievement of EPDs certification for many products, saving time and money.

The increased implementation of environmental management systems in many organisations will automatically lead to the establishment of reliable internal follow-up routines which suit very well many of the requirements of the EPD process certification procedure. Hence, well managed internal EPD routines will make data collection and its conversion into EPDs more straightforward and less expensive, allowing the organisation to operate it in a resource- and time efficient manner.

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Policy options for LCA deployment in automotive industry

Annekatrin Lehmann,*[1] Matthias Finkbeiner[1], Kirana Wolf,[1] and Cees ten Broek[2]

[1]*Technische Universität Berlin, Germany,* [2]*World Steel Association, Belgium*
*Corresponding author: annekatrin.lehmann@tu-berlin.de

1. Introduction

Life Cycle (LC) Thinking is on the political agenda and many industries are actively developing LCA approaches since many years. In 2013 WorldAutoSteel commissioned the Technical University of Berlin to explore and develop policy options for integrating Life Cycle Assessment (LCA) into (automotive) legislation. Phase 1 of the research to define and to compare policy options was centered on the EU.

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2. Approach

This research process of exploring and describing different policy options was done with the following approach:

- Identification of various policy options
- Prioritization of policy options
- Analysis of technical requirements
- SWOT-/ RACER analysis (evaluation of strengths, weaknesses, opportunities, threats and relevance, acceptance, credibility, easiness, robustness)
- Development of scenarios for policy implementation

To identify policy options, different theoretical/structural elements were used. These are described in Table 1.

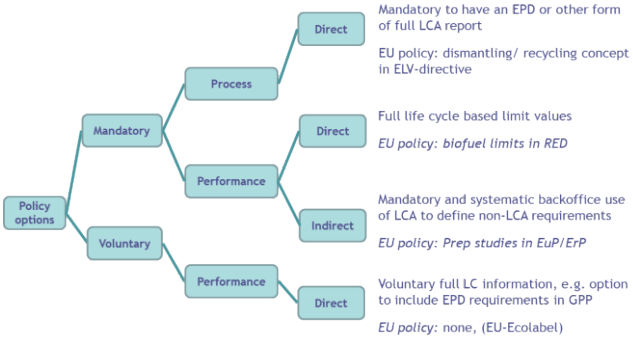


Figure 1 Selected policy options for LCA deployment and examples – theoretical and EU policy ones

Table 1. Structural elements to define policy options

Strucural elements	Descriptions of policy option
Mandatory	Legally binding, thus, the defined requirements have to be fulfilled.
Voluntary	Not legally binding but intends to have indirect effects, e.g. via market incentives.
Performance	Related to the product performance; product needs to be re-designed, if not meeting defined requirements.
Process	Defines process requirements on company level for improvement (not directly leading to product re-design)
Direct	Direct definition of LC based limit/ target values or communication of full LCA results
Indirect	"Backoffice" use of LCA or LCA data during policy development, e.g. for impact assessment of conventional limits or for target value setting processes (e.g. for identified hotspots).
Market access	Provides minimum requirements (threshold values) for products to be able to enter the market.
Market incentive	Provides policy framework (e.g. criteria) for promoting environmentally preferred products.

3. Results

As a result, eleven policy options for LCA deployment were developed. It was found that theoretically a broad range of options for implementing LCA into policies exist and that practically (with focus EU) some of these options are already implemented in real world legislation. As the granularity level developed proved to be partly difficult to differentiate without overlaps it was decided to narrow them down by selecting the most promising ones for each theoretical structure. The four selected policies are shown in Figure 1, including theoretical examples for LC CO_2 legislation and existing examples for European LC based legislation (beyond the CO_2 focus).

As a next step technical requirements for implementation of the policy options were identified and described (methodology, models, tools, data, quality assurance, communication). It was found, that some are the same for both voluntary and mandatory policies, that sometimes, voluntary policy has strictest requirements and that the differentiation of requirements depends on policy implementation.

The SWOT- and a RACER analysis from different stakeholder perspectives (e.g. OEMs, material industry, environmental NGOs) showed, that generally highest relevance regarding CO_2 reduction, but also highest efforts for implementation seem to be related to the mandatory-performance-direct option. Moreover, it was shown, that robustness and credibility can principally be guaranteed by all policy options and that acceptance strongly depends on the perspective of the stakeholder groups and can vary significantly within one group. Findings from stakeholder meetings with German OEMs complemented these results.

4. Discussion and Outlook

The main findings were that there is no clear analytical, scientific overall preference for one single policy option and that technical implementation strongly depends on the implementation level. Moreover, it was shown, that solutions for most technical requirements are already available, but that a consensus on proper setting of these requirements is missing.

Within phase 1 of the research process promising policy options were identified and possible implementation scenarios were developed, describing e.g. how current regulations could potentially be amended to include a LC perspective and/or how new co-existing LC CO_2-regulations could look like.

This research process continues in 2014, including a broader stakeholder dialogue to communicate and refine the policy options as well as a broadening of focus beyond Europe.

A new Direction for LCA: Organizational LCA

Matthias Finkbeiner,*[1] Julia Martínez-Blanco,[1] and Atsushi Inaba[2]

[1]*Technische Universität Berlin, Germany;* [2]*Kogakuin University, Japan*
*Corresponding author: matthias.finkbeiner@tu-berlin.de

1. Introduction

The benefits and the potential of the life cycle approach are not limited to the application to products. While it was originally thought for products, its benefits and potential might be extended for organization assessment [1].

The discussions on the carbon footprint of organizations and the development of the so-called "Supply Chain"- or "Scope 3"-Standard of the GHG-Protocol promoted the future use of such an approach [2]. Grounding on that, the ISO/TR 14069 standardizes the quantification and reporting of GHG emissions of organizations. Carbon footprinting has shown that the environmental impact up- and downstream can play an important role in the overall impact of an organization.

While it is definitely useful to cover specific important environmental areas such as greenhouse gases emissions, a multi-impact approach is needed in order to prevent trade-offs [1]. Furthermore, assessing multiple impacts may offer more innovative and actionable reduction solutions.

Several initiatives exist or are undergoing on the development and agreement of approaches for the multi-impact assessment of organizations from a life cycle perspective. At the global level, ISO developed a Technical Specification ISO/TS 14072, which also serves as the backbone for the flagship project of the UNEP/SETAC Life Cycle Initiative. At the regional and national level, the European Commission launched the Organisation Environmental Footprint (OEF) Guide and there is a Japanese project with regard to scope 3 and LCA of organizations. These initiatives are briefly described in the following sections.

2. ISO/TS 14072 (ISO)

The technical standard "ISO/TS 14072: Environmental management — Life cycle assessment — Requirements and guidelines for Organizational Life Cycle Assessment", to be published in 2014, gives detail on how to adapt the requirements of product LCA to organizations and states some potential benefits that LCA can bring to organizations. The main recommendations for organizational life cycle assessment (ISO abbreviation: OLCA) are regarding system boundaries, and the limitations on reporting, environmental declarations and comparative assertions.

An explicit adaptation of the requirements of ISO 14040 and ISO 14044 to organizational context and an example of the application of OLCA are included.

3. Flagship project "LCA of organizations" (LCI)

In mid-2013, the UNEP/SETAC Life Cycle initiative [3] launched the flagship project "LCA of Organizations". The main outcome is the "Organizational Life Cycle Assessment – Guidance for organizations to conduct LCA considering their value chain", expected to be published by February 2015.

It is intended to be a detailed document accompanying ISO/TS 14072. It seeks to go in greater detail on the capabilities of organizational assessment and on providing support regarding the methodological framework. The publication includes eight case studies.

4. Organisation Environmental Footprint, OEF (EC)

OEF is a multi-criteria measure of the environmental performance of a product-providing organization from a life cycle perspective. The Guide has been developed by the Joint Research Centre of the European Commission, in parallel to the so called Product Environmental Footprint. The document aims to increase reproducibility and comparability by emphasizing prescriptiveness over flexibility to ensure that the methodology is applied consistently [4].

The document has some requirements that do not align with life cycle standard principles and which are neither extensively tested nor used, for example the screening step, the disallowance of cut-off criteria, the recycling formula for end-of-life, and the default set of impact categories and indicators [5]. Besides, OEF Guide considers the option of comparative assertions intended to be disclosed to the public within a same sector and according to the Organisation Environmental Footprint Sector Rules (under development).

5. Related activities in Japan

Several examples of organizations applying life cycle perspective at the corporate level could be found in Japan, although mostly focused on carbon and water footprints, e.g. Shiseido and Honda. An important and closely related event was the "International Workshop of Scope 3 and LCA for Organization" held in Tokyo last November, 2013.

6. Conclusions

It was shown that the application of LCA on organizations is relevant, meaningful and already possible based on existing standards and guidelines. Due to the unresolved challenges in comparing different organizations, organizational LCA should for now focus on performance tracking for individual organizations instead of comparing different organizations.

Some early success stories of application of this type of approaches were identified by the flagship project of UNEP/SETAC LCI and the methodology will be tested during the road-testing of the Guidance. Furthermore, OEF is being applied to selected case studies during its pilot phase.

Acknowledgments

The authors would like to thank members of the International Organization for Standardization and the UNEP/SETAC Life Cycle Initiative for their contribution.

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Guidance on Organizational LCA by the UNEP/SETAC Life Cycle Initiative

Julia Martínez-Blanco,*[1] Sonia Valdivia,[2] Ana Quiros,[3] Llorenç Milà i Canals,[4] Atsushi Inaba,[5] and Matthias Finkbeiner[1]

[1]*Technische Universität Berlin, Germany;* [2]*World Resources Forum;* [3]*ECOGLOBAL, Costa Rica;*
[4]*UNEP-SETAC Life Cycle Initiative;* [5]*Kogakuin University, Japan*
*Corresponding author: julia.martinezblanco@tu-berlin.de

1. Introduction

In order to protect the environment in a credible manner, organizations need to rely on stable schemes. The most applied and spread approaches for the environmental assessment at the organization level have only recently considered the full value chain and mostly concentrate on a single aspect (e.g. [1]).

Life cycle assessment (LCA) has been promoted as a robust quantitative tool, and a keystone in decision making. While the life-cycle-approach was originally thought for products, its benefits and potential might be extended for organization assessment. However, an LCA for an organization appears to be even more complex, as there are many product life cycles to follow and a large part of environmental impacts can reside outside the organization's gate [2].

In this context, the "Organisation Environmental Footprint (OEF) Guide" was launched by the European Commission [3]. Even more recently, the International Organization for Standardisation (ISO) started a project to develop a Technical Specification for LCA of Organizations, the upcoming ISO/TS 14072 [4].

2. The flagship project "LCA of Organizations"

In mid-2013, the UNEP/SETAC Life Cycle initiative [5] launched the flagship project "LCA of Organizations". It aims to show that the application of the life-cycle-approach on organizations is relevant, meaningful and feasible within the framework of product LCA standards.

The nearly 60 participants of the project contribute to the drafting, consolidation and road-testing of the "Organizational Life Cycle Assessment – Guidance for organizations to conduct LCA considering their value chain". Furthermore, a number of regional and international stakeholder consultations support the review process (e.g. in Japan, Panama, Basel…).

3. The Guidance document

The Guidance highlights the potential of organizational perspective within life-cycle-thinking and supports practitioners facing the main important methodological challenges when using organizational life cycle assessment (O-LCA).

It builds on existing internationally-agreed guides, methods and standards on the assessment of the environmental performance of organizations. The Guidance specially strives to align with the upcoming ISO/ TS 14072.

Because there is not a "one-size-fits-all" approach to O-LCA, several alternatives of organization's pathways are presented with specific guidance for its application. Moreover, the Guidance provides real case studies using organizational approaches around the world.

4. Organizational life cycle assessment

O-LCA is a compilation and evaluation of the inputs, outputs and potential environmental impacts (considering a multi-impact approach) of the activities associated with the organization adopting a life-cycle-perspective. The three main items to define within the scope of O-LCA are presented in Figure 1.

O-LCA is capable of serving multiple goals at the same time (e.g. to support strategic decisions, to identify shifting burdens between stages of the value chain, for performance tracking, and to engage suppliers). O-LCA is not intended to be applied for comparison of different organizations.

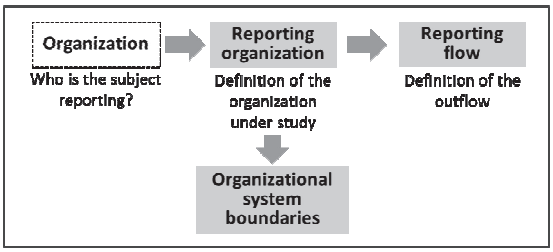


Figure 1. Main elements on the scope definition of O-LCA.

5. Future steps

This methodology may overcome some of the barriers for the spread of LCA in developing countries, for instance the threat of selecting against non-best available technologies, as comparative assertions are discouraged. Furthermore, it is a promising field for future advancements on social and economic LCA, as social and economic impacts may be better tracked at the organization level.

The Guidance will be available for public consultation in few months [5]; we would like to encourage you to provide feedback and help on moving it a step further. The experience acquired during the upcoming road-testing of the final version of the Guidance will also contribute to highlight the potential of O-LCA.

Acknowledgments

The authors would like to thank to the participants of the project and in general to everybody who has contributed to the flagship project providing valuable background, ideas, comments, and case studies.

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Activity to Evaluate a Positive Impact of an Organization

Hiroko Ioka[1], Seiya Yamazaki[1], Takafumi Hashitani[1]

[1]*Fujitsu Ltd., Japan*
*Corresponding author: ioka.hiroko@jp.fujitsu.com

1. Introduction

ICTs (information and communication technologies) like other business have let do concerns on their environmental impact and many companies are keen to assess and disclose GHG emissions based on harmonized methodologies.

However, business has potential to reduce environmental impact by its products and services. Indeed, ITU-T points ICT sector distinguishes itself by its double-edged nature. On the one hand, ICTs have an environmental impact at each stage of its life cycle. On the other hand, ICTs can enable vast efficiencies in lifestyle and in all sectors of the economy by the provision of digital solutions [1].

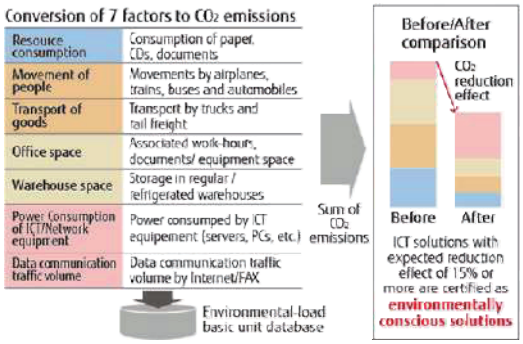
Challenge is that there is no commonly agreed definition and methodology to assess and report an organizational positive impact. This paper address how to assess such positive impact – avoided emissions - of an organization based on the assessment of ICT services.

2. Methodology to assess the environmental positive impact of an organization – in case of Fujitsu Ltd.

Fujitsu, a private company in ICT sector, calculate its organizational positive impacts (avoided emission of CO_2) based on assessment of more than 300 services sold in markets.

Fujitsu refers ITU-T's Recommendation '*L.1410 : Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services*' which complements ISO 14040 and ISO 14044 for the assessment of services. Emissions from two target systems – baseline case and the case where the ICT service is applied - are compared to get avoided emissions (Figure 1). The assessment targets use phase in life cycle of the service. It is because the impact of other life cycle stages is relatively small. Another reason is that organizational negative emission of other life cycle stage such as raw material acquisition and end-of-life treatment are reported as part of scope 3.

Figure 1. Overview of assessment methodology



These 300 assessments are used as model cases to set up conversion factor (tonne of avoided CO_2 per revenue) of each service category. Accordingly 14 conversion factors are set (e.g. Information Management, Data Center Services, and Application Services). These conversion factors are multiplied by revenue of each service category to get total avoided CO_2 emissions of Fujitsu.

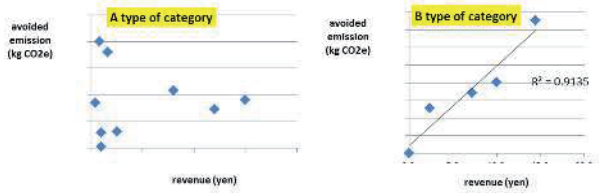
3. Consistency with reporting of scope 1, 2 and 3

Fujitsu reports organizational GHG emissions based on GHG Protocol Standards (scope 1, 2 and 3) and avoided emissions could be ideally reported with consistency to these scopes. In that context, avoided emissions targeted to use phase could be an extended indirect emissions of 'use of sold products' in scope 3 (direct emissions are power consumption of ICT equipment and networks).

4. Limit of accuracy

We examined correlation between the amount of avoided emissions of a service and its revenue to understand accuracy of the conversion factor (kg CO_2 per revenue). We found that some type of category show little correlation between them. (Figure 2.)

Figure 2. Relations between amount of avoided emissions and revenue of the services in two different types of category



We assumed following reasons why little correlation occurs in some types of category. First, ICT services and solutions are typically custom made and also frequently upgraded. As such, systems and performance could differ by services and solutions even in the same category. Secondly, difficulties to identify a system boundary when assessing a service and solution which may cause inaccuracy of the result of avoided CO_2 emission.

5. Conclusion

We suggest continuing discussions on the assessment methodology of organizational positive impact including two questions we rise above (consistency with existing standards and limit of accuracy) and reflect on future guidelines or standards of assessment methodology of organizational positive impact.

Acknowledgments

I'd like to express my gratitude to Prof. Inaba of Kogakuin University and members of the Study Group of Scope 3 and Organizational LCA in LCA Society of Japan for their kind guidance.

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Proposal for a Supplementary Calculation Method for Scope 3 Emissions

Sachiko Motoike,* Hideki Sasaki, and Hiroshi Onishi

Panasonic Corporation, Japan
*Corresponding author: motoike.sachiko@jp.panasonic.com

1. Introduction

This is to propose a supplementary calculation method for Category 2 and ways of thinking Categories 4 and 9 of GHG Protocol Scope 3 Standard for the manufacturing industry.

2. Proposal of Category 2 emissions calculation method

The technical guidance of Scope 3 Standard [1] does not describe the calculation method concerning the cases of selling capital goods or buying second-hand capital goods.

Using the approach toward recycled materials described in Category 5, we explored a method of calculating Category 2 emissions for cases involving second-hand capital goods. As a result, we concluded that avoided emissions associated with recycling/reusing should be counted in the calculation by subtracting the value of emissions based on the selling price when the product is sold second-hand. Grounds are as below.

When a company purchases second-hand goods and calculates emissions according to the technical guidance, the sum of upstream emissions originally defined and emissions from the reuse process corresponds to Category 2. In other words, using second-hand goods means using capital goods with higher environmental impact (see left part of Figure 1). Meanwhile, when calculating Category 2 emissions based on the purchasing price, second-hand goods have smaller values (see right part of Figure 1) since they generally have lower economic value. The avoided emissions by recycling are regarded as a drop in economic value, and therefore we believe the latter case better describes the environmental impact of second-hand goods.

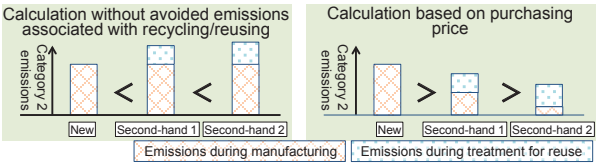


Figure 1. Two methods for calculating Category 2 emissions for second-hand goods

As for cases of selling capital goods, it can be deemed that capital goods produced through the same process have the same upstream emissions caused during manufacturing. However, those environmental impacts vary significantly depending on their lifecycles. Figure 2 shows that purchased capital goods whose lifecycles end in the first company "A" have the same amount of environmental impact as the upstream emissions; whereas for products repeatedly resold from companies "A" through "E," the total amount of environmental impact excluding the emissions in the recycling process is larger than the amount of upstream emissions. This is because Category 2 emissions are calculated at each company the product is resold to.

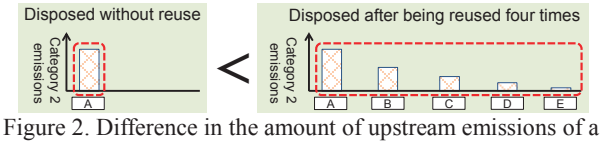


Figure 2. Difference in the amount of upstream emissions of a product when disposed of as a new product or second-hand

Purchasing/Selling prices of capital goods are indicated in cashflow statements, and upstream emissions can be allocated using both values, as shown in Figure 3. In purchasing capital goods, Category 2 emissions are calculated based on the purchasing price, and the emissions according to the remaining value (selling price) will be subtracted when being sold. This method is reasonable in that the buyer of the second-hand goods calculates Category 2 emissions using this subtracted value (i.e. purchasing price) which is regarded as the remaining amount of upstream emissions corresponding to the economic value of those second-hand capital goods at that point.

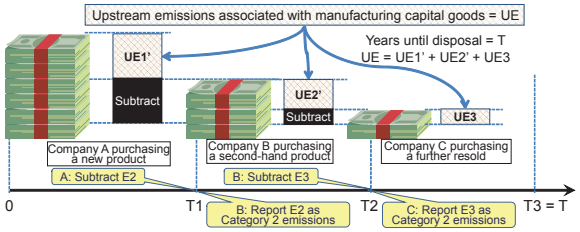


Figure 3. Allocation of upstream emissions

In this way, Category 2 emissions relating to second-hand capital goods can be calculated appropriately and easily.

3. Consideration to Categories 4 and 9

While Categories 4 and 9 require calculating emissions caused by transportation in cases where the transportation fee is paid by a supplier or a customer, collecting activity data as grounds for calculation is difficult.

Because forms of transportation vary among both upstream suppliers and downstream customers, it is very difficult in itself to extract only the activity data relating to the reporting company. Even if activity data is provided by the supplier, it is unrealistic for a manufacturer like us with over 10,000 suppliers to calculate emissions with actual activity data. Moreover, although the technical guidance recommends estimating activity data regarding these Categories, it is also difficult to explain the validity of the estimation.

As a result, we consider it acceptable for manufacturers like Panasonic to indicate N/A for emissions where the supplier/customer pays the transportation fee.

4. Summary

Through our experiences with Scope 3 calculation, we proposed a supplementary calculation method for Category 2 and ways of thinking Categories 4 and 9. We will also explore other Categories in order to materialize meaningful efforts that would help reduce environmental impact caused by companies.

Acknowledgments

The authors wish to acknowledge valuable discussions with Dr. A. Inaba and the members of the working group of LCA Society of Japan.

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Estimating multiple changes of GHG emissions on Mitsubishi Electric group's supply chain; Category11-possible variation of GHG during use stage

Chie N. Uchiyama*[1]

[1]*Mitsubishi Electric, Japan*
*Corresponding author: Uchiyama.Chie@db.MitsubishiElectric.co.jp

1. Introduction

In recent years, quantitative evaluation methods of GHG emissions and other environmental impacts on the entire supply chain of the organization, such as Scope 3 initiated by GHG protocol, related ISO standards and environmental footprint of the organization proposed by EU, have been developed.

However, existing approaches define only the framework of the calculation rules. In fact, evaluation result is largely dependent on selecting which category in the upstream and downstream of the organization, setting the system boundary of each category, data representativeness. In addition, the outcome deeply relies on the estimates due to the constraints of the data availability in each category.

So far, more companies have disclosed the information on GHG emissions of the organization based on these methods. but there is no organization which shows multiple outcomes, mentioning the change of the evaluation results due to variation in the way of taking selection of categories, system boundaries and others. This study, providing a case study that targets the main segment of Mitsubishi Electric, aims to evaluate the effect of a variation of certain conditions in the calculation of GHG emissions.

2. Methods, Research design

Based on GHG Protocol and the Ministry of the Environment guidelines, GHG emissions on the supply chain of HVACs, Mitsubishi Electric Europe (ME-Europe) in FY2012 were calculated. Two kinds of emission factors were applied, Japanese carbon footprint communication program and UK-DEFRA.

3. Analysis

The results of GHG emissions from ME-Europe shows that, category 11 accounts for more than 90%, then category1 is about 3 %. This outcome reflects GHGs of electronics usually occur during use stage. Hence, focusing more on category 11, sensitivity analysis and scenario comparison were examined. For each analysis, the conversion factors of electricity both from Japan and UK were used. Normally, electronics companies manufacture a wide variety of products with diversified specification to meet the needs of users. Considering countries and use scenarios, the amount of computation will be large and its combination is enormous and complex. From a practical viewpoint, the method should be ideally simple and comprehensive. As the sensitivity analysis, three calculations were studied, 1) base scenario (calculation model by model), 2) weighted average, 3) assumption based on the best-selling model, and 4) simple average and then data representativeness was compared. Next, different scenarios for operating conditions were evaluated, temperature, the heating period and heat insulating performance.

4. Results

The results of the analysis are shown in Figure 1 and 2. Overall, results from Japanese coefficient exceeded those from UK. As for representatives of the data, "simple average" revealed a large value compared to several other cases. This is caused by the wide range of product lines from low to high –power models. If the discussion is restricted to FY2012, the case of best-selling model showed the minimum result since low-power model products were sold well during that period, Scenario comparison, depending on how wide the assumption is, the difference by the effect of heat insulating performance conditions is maximized.

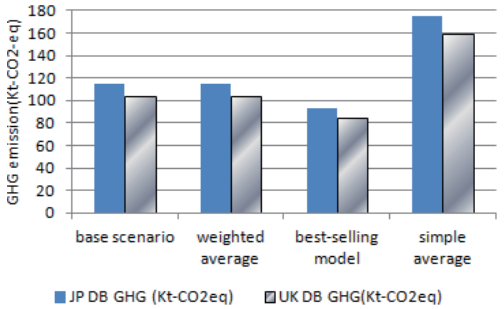


Figure 1. Comparison of different calculation rules

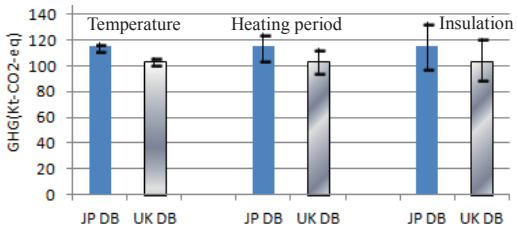


Figure 2. Comparison of different scenarios

5. Discussion and Conclusions

In this study, by applying calculating GHG for supply chain of electronics, category 11 was especially examined, focusing changes in the calculation results in different situation. The largest impact on the result is due to the difference in emission factors, which equals roughly the amount of category 1. Considering applications by global companies, the data quality and sources should be harmonized among countries.

EU has published a guidance of Organization Environmental Footprint (OEF) and intended comparability among the same industry sector. However, differences by each country's conversion factors, representativeness, and scenario setting might be explained in variation in a mixture of aspects of product's performance. Only a sector-specific guideline would not be enough. This implies that more discussion is needed with sufficient samples toward standardization for comparative analysis.

Acknowledgments

This study has been greatly enhanced by the support from members of "LCA of organization and SCOPE3" working group under LCA Japan Forum and MERCE-UK.

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What allocation method should be taken to provide the data for SCOPE3 by supplier to customer? - An example of the printing company -

Hiromichi Sasaki,*[1] and Nobuyasu Tanaka[1]

[1]*Sun Messe Co., Ltd. Japan*
*Corresponding author: h-sasaki@sunmesse.co.jp

1. Introduction

Recently, the CO_2 emission of organization such as SCOPE3 has been disclosed by many companies in Japan, partly because they have to report it to the rating organization such as CDP. In this context, the company that provide products (material, parts, etc) and service have to disclose the CO_2 emission of their products and/or service to their customers. As Sun Messe Co., Ltd. Japan is a printing company, the CO_2 emission caused mainly by used paper and energy consumption for printing, which should be allocated into many customers that Sun Messe Co., Ltd. Japan provide printed materials. In this paper the difference of the results by allocation methods such as the product quantity, the cost of printing paper and weights were introduced. In addition to this, the measures to reduce CO_2 emission in the printing company will be discussed.

According to the guidelines of SCOPE3, it can be based on the sales, to allocate to each of the customers the whole CO_2 emissions of the Sun Messe Co., Ltd. However, this method can not represent the diversity of order form. All products of the printing company are made-to-order. Forms, sizes and quantities are completely different because all productions have to meet the needs of customers.

In this presentation, we will report the results of a study from the view point of suppliers, how to allocate to each customer the CO_2 emissions of the Sun Messe Co., Ltd.

2. The CO_2 Emission of Sun Messse CO., Ltd by SCOPE3

The Figure 1 shows the calculation result of the CO_2 emissions by the SCOPE3 of Sun Messe Co., Ltd. Category 1 accounts for 70% of the total. In addition, 95% of this category 1 is the emissions for the production of printing paper. From this result, we would suggest that the method allocating the customer the CO_2 emissions of printing paper is a major factor in determining the CO_2 emissions of each customer. In this study, we consider the most appropriate method to allocate the CO_2 emissions of printing paper to each customer.

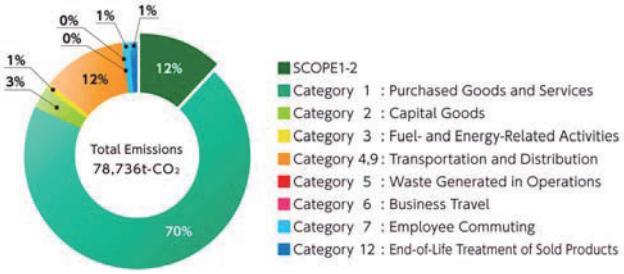


Figure 1. The CO_2 Emission of Sun Messe CO., Ltd. by SCOPE3

3. Case Study

Case 0 is based on the sales. That is the most popular method has been shown in the guidance of SCOPE3. Case 1, Case 2 and Case 3 are based on the product quantity, the cost of printing paper and the weight of printing paper respectively to allocate the customer the CO_2 emissions. As the examples of the customers, three companies are selected. The main products of company A, B and C are flyers for sales promotion, books, and direct mails respectively.

4. Results and Discussion

Figure 2 shows the results of Case 0, 1, 2 and 3 allocating the whole CO_2 emission of the Sun Messe Co., Ltd. to each company A, B and C.

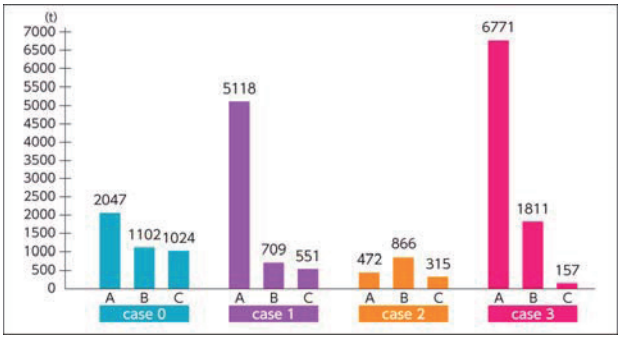


Figure 2. Allocation results of the whole CO_2 Emission of Sun Messe CO., Ltd. to company A,B and C on Case 0, 1, 2 and 3.

In Case 0, since the CO_2 emission is allocated based on the sales, the difference of the amount of printing between the companies was not reflected on the results. In Case 1, since it is allocated based on number of volumes, a small volume flyer has the same result of a large volume book. In Case 2, since it is allocated based on the cost of printing paper, the weight of printing paper that the customer has paid and provided to Sun Messe Co., Ltd. is not reflected on the results. Considering printing works, Case 3 which is allocated by the weight of printing paper seems to be the best method because it reflects the energy consumption of printing works.

Table 1 shows the CO_2 emission per 1 million yen of the sales for each company. In Case 0, the CO_2 emission of each company is consequentially the same because it was allocated based on the sales. However, in Case 3, the CO_2 emission of Company A is more than over 20 times of Company C.

5. Conclusion

In the guidance of SCOPE3, the allocation method based on the sales is very popular, but the characteristics of the works of the company should be reflected. And, it should be agreed with the customer.

Table 1. The CO_2 Emission of each company per 1 million JPY

	CO_2 emission factor (t-CO_2/million JPY)		
	A	B	C
case 0	5.5	5.5	5.5
case 1	13.6	3.5	2.9
case 2	1.3	4.3	1.7
case 3	18.0	9.0	0.8

Acknowledgments

I would like to thank Professor A. Inaba of Kougakuin University, provided helpful comments and suggestions. I also would like to thank Dr. M. Motoshita of National Institute of Advanced Industrial Science and Technology (AIST), provided incisive comments.

Water consumption evaluation along the supply chain

Junichi Nakahashi,[*1] Masaharu Motoshita[*2]

[1]*ASAHI KASEI CORPORATION, Japan;* [2]*AIST(National Institute of Advanced Industrial Science and Technology), Japan*

1. Introduction

Human activity has begun to affect significantly to the globe environment. Climate change, water drought, material exhaustion, food shortage etc. are primary issues to be tackled [1].

ASAHI KASEI CORP. has published water consumption amount at the factories on annual CSR report, but has not tried to evaluate the water consumption amount along the supply chain yet.

IDEA2, life cycle inventory data base including water consumption factors on industrial goods is now under construction by AIST. And so we can try to evaluate the water consumption amount along the supply chain of ASAHI KASEI CORP.'s purchased materials using it.

2. Objectives

(1) To evaluate the water consumption amount along the supply chain of ASAHI KASEI CORP.'s purchased materials using IDEA2 and compare to the water consumption amount at the factories.

(2) To evaluate the effect of using the individual damage factors for countries in IDEA2 comparing to the case using only the damage factor for Japan for all countries in evaluating the damage value.

3. Evaluation of water consumption and its damage along the supply chain

(1) Water consumption amount evaluation

Factories

(water consumption) = (water amount took from river) – (water amount returned to river)

Supply chain of purchased goods

(Water consumption) = Σ((water consumption factor*) x (purchased good amount))

* referred to life cycle inventory data IDEA2 now under construction by AIST

(2) Damage evaluation

1) Estimation of the primary purchased goods amount by countries using foreign trade data in IDEA2

2) Evaluation on the effect of using the individual damage factors for countries

Da = Σ((purchased good amount by country) x (water consumption factor by country) x (damage factor by country))

Db = Σ((purchased good amount) x (water consumption factor) x (damage factor))

Effect of using the individual damage factors for countries is evaluated as the value Da / Db.

If Da / Db is 1, there is no effect. If Da / Db is less than 1, using the individual damage factors for countries generates larger damage value. If the Da / Db is larger than 1, using the individual damage factors for countries generates smaller damage value.

4. Result

(1) Water consumption amount along the supply chain of purchased goods was about 2.9 times as much as water consumption amount at the factories [2].

(2) The effect of using the individual damage factors for countries Da / Db was about 0.7.

5. Discussion

(1) Water consumption factors on goods derived from wood or timber are higher than other factors.

(2) Wood and forest seems to keep water rather than to consume water. Water consumption factors are not generated based on this fact.

(3) It takes about 60 years for wood to grow up. It is quite different from annual plants like as rice plant or corn etc.. Water consumption factors are not generated based on this fact also.

6. Conclusion

Water consumption factors have subjects to be solved. And so the water consumption amount calculated using such factors may be different from the true value.

Damage factors are generated through multiple assumptions, so damage values using such factors have also subjects to be solved and are now difficult to be compared to real economy and also difficult to be compared to each other.

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Supply-chain Environmental Assessment for Sustainable Procurement

Kenji Ohashi

SHISEIDO Co., Ltd.
kenji.oohashi@to.shiseido.co.jp

1. Introduction

SHISEIDO Co., Ltd. is a cosmetic product manufacturer and seller company in Japan. SHISEIDO provides products and services that support the beauty and wellness of people within sustainable thinking. Several efforts are now in progress to this commitment. First, we are spreading the re-fill products, which can reduce the amount of resource for packaging. Second, SHISEIDO provides the cosmetic products which packaging is made from sugarcane-derived polyethylene. We have a plan to switch to green-polyethylene, more than 70% of the total polyethylene, by 2020.

On the other hand, it is an essential requirement for all companies to collect, measure, manage and disclose the information about environmental burden in various categories as well as GHG emissions. We focused on GHG emissions and water consumption because of the materiality. Here we report our approach about GHG and water accounting in order to make sure of some objectives, as following;

(1) Total amount of GHG emissions and water consumption
(2) Hot spots
(3) Avoided load and trade off due to our efforts
(4) Weakness and resilience of our supply chain

2. GHG & water accounting through the value chain

We carried out assessing on direct/indirect GHG emissions and water consumption through the value chain of Japanese business activity in cosmetic field of Shiseido, according the method of GHG protocol Scope3 standard [1].

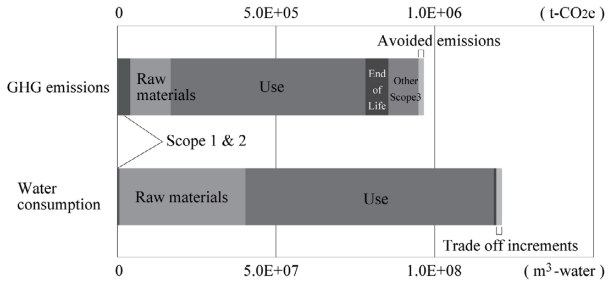


Figure 1. GHG emissions and water consumption of Scope1, 2 and 3

As a result, the indirect GHG emissions from upstream and downstream of the value chain are approximately 19 times as much as direct emissions (Figure 1). Further, the fact that more than 99% of water was consumed indirectly in the crop cultivation and in the use stage by consumers has revealed. Additionally, approximately 17,000 t-CO_2e of GHG emissions was suppressed due to our efforts.

3. Traceability research of the raw materials

The significance of impacts related to water consumption depends on its locality because of uneven distribution of water resource. The fact indicates the next goal of our water analysis with the locality as well as the quantity.

We therefore started traceability research about the plant-derived materials used in the cosmetic raw materials. This research aims for identifying the growing or cultivating area at the national level and for making a "supply chain water map". This map would show us which area's water our business depends on.

4. Discussion

Heightened concerns regarding global environmental problems have led consumers to make strong demands for the incorporation of sustainability into any product development or economic activity. Indeed environmental issues must be considered one of the most important tasks in businesses today, and failure to address these issues is now recognized as a major business risk to any company. In addition, various investment institutions and environmental NGOs demand us disclosing certain information relating to environmental issues based on LCA method. We carried out accounting GHG emissions and water consumption through our value chain. The results indicate the importance of environmental management through the value chain.

Cosmetic business relies on many kinds of raw materials made from plants, which are dependent on fresh water resource. Because the water resource is distributed unevenly [2][3], when it comes to sustainable water use, it is important to manage not only with its quantity but also with the geographic data. We are trying to draw a "supply chain water map" by traceability research about cosmetic raw materials. It can suggest the supply chain business risk related to water with the vicissitudes of water scarcity [4], flood occurrence [5], demographics, social and economic structure on the cultivation area in future. While LCA expresses the impacts to the environment owing to economic activities, the analysis combined with some information can improve LCA to the "supply chain business risk assessment tool" and it would help us to establish sustainable and resilient procurement.

Conclusions

Value chain environmental assessment brings immediately results on discovering hotspots, avoided load, trade off, cost reduction opportunities and so on. Moreover it would be useful to forecast the business risks on the supply chain.

Acknowledgments

I thank for the fruitful advices and discussions with Prof. A. Inaba and the member of the "Workshop of Scope 3 and O-LCA" in JLCA.

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Green GDP Study Based on Life Cycle Impact Assessment of Refinery Sector in Thailand

Kultida Kunanuntakij,[1] Viganda Varabuntoonvit,[1] Natanee Vorayos,[2] and Thumrongrut Mungcharoen*[1]

[1]*Kasetsart University, Thailand*; [2]*Chiang Mai University, Thailand*
*Corresponding author: fengtrm@ku.ac.th

1. Introduction

Gross Domestic Product (GDP) is one of the indicators used to assess economic development and production growth of the country or some specific sectors. In the past two decade, Thailand's GDP average growth is 0.93 percent, while petroleum refinery sector average growth is 13% due to the growth of energy demand. GDP reflects only wealth of country but does not reflect other factors such as quality of life, impact on environment and depletion of natural resources due to the increasing of production, consumption and the impact of human activities on the environment.

Sustainability Development normally covers 3 factors which are economic, social and environmental growths. Green GDP is therefore expected to reflect the impact of environmental degradation and resource depletion on the traditional GDP. This study aims to develop Green GDP model for petroleum refinery production sector in Thailand by using the value of environmental impacts from Life Cycle Assessment (LCA) results.

2. Methodology

Green GDP is an index which incorporates the environmental impacts into the traditional GDP. This can be done by monetization of the environmental impacts such as eutrophication, climate change and other relevant impacts.

There are several methods used to convert environmental impact to monetary term such as weighting factors evaluation from environmental taxes or fees. Another method based on end-point is LIME which converted environmental impact to Japanese Yen. Most of the methods to convert environmental impact to economic value are based on Willingness to Pay (WTP) or Distance to Target (DtT). However, a method based on environmental impact treatment cost is an attractive scientific method to convert environmental impact to monetary term. This method depends on treatment technologies and uses interest rate and exchange rate to convert in to Thai Baht.

$$\textbf{Green GDP} = \textbf{Traditional GDP} - \textbf{Treatment Cost} \quad (1)$$

"Figure 1" shows the overall methodology of this work.

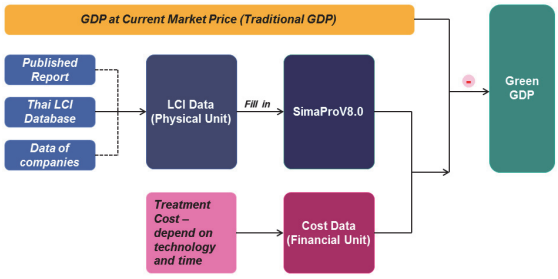


Figure 1. Overall Green GDP Calculation Method

Thailand National Life Cycle Inventory Database (Thai LCI database) of petroleum refined products is used to calculate environmental impacts. Some of the inventory data from petroleum (exploration and production) which is imported from other countries are from Ecoinvent3 database. "Table 1" shows some environmental impacts using ReCiPe method. The treatment cost of specific technology for each impact category is shown in "Table 2". In this study, economic cost is calculated by using the average exchange rate with the inflation by interest rate.

Table 1. The LCA Results by Using ReCiPe Method

Impact	Unit	2010	2011	2012
Photochemical oxidant	kg NMVOC	5.0E5	4.9E5	4.4E5
Eutrophication	kg P eq	5.4E1	5.3E1	4.8E1
Acidification	kg SO2 eq	4.3E7	4.2E7	4.4E7
Climate change	kg CO2 eq	1.4E8	1.4E8	1.4E8

Table 2. Technology and Treatment Cost in THB per Unit

Technology	Year	Unit	Lower	Upper
Setting LDAR1,2	2005	kg NMVOC	6.88	15.56
Activated sludge	2004	kg P eq	741,041	1,482,143
FGD	2005	kg SO2 eq	5.48	7.20
CO2 capture	2009	kg CO2 eq	1.88	10.20

3. Results and Discussion

It is found that Green GDP value is about 2-4% less than traditional GDP. The most impact in the refinery sector comes from the increasing use of energy which is caused from the increasing demand of refinery products.

This study considers 4 environmental impacts which are the main impacts obtained from the characterization step. About 80% of the main impact comes from the treatment cost of SO2 removal and CO2 capture. "Figure 2" shows the comparison of traditional GDP and Green GDP for the refinery sector during the year 2010 to 2012.

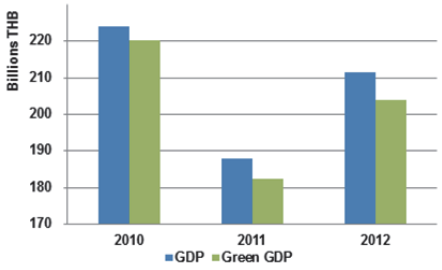


Figure 2. Comparison of traditional GDP and Green GDP

4. Conclusion

Green GDP is used to reflect the environment impact comparing to the traditional GDP. The treatment cost for each of the impact categories can be obtained by conversion of the impact to monetary term. Green GDP of the refinery sector, using the treatment cost method, is about 2-4% less than the traditional GDP. Further study will include other major impacts such as fossil depletion, eco-toxicity and human toxicity.

Acknowledgments

The authors gratefully acknowledge financial support from the Sustainable Environment Program, National Science and Technology Development Agency (NSTDA), Thailand.

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Fast screening of alternative life cycles and system optimization using flexibly linkable process subsystems

Bernhard Steubing,*[1] Chris Mutel,[1] Florian Suter,[1] and Stefanie Hellweg[1]

[1]*ETH Zurich, Switzerland*
*Corresponding author: steubing@ifu.baug.ethz.ch

1. Introduction

Life cycle inventory databases, such as ecoinvent, usually provide detailed process models, which has resulted in a large number of unit processes. While this is necessary to ensure high quality data, it would often be handy for LCA practitioners to aggregate such detailed process chains into a smaller number of major building blocks – only the principal elements that they are interested in – for example raw material production, transportation, product manufacture, product use and recycling.

On the other hand, life cycle inventory (LCI) databases often contain more useful datasets than is actually made use of. For example, ecoinvent contains both datasets that describe the production of methane from biomass (biomethane) as well as a number of datasets that describe the use of natural gas for the delivery of energy services (e.g. electricity). However, datasets for the generation of the same energy services from biomethane do not exist, for the simple reason that including all these possibilities would dramatically increase the number of processes in a database which is meant to serve as a background database.

Further, in order to solve the inventory problem, LCI databases generally have square matrices, which means that each input to a dataset is clearly determined and each output is unique (e.g. not just "electricity"). In LCA, however, comparable, i.e. identical, products are often required (e.g. "electricity from natural gas" and "electricity from biomethane" could be subject to a comparison). Also, many upstream inputs are in reality substitutable (e.g. heat from different sources, or different machines with the same delivered function). When many choices arise from such upstream (or downstream) substitutes, the formulation as an optimization problem may be an insightful way (or the only way) to reach conclusions about a meaningful system design.

In this paper we make use of what we call *process subsystems* to support analysts to build models and overcome the aforementioned issues more easily.

2. Approach

Based on the open source software Brightway2 [1], we have developed an approach to group any number of processes into what we call here process subsystems. Process subsystems are characterized by a name, its outputs and its inputs, and a chain of processes that belong to the process subsystem. The name can be specified by the user. There can be one or several outputs for which the user equally provides a name. Multi-output processes are supported (which is especially useful in optimization problems). By default, a process subsystem links to all upstream unit processes of the unit processes that are included in the chain of a process subsystem (the unit processes that are intended to make up the process subsystem). However, links to upstream processes are cut (i.e. not maintained), if the user defines these as "inputs" to the process subsystem. In this case, the information contained in the process subsystem for this previously existing link is an amount and a user-defined name of the input, but not an explicit link to another unit process or process subsystem. The required input can later be delivered from another process subsystem.

To illustrate the advantage of this, we stick with the above example (Figure 1): natural gas and biomethane are essentially equal products, although produced in different ways. By defining an input "methane" in the process subsystem "electricity production" (for which there will be no link to a unit process anymore; cut-off) and defining two additional process subsystems "natural gas production" and "biomethane production" that both produce the product "methane" we have developed three process subsystems that can be combined by the name of their products.

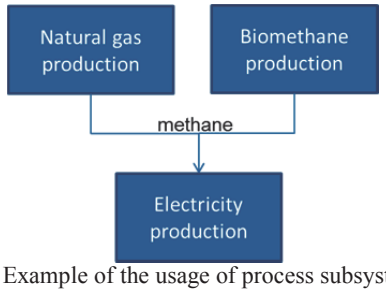


Figure 1. Example of the usage of process subsystems

While this may seem exceedingly complicated for such a small system, it is a powerful way of representing often large numbers of possibilities in more complex systems.

3. Case study

We have applied this approach to analyze the ecological benefits of using the resource wood. First, the approximately 300 life cycle inventories relating to the production of wood products in ecoinvent 2.2 as well as processes for alternative non-wood products were associated with less than 40 flexibly linkable process subsystems to represent the essential possibilities for the material and energy uses of wood, including cascade uses. Then, linear programming was applied to optimize the use of process subsystems based on their LCA results and other systemic constraints.

4. Discussion

Process subsystems appeared to be useful as they:

- Reduce the complexity associated with linked unit processes to a level that is easier to understand and manage and communicate by the modeler
- Facilitate the modeling of combinations of in principle possible, but not yet modelled process chains (such as electricity from biomethane)
- Are an important step towards formulating optimization problems

Naturally there are also drawbacks associated with process subsystems. For example:

- It takes time and good system knowledge to formulate meaningful process subsystems
- Errors can be made regarding product equivalency
- The approach relies currently on a specific software

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Investigation of the differences between static and probabilistic LCA/LCC results of different floor finishes

Johannes Gantner*[1], Dr. William Fawcett[2], and Matthias Fischer[3]

[1] *University of Stuttgart, Germany*; [2] *Cambridge Architectural Research Ltd, United Kingdom*; [3]*Fraunhofer IBP, Germany*
*Corresponding author: Johannes.gantner@lbp.uni-stuttgart.de

1. Introduction

Due to technological innovations but also its implications our world is changing more and more rapid. Assessing the environmental impacts of products in context of very long lifetimes, the uncertainty of future events and decisions is highly influencing the overall environmental results.

2. Statement of the problem

Decision makers have to undertake decisions not just based on limited information but also on uncertain or altering information. In addition the questions the complexity of the different options increases in terms of influencing parameters and interconnections. Therefore most of the decisions are based on experience or simply gut feeling and not on fact based model. Thus methodologies and tools are needed to support decision makers.

3. Methodological Approach

In order to allow for a better decision making a combined life cycle costing (LCC) and life cycle assessment (LCA) approach is described that takes into account future changes and events. Therefore a probabilistic model is set up and cost and environmental data is used as an input. Primary focus is thereby on the uncertainty with regards to future changes and decisions of environmental impacts. In order to develop the environmental input needed for the probabilistic model (time-) dynamic LCIA datasets are set up. For ease of interpretation several environmental impacts are combined to a single point indicator. This environmental single point indicator is used in combination with the economic LCC value to set up an Eco-portfolio [1] diagram that can be used to allow managers and designers performing fast decisions.

4. Case Study

Based on this methodological approach, different design alternatives and material choices of floor coverings are compared with regards to uncertainties of timescale of the refurbishment and production and end-of-life technology. As a basis for the dynamic LCIA datasets the LCA models of the "Ökopot" [2] project were used. The economic vales for production and end-of-life are based on [3]. Detailed focus of study is on the effect of different estimated service lifes of floor materials (e.g. 5, 10 or 15 years for carpets) on the environmental results over the whole life cycle (production, refurbishment, EoL) based on dynamic energetic datasets (e.g. yearly electricity profile (see figure 1)). In addition a LCC analysis of the different floor finishes is conducted to provide also an economic decision basis for later eco-design. Figure 2 shows the final results of comparison of different floor coverings over a timescale of 50 years as an Eco-Portfolio diagram. Within the Eco-Portfolio the uncertainty of the results are shown as well as the probability of occurrence of this values (brighter ellipses). If the results are in the bottom left part of the diagram the option is economic and environmentally beneficial. In contrast, if the option is in the upper right corner the option is environmentally and economical not beneficial. If the option is in the upper left or in the lower right corner the choice depends on whether there is a focus on economic or environmental aspects.

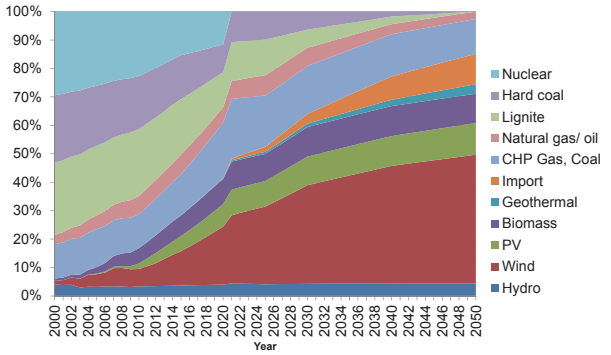


Figure 1. Yearly share of energy sources for the German electricity mix (based on [4])

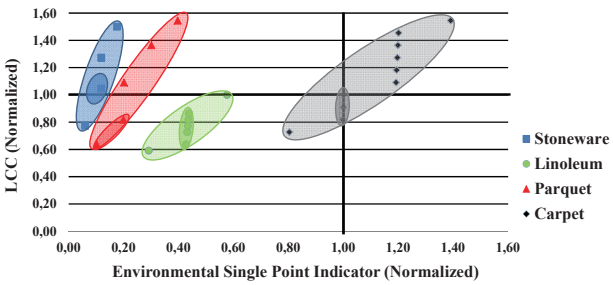


Figure 2. Eco-Portfolio of different floor coverings

5. Conclusion

All in all this methodology could support architects, product designers or engineers to assess not only current environmental impacts of a product or service, but also estimate the magnitude and likelihood of future impacts. Therefore it´s possible to avoid misjudgments by only focusing on today´s circumstances and make better decisions. This could result in more sustainable products for a more sustainable future.

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Supporting uncertainty evaluation in prospective assessment of innovations: A case on ecological method in shrimp farming

Heng Yi Teah*[1], Yasuhiro Fukushima[1], and Motoharu Onuki[2]

[1]*National Cheng Kung University, Taiwan;* [2]*The University of Tokyo, Japan*
*Corresponding author: teah1989@gmail.com

1. Introduction

Innovation of heterotrophic bacteria addition with revised feeding strategy may improve aqua-cultural pond ecology; thereby expected to reduce virus outbreaks, main cause of unstable shrimp production [1]. However, no valid scientific quantification of this effect exists yet. Thus, uncertainties in its economic and environmental effectiveness hold back the improvement and implementation of this innovative practice. This study presents decision tool under the concept of 'indifference curve', to support farmers in tailoring the application strategy to respective ponds. Based on expert judgments (i.e., local farmer) on expected effectiveness, our approach treats the uncertain in prospective changes, and clarifies decision criteria in cost and life cycle environmental impact (GHG emission in this study) in an integrated manner.

2. Methodology

First, a cradle-to-gate, stand-alone LCA is performed to benchmark the contribution of the ecological innovation in terms of cost and GHG emission for shrimp production, based on inventory data farm-scale experiment and literatures [2, 3, 4]. To allow farmers to explore alternatives in bacteria addition and feeding strategies, 1) an indifference curve, which shows the required productivity enhancement to outweigh additional economic and environmental cost on the basis of benchmark practice and 2) a mixing triangle for two-way sensitivity with three potential outcomes are developed.

3. Case study

Local farmer, Mr. Yan had discovered that specific heterotrophic bacteria (*Bacillus spp.*) inhibit virus outbreak. He has successfully implemented his discovery, with a popular shrimp species *Penaeus vannamei* in 0.2-hectare earthen pond with zero-exchange of water for 245 days, with a 28-day -interval bacteria application along with total feed of 1953 kg. These parameters are not yet an optimized recipe. Along the course of this experiment, viruses (IHHNV, TSV, WSSV, and YHV) detection test was performed by an ISO-certified laboratory, Bio-TigerMein [5]. The effect of changes in bacteria addition frequency on shrimp yield is uncertain due to ecological variability and experiments are costly; the farmer's implicit knowledge may better predict productivity. On the other hand, it is more difficult for the farmer to link the prediction with economic and environmental outcomes. Heterotrophic microbes and phytoplankton can convert shrimp metabolic waste into biomass, which serve as alternate shrimp feed, but its substitutability is also uncertain.

We first applied LCA reversely showing farmer the indifference (or tipping-point) curves of productivity to breakeven the cost and GHG at any given input interval relative to benchmark. The curves are shown for bacteria addition support. Next, feeding strategies (same, reduce - direct feed reduction, and replace – use of low-protein-feed but at the same amount) are evaluated with scenarios of increase, stagnant, or decrease in shrimp yield with undesignated probabilities of occurrence, which are to be judged by farmer in decision tree (Figure 1). Preference feed strategy is recommended with the information.

4. Results and Discussion

Fresh shrimp at farm gate cost 161 TWD kg^{-1} and is associated with 3.97 kg-CO_2eq. kg^{-1} in benchmark application.

The indifference curve (Figure 2) shows for example, increase in bacteria frequency to a 22 day-interval expecting a 1% increase in production is worthy in terms of GHG emission reduction but does not pay off in terms of cost. The decision tree analysis for feed altering strategies is illustrated in mixing triangle (Figure 3), presenting the cost effective and low GHG domain at given condition.

Any decision must be made under some degree of uncertainty. Our approach delegates the role of uncertainty judgment to the experts, while taking responsibilities on removing the complexity due to expansion of scope across the product lifecycles. This approach is particularly useful in agri-/aqua- cultural studies, because acquiring sufficient volume of data for highly variable environments consumes years of time. Farmers' experiences and implicit knowledge are assumed to be the best available alternative to scientifically valid data in most of the cases.

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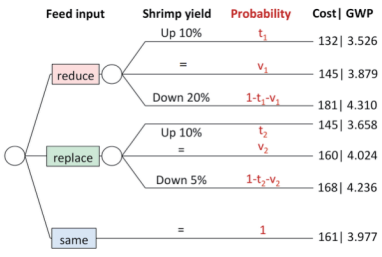


Figure 1. Decision tree analysis for feed altering strategies.

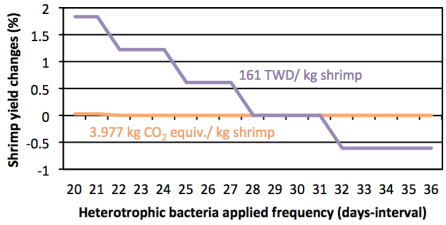


Figure 2. Indifference curve for bacteria addition support.

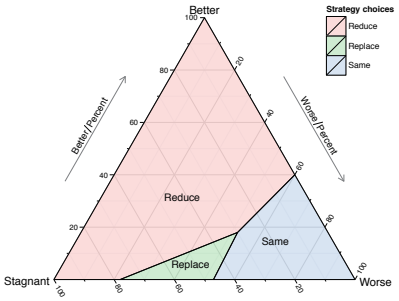


Figure 3. Mixing triangle for cost benefit feed altering strategies support (low GHG strategy is not show due to space constraint).

Development of supply-chain matrix database with IDEA aiming for the application to consequential LCA

Kiyotaka Tahara*[1], Masaharu Motoshita[1,2], Kotaro Kawajiri[1], Hiroki Hatayama[1], Chunyoul Baek[1] and Tomohiko Ihara[3]

[1]*National Institute of Advanced Industrial Science and Technology, Japan*; [2]*Techische Universitaet Berlin, Germany*; [3]*The University of Tokyo, Japan*
*Corresponding author: k.tahara@aist.go.jp

1. Introduction

It is crucial to predict the consequences of introducing new technologies and policies. However, in many cases, the assessment has been performed based on the attributional approach without considering the induced changes in the demand and supply of materials, products and services by the introduction of new technologies and policies. It is needed to establish the assessment model that can analyze comprehensive consequences including the induced results in the whole industry. Therefore, we are developing a supply-chain matrix database to establish a method for assessing consequential results in industrial activities caused by introducing new technologies/policies.

2. Concept of IDEA

All economic activities in Japan are compiled in statistics according to Japan Standard Industrial Classification (JSIC). Following the classification, there are various statistics produced for manufacturing and non-manufacturing industries. Therefore, IDEA codes were prepared based upon classification by industry and commodity. Consequently, IDEA has a hierarchical structure as shown in figure 1, where unit processes, classified by a 6 digit code, were prepared mainly using statistics (about 2000 processes), and the more important inventory data are collected by using process data (about 1800 processes). By classifying and managing all products with IDEA codes, it is expected to provide an exhaustive database covering a large number of products for use as background data.

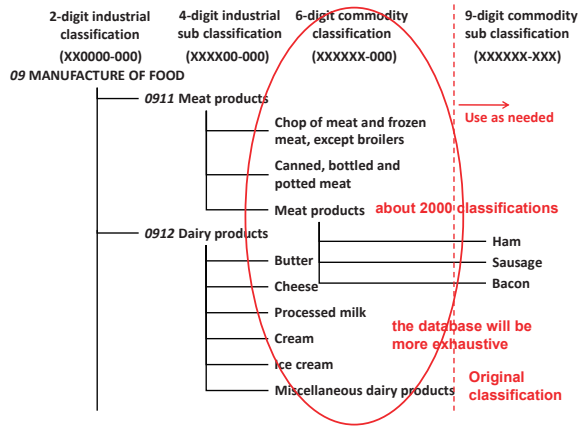


Figure 1 Outline of IDEA classification

3. The IDEA Matrix

For supply chain matrix database development, it is necessary that data flows of products have a representative and completeness of the manufacturing process. So, we used IDEA to create a matrix. The unit process data created the matrix A (IDEA input coefficient matrix), that is 2000 × 2000 matrix. And then, as shown in figure 2, the matrix M (IDEA matrix) was obtained by multiplying the matrix P (annual Japanese production) and the matrix A. The IDEA matrix also considered the amount of products annually imported (matrix G) and annually exported (matrix E), and final domestic consumption (matrix C). The balance of the amount of supply (P + G) and demand (AP + E + C) within the IDEA matrix was confirmed and inconsistencies between supply and demand in were identified due to differences in classification of IDEA and statistics, differences of the reference year, differences of system boundary and differences in the unit of products. We adjusted the supply and demand balances as much as possible. If balances were not achieved, we added correction terms using matrix X.

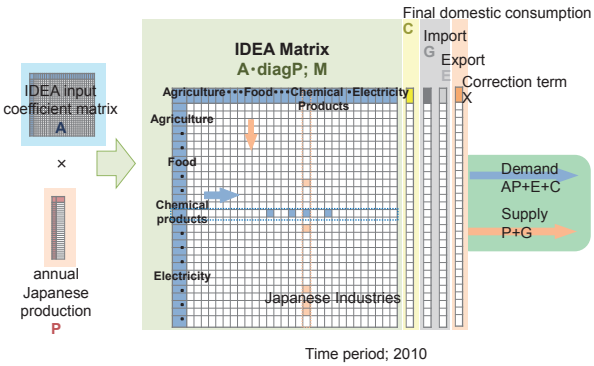


Figure 2 Outline of IDEA matrix

4. Issues to resolve

1) Issues of unit process data
- Unit processes should include intermediate parts, however some unit processes only include input materials, such as steel. In addition, some chemical products have intermediate products which are not reflected in statistics.
- For some unit processes only one method of production was chosen even though there are several methods.

2) Issues of data maintenance
- There are differences in measurement methods between domestic products and import and export products. For example, domestic buckwheat's weight is the weight of grains, but imported buckwheat's weight includes the weight of the husk and grains. It is necessary to unify and confirm the measurement methods and definition of products.
- It is difficult to match the classification of trade statistics with IDEA classifications as there are some classifications within IDEA which cover more or less products than trade statistics. The classification of some products is in a nested structure.

5. Case study

In order to confirm the validity of the IDEA matrix, we have conducted a case study on the introduction of next-generation vehicles.

Resolution of Nuclear Power Plant Construction Conflicts— Argument of Tsunami Issues Through Concept Mapping and Lifecycle Thinking.

Ting-Fang Hsieh and Yuh-Ming Lee *

National Taipei University, Taiwan
*Corresponding author: yml@mail.ntpu.edu.tw

1. Introduction

The human and economic disaster caused by tsunamis in densely populated and industrial coastal regions has been documented as horrific tsunami events. Even though the frequency of tsunami disasters is low, its threat should not be underestimated. There are three approaches to the argument of this study. The first is to estimate the features of the tsunami barrier, one of the parts of nuclear power plant constructions, built as an outside wall to block the tsunami. Besides, try to discuss the effects on the barrier through lifecycle thinking assessments. Furthermore, we create the concept mapping to display the relationship among the nuclear power plant construction, the coastal area, and the land use of human beings. Coastal zone, also an environmentally-sensitive area, is considered to reserve plentiful biodiversity.

2. The Influence of the Constructions

The barrier that alters the longshore current which will change the coastal terrain is called "Jetty Effect". The influences are involved in the coastal environmental conflicts, the biodiversity reduction, and the impact of human use resulting in the loss of homeland.

Traditionally, coastal protection facilities are mainly used to prevent disasters. However, under the premise of today's emphasis on sustainable development, the tsunami barrier setting would be regarded as the detriment on coastal ecological environment.The impact on the ecology of coastal constructions:

1)The habitat disappears, leading to reduction in the number of biological populations and even species disappearance.
2)The degradation or disturbance of the habitat.
3)The tremendous changes of biodiversity.
4)The coastal constructions block the ecological corridor, resulting in the disappearance of species.
5)Jetty effect: the barrier which obstructs longshore transport results in coastal erosion and the loss of land. [1]

3. The Twin-Wing Tsunami Barrier

The increasing incidence and frequency of tsunami events, particularly around the Asia Pacific rim, created an urgent need to respond to the challenge of developing a barrier capable of disrupting and neutralizing the overwhelming power of tsunami waves. The Twin-Wing Tsunami Barrier has been developed in order to disrupt and neutralize the tsunami flood wave. The latest break-through invention, the Twin-Wing Tsunami Barrier is the ultimate solution which has been designed to protect designated tsunami prone areas. Lying passively on the sea bed, it is instantly activated by the approaching water surge of the tsunami wave and is automatically deployed to offer large scale coastal protection.

Operating independently from coastal warning systems, it can be positioned across a bay shape or along a coastal stretch and in its passive resting position it interrupts neither shipping nor marine life. Alternatively, the barriers could be built from gabions and lowered into the sea. The space between these tsunami barriers and the coast can be filled with solid material, thus allowing reclamation of new land, or this gap can be used for fish farming. These barriers can contribute to preservation of beaches and natural ecosystems at the coast. [2]

4. The Concept Mapping and Lifecycle Thinking

Minimizing the environmental destruction and damage is necessary. It's a very important concept about nature environmental protection to make impact-reduced measures and alternatives in coastal constructions, including seawalls, tsunami barrier, jetty and so on. This system is the assessment for evaluating the negative impact from human activities. The approach processing is: avoidance, minimization, rectifying, reduction and compensation. [3]

Avoidance is in the development of behavioral, biological or avoiding protected species habitat protection measures. Minimization is as far as possible to minimize the impact of development. Repair means the restoration of the environment will be affected. Rectifying is maintained by measures to protect or to reduce the impact of development activities on the environment. Compensation is when you cannot avoid damage to the environment, you can provide an alternative environment as a compensation for environmental damage methods.

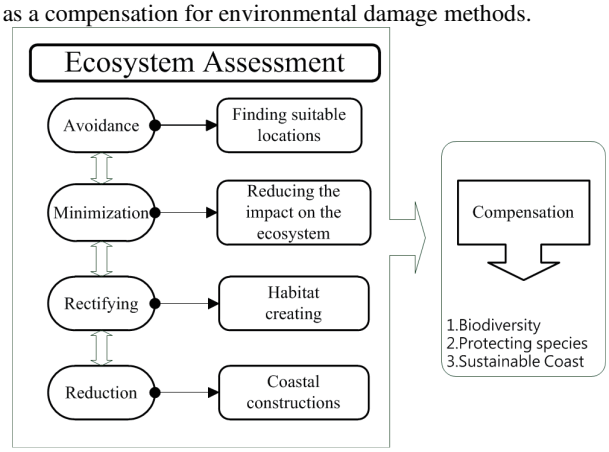


Figure 1.The ecosystem assessment of coastal constructions

5. Conclusion

Strengthening the nuclear power plant structures to achieve the protective function is imperative; meanwhile, retaining the plentiful ecological function also cannot be ignored. Based on the concept of symbiosis with nature, we are building upon the coast, not only consider economic issues of land use, but also considering the issue of ecological environmental protection. Thus, how to minimize the impact on the ecosystem of the natural environment as possible as we can is a significant topic for implementing the sustainable management.

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LCA system boundary selection using the industrial clustering analysis

Shunsuke Okamoto*[1]

[1]*Kyushu University*

*Corresponding author: solitario_halcon_azul@yahoo.co.jp

1. Introduction

In Japan, a large number of organizations have regularly published life-cycle assessment (LCA) reports as specified in the ISO 14000 series. An important issue is how an organization estimates its life-cycle CO_2 emissions. An LCA is divided into two analyses: a process analysis and an input–output analysis. The process analysis has an advantage in accuracy in the production processes, while the input–output analysis has an advantage in its completeness with regards to the production network system (i.e., it uses a complete system boundary). The process LCA method is subjective, in the sense that the LCA system boundary is freely decided by analysts, which consequently leads to truncation error and underestimation of life-cycle emissions. In the present paper, we propose an analytical method for identifying environmentally important production processes and production networks that uses both nonnegative matrix factorization and input–output analysis. Applying this method to a 2005 Japanese input–output table, we detected important production systems for industries with relatively high life-cycle CO_2 emissions and determined which production systems should have a higher priority for being included in the LCA framework. Finally, we describe the implications for how industries should manage life-cycle CO_2 emissions.

2. Methodology

Following the unit structure model (Kagawa *et al*, 2013), the intermediate inputs induced by the final demand of *j** th industrial sector, or $\mathbf{B}^{j}$, is written as eq. (1):

$$\mathbf{B}^{j^*} = \mathrm{diag}\left(\mathbf{f}^{j^*}\right) + \mathbf{A}\,\mathrm{diag}\left(\mathbf{f}^{j^*}\right) + \mathbf{A}\,\mathrm{diag}\left(\mathbf{A}\mathbf{f}^{j^*}\right) \qquad (1)$$

Here $\mathbf{A}=(a_{ij})(i, j=1, 2, 3, \ldots, n)$ is input coefficient matrix, reflecting the input of a commodity from industry i to industry j, is the vector which represents the final demand of industry j^* at the j^*th column and 0 at the any other columns of this vector, and diag () is the diagonalizaton. The CO_2 emissions induced by the final demand of industry j^* can be estimated as below:

$$\mathbf{G}^{j^*} = \mathrm{diag}(\boldsymbol{\alpha})\mathbf{B}^{j^*} \qquad (2)$$

Here $\boldsymbol{\alpha}=(\alpha_i)(i=1,2,\cdots,n)$ is the vector representing CO_2 intensities obtained by dividing the amount of sectoral CO_2 emissions by sectoral outputs. The matrix $\mathbf{G}^{j^*}$ represents the CO_2 emissions induced by the inter-industry transaction from industry i to industry j, which is associated with the final demand of specific industry j^*.

To apply nonnegative matrix factorization, we transform eq. (2) to eq. (3) as below:

$$\tilde{\mathbf{G}}^{j^*} = \begin{cases} \frac{1}{2}\left(g_{ij}^{j^*} + g_{ji}^{j^*}\right) & (i \neq j) \\ 0 & (i = j) \end{cases} \qquad (3)$$

Here $g_{ij}^{j^*}$ is the (i, j)th element of the matrix $\mathbf{G}^{j^*}$. A large number of existing environmental input-output studies employ a directed matrix in which each matrix element represents inter-industry transaction from industry i to industry j, while this study employs an undirected matrix in which each matrix element represents the strength of CO_2 emissions induced by the inter-industry transaction between industry i and industry j. In this study, we will detect the CO_2 clusters from the supply chain networks described by eq. (3). Following the method of nonnegative matrix factorization introduced in Ding *et al*. (2005), we can find CO_2 clusters by solving the eq. (4):

$$\underset{\mathbf{H}\geq 0}{\text{Minimize}} \quad J = \left\| \mathbf{D}^{-\frac{1}{2}} \tilde{\mathbf{G}}^{j^*} \mathbf{D}^{-\frac{1}{2}} - \mathbf{H}\mathbf{H}' \right\|_F^2 \qquad (4)$$

Here, $\mathbf{D}=(d_i)$ is the degree matrix which represents the CO_2 emissions induced by inter-industry connections of industry i and $d_i = \sum_j g_{ij}^{j^*}$. $\mathbf{H}=(h_{iK})$ is the indicator matrix which is obtained endogenously. The superscript prime represents transposition of a matrix, K represents the number of clusters, and $\| \|_F^2$ represents the Frobenius norm.

3. Results and conclusions

Results and conclusions will be shown at the conference.

4. Refernces

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Assessing Climate Impact of Industrial Symbioses: A Dynamic Approach

François Dumoulin,*[12] Tom Wassenaar,[1] Jean-Marie Paillat,[1]

[1]*CIRAD, UPR Recyclage et risque, F-97743 Saint-Denis, La Réunion, France*;
[2]*ADEME (French Environment and Energy Management Agency), Angers 49004, France*
*Corresponding author: francois.dumoulin@gmx.com

1. Introduction

In economies where natural resources are rarefying, Industrial Symbioses (IS) are becoming promising solutions to manage natural resources. IS however do not have as corollary the absence of environmental impacts, that thus remain to be assessed [1]. Global warming impact (GWI) is an environmental phenomenon the reduction of which is at present of major importance. The most widely used method to link GWI to GHG emissions of industrial systems (as used in product life-cycles) is the Global warming potential (GWP) and its indicator CO_2 equivalent (CO_2-eq), also commonly used to express the GWI of IS [2;3] However, although its use is relevant for assessing GWI of products or comparing efficiencies between several emission years, it does not express the GWI at different time horizons. Both dynamics GHG emissions and their GWI assessment, that are essential to aptly assessing structural changes engendered by IS projects, are not considered while using the GWP, which biases the analysis.

Here, we briefly recall the semantic and mathematical reason of the limits of assessing an activity's impact through GWP and propose a derived model and tool that we subsequently illustrate.

Global warming potential

GWP is defined [4] as the quotient of time-integrated global mean radiative-forcing (RF) of a pulse emission of 1kg of a gas (g), relative to that of CO_2, as follows:

$$GWP_g = \frac{AGWP_g}{AGWP_{CO_2}} = \frac{\int_0^t RF_g(t)\,dt}{\int_0^t RF_{CO_2}(t)\,dt} \qquad (1)$$

where time-integrated RF is equally called absolute global warming potential (AGWP) and t temporal horizon that in reference to Kyoto protocol in currently set to 100 years [4]. Since CO_2 is a persistent GHG, as such the GWP minimizes the impact of short-lived GHG.

In addition, a fixed time horizon, e.g. from 0 to 100 years, limits the use of invariant potentials and thus does not allow to assess GWI over time, either residual RF or cumulative RF (i.e. AGWP).

Assessing AGWP over time

The GWP is inconsistent with the GWI assessment of structural system changes. Acknowledging the relevance of RF concept and its cumulative effect, as suggested by IPCC, we propose to assess their GWI by using AGWP. This, however, implies to consider the emission year as variable (**temporal inventory**), as well as RF. Indeed, RF is defined as follows:

$$RF_g(t) = a_g . C_g(t) \qquad (2)$$

where a_g is the radiative efficiency of a given GHG and C_g its time dependent abundance function, which has an exponential form.

The ultimate formula stating the AGWP of multi-annual system σ then becomes:

$$AGWP^{\sigma}(t) = \sum_{y=0}^{l} \sum_{g} E^{\sigma}_{gy} \cdot \int_0^{t-y} RF_g(t)\,dt \qquad (3)$$

where y is the (variable) emission year, l the last emission year, E_{gy} temporal inventory of gas emissions (in kg).

Projections comparison and discussion

Once a temporal inventory is established, its AGWP has to be assessed by using equation (3); we built a R-script for this purpose that enables to compare it to the current GWP method.

Figure 1 presents the results for two dummy processes simulated over 30 years (2015-2045). Process 1 is a transport-type process (mainly CO_2 and CO emissions) and Process 2 is composting-type process (mainly CH_4, CO_2, N_2O emissions).

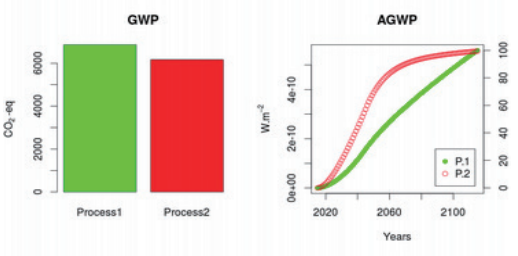


Figure 1. GWP vs. AGWP from a temporal inventory

On the left, current GWP aggregates all the emission impact over time and concludes that process 1 is more harmful, while the dynamic AGWP (right) mitigates such a conclusion: P1 barely exceeds P2 after 100 years.

This clearly calls 1) to reconsider the current use of GWP and 2) to explicitly address the temporal horizon with stakeholders when eco-designing structural system changes such as IS.

Acknowledgments

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Towards a Low-carbon Future in China's Rural Residential Sector

Rui Xing,* Tatsuya Hanaoka, Yuko Kanamori, Hancheng Dai, Toshihiko Masui

National Institute for Environmental Studies, Japan
*Corresponding author: xing.rui@nies.go.jp

1. Introduction

Until recently rural areas accounted for a majority of population in China. In 2011 urban population surpassed rural population for the first time due to urbanization process, still there are over 650 million people and over 210 million households [1] live in rural areas. Instead of commercial energy, most of the rural households rely on straw and firewood for their daily energy use. It is necessary to increase rural access to less polluting commercial energy and alleviate environmental problems caused by the highly unsustainable energy structure.

2. Estimation of service demands

In this research, the service demands of rural residential sector are estimated by a macro-model [2] through 2030. The macro-model simulates the demands for final energy services on the parameter inputs of futures trends in a variety of factors. The urbanization process is also taken into account by estimating future rural population and floor area. The model estimates the changes in service demands by different applications every 5 years.

The preliminary estimation from the model appears to be much higher than statistical data [1] in base year (2010). One possible reason is that in the model energy usage patterns such like frequency of shower times and operation hours of household electronics are set on standard level of developed countries. While in rural China these usage terms may not be fully applied due to the limited financial resource. Thus we introduce corrective coefficients – satisfaction factors to calibrate the model estimation. The calibrated service demand is calculated by using Equation (1).

$$SD_i = U_i \times A_i \times SF_i \quad (1)$$

Here, SD_i is service demand of each province. U_i represents service demand of each application per household or per floor area, A_i represents amount of household or floor area, SF_i represents satisfaction factors.

Satisfaction factors are coefficients which evaluate adequacies of service demands and are closely related to per capita income. Satisfaction factor of each application is resulted by optimization analysis in order to keep model estimation consistent with historical data in the base year.

For hot water application, SF is calculated by Equation (2).

$$SF_i = \frac{18653 \times PCIC_i}{17034 \times (PCIC_i + 1619)} \quad (2)$$

where $PCIC_i$ is rural per capita income (2011 US$) of each province.

For other applications SF is calculated by Equation (3).

$$SF_i = \frac{25775 \times PCIC_i}{17034 \times (PCIC_i + 8741)} \quad (3)$$

Figure 1 shows satisfaction factors of hot water use and per capita incomes of 31 provinces.

3. Low-carbon technologies

To select effective low-carbon technologies for rural residential sector, we use the AIM/Enduse model [3], a bottom-up optimization model with a detailed mitigation technology database, to estimate mitigation potential of low-carbon policies. In the base year (2010) the estimated service demands are disaggregated to energy usage of existing technologies, while in the target year (2030) service demands are satisfied with energy efficient technologies. The model selects technology combination for each province under the least total-system cost.

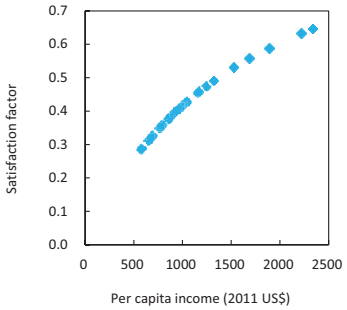


Figure 1. Satisfaction factors of hot water use

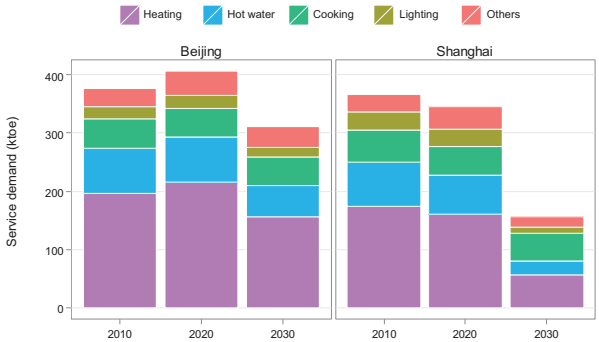


Figure 2. Estimation of rural residential service demands

4. Results and discussions

Figure 2 indicates breaks downs of service demands from 2 regions as an example. In most of the provinces rural residential service demands will decrease in the future due to urbanization process. Still implementation of low-carbon technologies will improve rural energy structure and bring CO_2 emission reductions as well as financial benefits.

Acknowledgments

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Exploring Intersection of Product Lifecycles: GHG Emissions Associated With Vehicles And Pavement Influenced By Pavement Maintenance Strategies

Yasuhiro Fukushima,*[1] Fitria,[2] and Shi-Hsien Yang[2]

[1]*Tohoku University, Japan*; [2]*National Cheng Kung University, Taiwan*
*Corresponding author: fuku@sis.che.tohoku.ac.jp

1. Introduction

In a lifetime of pavement, the use and maintenance phases occupy the longest period. Maintenance is constantly performed every several years, and the approaches (roughness thresholds, intervals, used materials, methods, etc.) are diverse in different countries. Different maintenance strategies determine emissions occurring during material production, construction, end-of-life and/or recycling. The works involved are material and energy intensive, thus have high potential to burden environment. Moreover, the way maintenance is applied determines the road conditions that influence the fuel consumption of vehicles.

New materials and methods for maintenance are being developed, however, there are no platform to evaluate their contribution in reduction of environmental impacts. This means that there is a gap between the technology development and its swift implementation to start changing the environmental performance of pavements.

Climate change influences pavement conditions. Advancement in climate sciences allows predictions for specific regions of interest; however, currently there is no linkage with planning of pavement maintenance.

Here, we present results of our ongoing efforts to develop a platform that incorporate various maintenance technologies and pavement materials to work out maintenance schedules and methods based on life cycle thinking. Both the lifecycles of 1) road materials used, transportation, maintenance, and 2) the difference in emission from vehicles due to difference in roughness of the pavement are considered in the evaluation. This platform utilizes the roughness data measured every year, to update the pavement deterioration model that will be used for the scheduling.

2. Methods used on the platform

To evaluate the changes in GHG emission of maintenance activities and vehicle fuel consumption due to either switching current maintenance practice to alternative technology or performing the road treatment based on specified threshold rather than a fixed timing interval, life cycle inventory and roughness prediction models were prepared. The roughness prediction model predicts International Roughness Index (IRI, m km^{-1}) over pavement age; it is one of the parameters used to further generate maintenance strategies. This model incorporates climate conditions; therefore, it may be possible to incorporate climate change scenarios in the analyses, although this is still ongoing. Vehicle fuel consumption was calculated based on the assumed number of vehicle to use the road every year and the associated fuel consumed by each vehicle. Most of the inventory data are taken from literatures [1-3]. Both road roughness and speed of vehicles were considered in calculation of vehicle emissions using data from literature [4].

3. Case study

In Taiwan, currently, maintenance is performed with overlay method every 5 years in average. The cumulative GHG emission reductions related to both maintenance activity and vehicle fuel consumption compared to the current practice (i.e., overlay maintenance every 5 year, vehicle avg. speed 88 km hr^{-1}, traffic intensity of 5000 vehicles day^{-1}) for a specific road is shown in Figure 2. The compared scenarios here are OL4, OL4.5, and MS. In OL4 and OL4.5, overlay is applied when pavement roughness exceeds IRI = 4 and 4.5, respectively. In MS scenario, micro-surfacing is applied when IRI reaches 3.6.

From the results, despite lower emission associated with revised maintenance activity or frequency, increase in emissions from vehicle makes the current practice lower in GHG emission after 25 years.

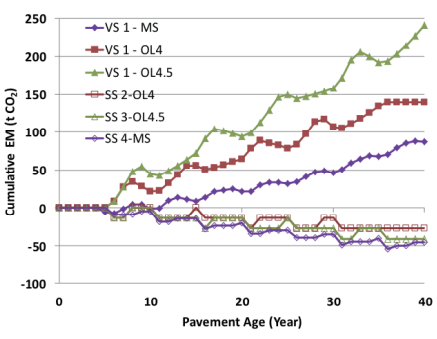
On this platform, it is also possible to generate scenarios according to some criteria. In this presentation, we also present the generated maintenance scenario by minimizing total emission over 50 years, open to use of both the overlay and the micro-sufacing technologies.

4. Conclusion

Now, by using the platform together with the road roughness data over years, it is possible to introduce life cycle thinking in the planning of road maintenance. Methods to incorporate consideration of climate change and new materials that have no actual deterioration data must be worked out together with the standardized experimental tests on pavement deterioration.

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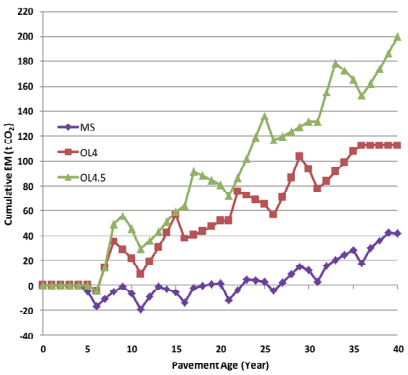


Figure 1 (left). Cumulative GHG emissions associated with maintenance activity (filled) and vehicle fuel consumption (hollow) for various maintenance strategies.

Figure 2 (right). Cumulative GHG emissions in total.

A Cradle-to-Cradle Assessment Framework for Green Building Evaluation – Emphases on Energy Management and Resource Recovery

Chia-Lin Hsu and Yuh-Ming Lee*

National Taipei University, Taiwan
*Corresponding author: yml@mail.ntpu.edu.tw

1. Introduction

The global resources are gradually depleted due to the excessive exploitation of natural resources and over development. In order to reduce the energy consumption and rapid resources exhaustion, the government tempts to promote plans that reduce carbon footprint. The construction industry is amount the highest carbon dioxide emission industries. It is imperative to endorse the control of carbon emission in building/construction industry to reduce the impact to environment.

In this study, People now could leverage of Cradle to Cradle to further research on the renewable energy and renewable green building life cycle model.

2. Methodology

Ever since the industrial revolution, people have been prioritizing economic development. As a result products are designed and manufactured in a linear “Cradle to Grave” paradigm. This “Cradle to Grave” paradigm means that once a natural resource is excavated, it follows the one way route of processing, manufacturing, usage and disposal (where it contaminates the environment). To compensate for the resulting resource depletion the slogan of the 3R (Reduce, Reuse, Recycle) has been propagated. However, without making fundamental changes to product design, the environment continues to be contaminated, just at a slower rate. For example, current energy saving strategies simply prolong the lives of products or optimize them for downcycling (they cannot be recycled at the same quality as virgin material). Although this reduces the resources and energy consumption rate, the products still end up in the “grave” in the end.

“Cradle to Cradle" is a concept which put all of the materials into an endless recycle and encourages to use the renewable energy. The materials for product manufacturing are no longer purchased, instead, they are borrowed. The life of a product does not end as a polluted waste, but start from a new lifecycle.

Braungart and McDonough have defined three basic principles that are essential to make a true transition towards sustainable society. The following three basic principles are being applied:

(1) Waste equals Food; everything is a Nutrient for Something Else.
(2) Use Current Solar Income, Energy that can be renewed as it is Used.
(3) Celebrate Diversity.[1]

3. Green Building Evaluation

The green building of Taiwan is developed based on Taiwan’s subtropical climate characteristics with high temperature and high humidity that can sufficiently meet the need in ecology, energy saving, waste reduction, and health. The EEWH green building labeling system was established in September 1999 as the second certification system in the world right after the US LEED. The original system comprised of seven evaluation indicators: greenery (vegetation planting), water infiltration and retention, daily energy conservation, water conservation, CO2 emission reduction, construction waste reduction, and sewage and waste disposal facility improvement. In 2003, two indicators were introduced in the system, including biodiversity and indoor environment quality. The current nine-indicator green building evaluation was thus finalized, known as the EEWH system (listed in Table 1). Furthermore, a scoring and rating system was launched in 2007 for enhancing green building design quality and motivating builders/owners to pursue better performance and innovative techniques. The rating system defines five classes of green building design, including Certified, Bronze, Silver, Gold, and Diamond. Meanwhile, the green building of Taiwan can be redefined as a building with Ecology, Energy Saving, Waste Reduction, as well as Health. [2-3]

Table 1 EEWH Green Building Evaluation System of Taiwan

Category	Contents	
	Indicator	Evaluation Items
Ecology	1.Biodiversity	Ecological network, biological habitat, plant diversity, soil ecosystem
	2.Greenery	CO_2absorption (kg-CO_2/(m^2·40yr))
	3.Water content of the site	Water infiltration and retention, stormwater runoff management
Energy Saving	4.Daily Energy Conservation(prerequisite)	Building envelope design ENVLOAD (20% higher than building regulation), and other techniques (including HVAC system, lighting, management system)
Waste Reduction	5.CO_2Emission Reduction	CO_2emission of building materials（kg-CO_2/m^2）
	6.Construction Waste Reduction	Waste of soil, construction, destruction, utilization of recycled materials
Health	7.Indoor Environment	Acoustics, illumination, and ventilation, interior finishing building materials
	8.Water Conservation (prerequisite)	Water usage (L/person), hygienic instrument with water saving, grey water reuse
	9.Sewage and waste disposal facility improvement	Sewer plumbing, sanitary condition for garbage gathering, compost

4. Results and Discussions

In this study, the green building material is an ecological, healthy, recycled, or high-performance building material that is capable of efficiently minimizing impacts to earth environment and damage to human health during its entire life cycle, and in accordance with the cradle to cradle concept.

5. Summary and Conclusion

The Cradle to Cradle concept has been widely embraced and promoted by the Taiwan government. In order to promote innovation in industries has incorporated the Concept into national policy for sustainable development and resource management, the government understands the challenge that creating a sustainable future presents, In addition, the government has brought Concept products into their sustainable purchasing plan and incorporated the Concept into the construction of Green Building.

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A Life Cycle Assessment of Silica Sand: Comparing the Beneficiation Processes

Anamarija Grbeš

University of Zagreb, Faculty of Mining, Geology and Petroleum Engineering, Croatia
anamarija.grbes@rgn.hr

1. Introduction

Silica sand or quartz sand is a mineral resource with wide varieties of applications; glass industry, construction and foundry are the most common example. Republic of Croatia has confirmed reserves of 40 million tons and long tradition of surface mining and processing. Average production of raw silica sand in Croatia is 150 thousand tons [1]. The presented results and findings are part of the doctoral dissertation [2].

2. Materials and methods

In this research eight alternatives of silica sand production process are designed. For the purpose of design, equipment and machinery database is generated. Designed inputs and outputs in production processes are checked for consistency with current industry data. Life cycle assessment is performed using Sima Pro software and the LCIA is performed using ReCiPe Endpoint method [3].

Alternatives are named as follows: 1-Electrostatic/dry; 2-Basic/wet; 3-Basic/dry; 4-Flotation/wet; 5-Flotation/dry; 6-Gravity/wet; 7-Gravity/dry; 8-Simulation. At the time of research (2009-2012) the glass grade silica sand production in Croatia corresponded to alternatives 2-3 (basic processing by sizing and washing) and 6-7 (gravity concentration). Electrostatic separation was considered at the design level, while flotation was abandoned after plant destruction in aggression 1991-1995.

Analyzed alternatives had in common the mining and basic processing operation. Main assumptions for the first seven alternatives were: surface mining using bulldozers; transportation from mining site to the processing plant (3 km) by dumpers; then washing and sizing in processing plant which included the sieve washing, attrition scrubbing, hydro-cyclone classifying and dewatering. The difference between the alternatives was in the concentration/separation operations following the basic (initial) processing: electrostatic and magnetic separation; flotation; gravity concentration. Important difference in assumptions on water consumption between the flotation and gravity concentration alternative is made. In the flotation it is assumed that the process water is collected and recirculated, while in the gravity concentration water is taken from the river and returned into the river downstream after the sedimentation. The final assumptions were based on whether the product is sold wet and then dried in glass factory or is dried and then transported to glass factory. Alternatives marked "wet" included: road transportation of wet silica sand (w=6%) by lorry (truck) on transporting distance 100 km; drying in glass plant using waste heat. Alternatives marked "dry" included: drying in the processing plant; road transportation of dried silica sand (w=1%) by lorry on transporting distance of 100 km.

Simulation alternative included surface mining and mineral processing outside the Croatia (data for sand production in Switzerland) and silica sand import by railroad transport on distance 700 km using EcoInvent database.

3. Results and discussion

Results have shown that the basic beneficiation process (sand washing and sizing) had the smallest impacts among the analyzed beneficiation processes (alternatives 1-7). However, its application for glass-grade silica sand production is limited only to very pure raw sand, or for construction and foundry grade products. In more complex processing (electrostatic separation, flotation and gravity concentration), assuming that emissions of chemicals into environment are prevented or minimal, deciding factor between the beneficiation alternatives was the water consumption and petrol based hydrocarbons use (fuels and reagents). Cradle-to-gate LCA of glass grade silica sand indicated the fossil fuel use as the major contributor to the impacts. Transportation of naturally dried wet sand (w=6%) and drying in glass factory using the waste heat resulted in smaller impact than drying in processing plant and then transporting it into the glass factory. Results of impact assessment for each alternative are shown in Table 1.

Table 1. Endpoint indicator values per ton of produced silica sand (ReCiPe Endpoint (H) V1.06 / Europe ReCiPe H)

Alternative	Human Health	Ecosystems	Resources
-	DALY	species.yr	$
1-Electrost./d	1,12E-04	4,33E-07	346,3
2-Basic/w	7,34E-05(L)	2,73E-07(L)	187,25(L)
3-Basic/d	8,97E-05	3,53E-07	287,42
4-Flotation/w	9,92E-05	3,58E-07	271,54
5-Flotation/d	1,59E-04 (H)	6,14E-07 (H)	490,54 (H)
6-Gravity/w	9,53E-05	3,63E-07	247,22
7-Gravity/d	1,12E-04	4,47E-07	349,74
8-Simulation	7,14E-05	2,52E-07	162,69

4. Conclusion and recommendations

Here presented results of LCA for Croatian glass-grade silica sand are used to identify the main focus for lowering the impact of silica sand at various production stages in various beneficiation processes, and to give the recommendations for the future process design.

- Surface mining: lowering the diesel consumption by use of mining machinery with better fuel efficiency per ton of produced sand; utilization of mining machinery with continuous work regime (e.g. rotary or bucket excavator instead of bulldozer).
- Sand washing and wet classifying: lowering the water consumption by the use of water collection, regeneration and water recirculation systems;
- Flotation: lowering the consumption of petrol based hydrocarbons as flotation reagents;
- Electrostatic separation and drying: lowering the fossil fuel consumption by using more fuel efficient drier; utilizing as much as possible the gravitational dewatering and natural evaporation; drying using waste heat or other heat sources that cause less damage than fossil fuels.

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A Life cycle thinking Assessment Framework for Land Reclamation Policy in Taiwan

Lih-Ren Liu ,[1] Yuh-Ming Lee* [2]

National Taipei University, Taiwan
*Corresponding author:yml @mail.ntpu.edu.tw

1. Introduction

Taiwan's EPA is committed to promoting the "resource recycling and zero waste" program, including the aspects of reduction, reuse, recycling, energy recovery, and land reclamation(5R's).This research aims to realize an effective cyclic utilization of resources and establish a resource recycling society. [1]

For achieving the goal of "zero waste" and "total recycling", Land Reclamation is a key component of resource recycling and zero waste. The promotion of the resource recycling and zero waste policies should be based on a review of the domestic noncombustible waste management policy.

1. Experience on Policy Implementation.
2. Technical Specifications and the Control of Incoming Materials.
3. Operation Management and Assurance Mechanism.

EPA try to establish regulatory framework to minimize environmental impact during the reclamation to conserve the marine ecosystem and environment.

Life cycle assessment (LCA) involves the evaluation of some aspects. This research adopt systems thinking to discuss LCA conceptual framework of Land Reclamation Policy in Taiwan.

2. Operation Procedure and Standard

ISO14040:2006 describes the principles and framework for LCA,including:definition the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases, and conditions for use of value choices and optional elements. [2]

3. Goal and Scope Difinition

LCA is a tool to assess resources used and potential environmental impacts (inputs and outputs) throughout a product's life from raw material acquisition through production use and disposal (i.e. from cradle to grave). [3]

In this research,noncombustible waste generation, defined as the starting point for LCA scope,after disposal,land reclamation is the end of the LCA.Newborn land development for industrial areas,functional unit for each hectare of land to produce energy consumed.

4. Inventory analysis (LCI)

the phase of LCI will examine the input of noncombustible waste and the output of reclaimed land. Input aspects, including the use of equipment, energy consumed , transportation. Output aspects,including the discharge of pollutants to the marine ecological damage, destruction coastline, affecting water resources, etc.(Figure 1) where all relevant data are identified and quantified. Constructing the process flow chart.Defining the system boundaries.

5. Discussion and Conclusion

After Scope and LCI phase , enter the life cycle impact assessment (LCIA) phase. Environmental problems to be included are defined and the data from the inventory analysis are grouped with relevant categories.

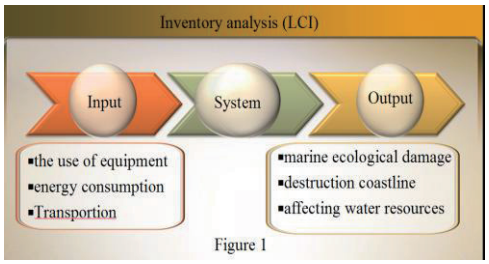


Figure 1

In summary, this search intends to apply the life cycle thinking methodologies and employ the tool of system thinking to construct an impact assessment framework for the implementation of land reclamation policy. Life cycle assessment (LCA) framework involves the evaluation of environmental aspects is adopted. In addition, the causal loops evoked from systems thinking methodologies are to constructed to discuss the LCA conceptual framework of land reclamation policy in Taiwan.

Environmental concerns such as siting issues, preservation of coastline,conservation of marine ecosystem, and arguments of "zero waste" policy are the key "stressors" to be considered in the phase of life cycle impact assessment. The discussions on suitability and sustainability of the land reclamation policy comprise the core of the life cycle interpretation.The research try to discuss about: [4]

1.The necessity of Land reclamation
2.The location choice of Land reclamation
3.EIA Considerations:Ecological compensation principle
4.Feasible construction methods
5.Plant management regulations
6.How land use
7.Regulations
8.Work and Responsibility

Through the above analysis, with the regulations, make policy decision.

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Constructing a System Thinking Model for Climate Policy Making Based on National GHG Inventory

Yu-Tsang Lu and Yuh-Ming Lee*

National Taipei University, Taiwan
*Corresponding author: yml@mail.ntpu.edu.tw

1. Introduction

Generally, a climate policy may cover only a sector or involve many sectors due to causing synergy. A climate policy may focus on mitigation or adaptation, even both of them. Under mid-term global climate regime, developing countries under the United Nations Framework Convention on Climate Change (UNFCCC) would voluntarily conduct their nationally appropriate mitigation actions (NAMAs) by 2020. Meanwhile, to take actions on adaptation to climate change, which may be integrated in national adaptation plan (NAP) in some developing countries, is beneficial to them. Both mitigation and adaptation activities under climate change policy may affect national GHG emissions. [1]

National Greenhouse Gas (GHG) inventory is a well-defined system for anthropogenic GHG emissions. Based on sectors and categories of national GHG inventory, this research explores to build up a system thinking model (STM) for climate change policy under the Driver-Pressure-State-Impact-Response (DPSIR) framework [3-4] and develop its casual diagram.

2. Boundary and Methodology

The structure boundary of STM is set on sectors and categories of national GHG inventory, which include energy sector, industrial process and product use (IPPU) sector, agriculture, forestry and land use (AFOLU) sector, and waste sector [2]. Each sector can divide into categories of layers and is like a tree structure. The same category of bottom layer is a GHG emission source or a removal sink and has the same feature on social behavior, technology, activity, product or consumption so that regression approach can apply to it. In general GHG emission equals to active data multiple emission factor.

DSPIR framework is utilized to describe the features of factors which could influence emission or removal. And then through casual analysis positive and negative feedback loops with mitigation and adaptation activities are identified to combine a casual diagram. System complexity of national GHG inventory can be simplified to a structure of the life cycle thinking model.

3. Casual Diagram and System Thinking Model

For forming a system thinking model, the relative patterns between GHG inventory and DPSIR framework are discussed. Respectively socio-economic aspects and climate policies are key factors that comprising Driver and Response. Environmental considerations, UNFCCC and its corresponding protocols could be the main sources of Pressure. Factors of State would be present state of emissions in national GHG inventory and those of Impact are changes of emissions in national GHG inventory. A STM for climate change policy under DPSIR framework is shown on Figure 1.

NAMA may reduce the need of socio-economic activity, decrease active data, and then GHG emission would decrease. Adaptation activity may increase the need of socio-economic activity compared by that of no adaptation, induce active data increasing, and then emission increases. NAMA also could induce technology improvement, abate emission factor, and

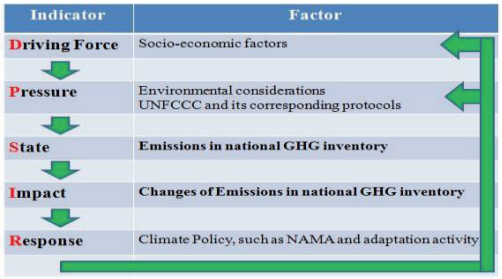


Figure 1. STM for climate change policy under DPSIR framework

then emission decreases. Voluntary mitigation target may depend on the reduction credit from emission trading and new market mechanism. Casual diagram is shown on figure 2.

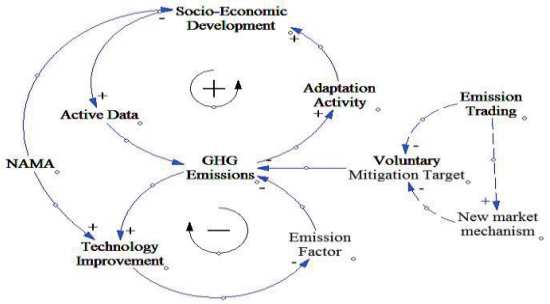


Figure 2. Casual Diagram of STM for climate change policy

4. Discussion

STM for climate change policy under DPSIR framework is clear. Left part on figure 2 has excellent casual loops. Right part on figure 2 still exist uncertain because the UNFCCC is negotiating new market mechanism.

5. Conclusion

This study aims at constructing a system thinking model for climate change policy in order to assist the decision-maker to identify how mitigation and adaptation activities affect national GHG inventory. This system and life cycle thinking model is helpful and successful to describe the systematic features of climate change policy within the boundary of national GHG inventory.

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Evaluating the change of psychological factors and pro-environmental behaviors through workshop about life cycle thinking and social norms

Eri Aoki*, Kiyo Kurisu, and Keisuke Hanaki

The University of Tokyo, Japan
*Corresponding author: eri@ir3s.u-tokyo.ac.jp

1. Introduction

Several factors are reported to influence on pro-environmental behaviors, especially in social psychology [1, 2]. However, how it works on behavior change has not been well investigated. Waste reduction and reuse behaviors (referred as 2RBs) have especially been given less attention than other pro-environmental behaviors. 2RBs have big potential to minimize wastes through minimizing excessive production. Previous research [3] showed that "Effectiveness and Attitude" have most influence on the behavior of "denial of plastic bags or wrapping (B1: Plastic bags)", and "Social and Personal Norms" have most influence on the behaviors of "denial of disposable chopsticks or plastic cutlery (B2: Chopsticks)" and of "Bringing my own cup (B3: Own cup)" as 2RBs.

We designed workshops to stimulate on "Effectiveness and Attitude" through life cycle thinking (LCT) and on "Social and Personal Norms" through visual information. The effectiveness of 2RBs is not only cutting wastes but also cutting every step of its producing, disposing and even recycling. LCT seems to fulfill this concept of effectiveness. Therefore, it was adopted to main stimuli of the workshops. The 'Social Norms' are perceived social rules, moral and other people's behavior and the 'Personal Norms' are strengthened by the 'Social Norms'. Therefore, showing social campaign and other people's behavior were adopted to main stimuli of the other workshops.

2. Methods

We designed three different types of workshops; workshop-E, -N, and -A. Participants were divided into three groups (n = 20, 14, and 15) in each. Workshop-E was focused on effectiveness using LCT method. Workshop-N was focused on norms. Workshop-A was focused on both effectiveness and norms. All workshops consisted of 20-minute lecture, 45-minute active group work. In the lecture, a project researcher made a presentation on effectiveness and norms respectively. In the group work, participants were asked to discuss in small groups and make some tasks; to write down all steps of "use own cup" and "use disposable cup"; to compare these in workshops-E and -A; to make approaches that encourage citizens to do the 2RB as it is the right thing to do imagining if they are local government officer in workshop-N. In the last part of group work, participants were asked to fill a worksheet why the 2RBs are effective for reducing environmental burden in workshop-E and why we should act the 2RBs in workshop-N and -A. As a homework, participants were asked to show the worksheets to others and get comments from them. This action reminds them what they did in the workshop. In addition, telling the opinion makes people's opinion fit in it.

The participants were university students in Tokyo (18-23 years old; 21 men and 28 women). We made a poster and asked to join workshop survey program as part-time job. We did not mention the program was about environmental issues for getting variable participants. The detailed questionnaire, which consisted of specific 20 perceptions and practice about each 2RBs, was supplied online to participants two-week before and after the workshops. Simple printed questionnaire, which consisted of the rough understanding of their change of perceptions and intention of 2RBs, was given to them just after the workshop on July 31, August 2 and 3, 2013.

3. Results and Discussion

The simple questionnaire indicated that the targeted psychological factors were stimulated and changed by each relative workshop. In addition, the intention and the practice of 2RBs were found to be higher than before. The before and after detailed questionnaire indicated that participating the workshop made their targeted psychological factors higher, except "Effectiveness" in workshop-E. In workshop-E, eight first-year students in private university who had the high perception of perceived effectiveness of B1 changed their perception. From their free-answer, they said *"I believed Eco-bag (bringing own bag) is a symbol of Ecology", "I didn't think using energy and oil for a production of plastic eco-bag"*. This means LCT made them to reconsider their surroundings, especially indirect consumptions. In some ways, this achieved objective of LCT, which is to recognize hidden environmental burden. Some of them, however, stopped their thinking at first awareness of hidden burden and not considered nor compered whole lifestyle environmental burden. Three of them changed their behavior lower and other three kept their behavior in medium. In workshop-N, most participants changed their perception of norms and even effectiveness became higher. The number of changing perceptions is largest in workshop-N. Even in norm oriented program, three male students in national university mentioned. *"Concrete data are important for promoting 2RBs"*. In workshop-A, both effectiveness and norms became higher.

Also, the same perceptions, perceived effectiveness, may be confirmed by different perspective depending on their values. Some feel effectiveness because the real burden was decreased; and others feel it because others did or said effectiveness. The later one is similar to social norms. Therefore, Workshop-N had most influence on the perceptions and the behaviors. LCT data reminds participants their indirect impacts of their lifestyle. However, we need to keep in mind that just one time information sometimes make people think they do not need to smaller effective behaviors than their image. Norm activation or repeated follow-up is needed for practical LCT programs which encourage people to have environmental-friendly lifestyle.

Acknowledgments

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People's environmental consciousness in daily activities

Ai Hiramatsu,*[1] Kiyo Kurisu[1]

[1] *The University of Tokyo, Japan*
*Corresponding author: ai@env.t.u-tokyo.ac.jp

1. Introduction

While people's environmental awareness has increased in recent years, the gap is pointed out between attitude and action for environment [1]. It is said that people tend to say "yes" when answering a questionnaire [2], to meet expected social value unconsciously or to continue answering affirmative automatically without deep thinking. As most surveys on environmental consciousness have been conducted with positively-phrased questions, in this research, large-scale questionnaire survey was conducted using negative questions in order to understand more deeply the actual process from consciousness to real action.

2. Materials and methods

The questions were designed in consideration of 'yes-tendency' and that people perform a pro-environment behavior (PEB) without consciousness of environment. Firstly, 25 questions, except for three, on the environmental awareness in daily behaviors were asked in a negative ways (Table1) using the six-point Likert Scale. Next, free-answer questions were asked on: (a) behaviors you usually feel good for the environment, (b) behaviors you wonder whether good or bad for the environment, (c) behaviors which are generally said good for the environment while you do not think so. The survey was conducted as the on-line survey to the 15-69 year-old citizen in Japan during 24-27 January 2014. Approximately 72,000 valid responses were collected in accordance with the ratio of the population census.

Table 1. List of negative questions

1. My PEBs come from a custom rather than envtl. consciousness.
2. My concern about envtl. issues is not particularly high.
3. I don't know how much media information on env. is reliable.
4R. Envtl. issues are important problems to be solved.
5. When acting, I don't care about env. in particular.
6. I cannot understand a person enthusiastic in envtl. activities
7. The word "Eco/Environmentally-friendly" is suspicious.
8. Companies and industries should take more efforts than individual.
9. Individual action will not improve the env..
10. I don't think my behavior is responsible for GW.
11. I have no enough time to act for env.
12. When purchasing, I don't care about env. (e.g. energy, resources and wastes), particularly.
13R. PEBs should be taken even if they are bothersome.
14. I won't perform PEBs without the eyes of others or society.
15. Even if good for env., I want to avoid life becomes inconvenient.
16. I perform PEBs for saving money.
17R. Individual action is important to solve envtl. problems.
18. There's not enough useful information for taking PEBs.
19. Honestly I don't know what behaviors are good/bad for the env..
20. The solution to GW will come from irrelevantly to myself.
21. There's not much influence even if an individual doesn't act for env.
22. There's a more important thing than envtl. problems for me.
23. I perform PEBs depending on whether there are eyes of another people.
24. I got fed up with being called for PEBs.
25. I don't mind even if the earth perish in the future.

(env.: environment, envtl.: environmental, GW: global warming,)

3. Results

Results are shown in Figure1. It showed the following situations apply to 80% of people; "behaviors are taken by habit or for the money rather than environmental consciousness" and "I don't know how much media information is reliable". Then, 60-70% of people said "agree" to the questions of "I have more important things than environmental problems", "honestly I don't know what behaviors are good/bad for the environment", "there is not enough useful information for taking environmental-friendly behaviors", "companies and industries should take more efforts than individual", and "I want to avoid life becomes inconvenient". On the other hand, 70% of people answered "disagree" to the questions of " I don't think my behavior is responsible for global warming", "there is not so much influence even if an individual does not act", and "I will not act without the eyes of others or society", with showing affirmative about an individual's influence and efforts. In total, positive attitude of people to the environment was seen. In comparison of other survey with positive questions, rate of positive attitude for the environment in daily life was about 10-20% lower on average overall.

It is implicated that women have more environmentally-friendly consciousness than men and elder people tend to be more conscious than younger people, which are consistent with other research results.

For free-answers for the questions shown above (a, b, and c), through word frequency and co-occurrence network analyses, it turned out that the common behaviors were highly ranked in all the questions: garbage separation, power saving, recycling and eco-bags, etc. It was observed that people worried about actions which had a trade-off relationship from diversified standpoints.

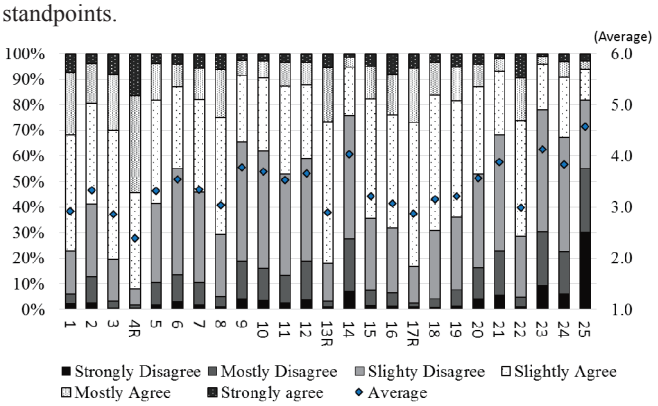


Figure 1. People's consciousness of daily life

Acknowledgments

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Visualizing Core Structure of International Carbon Network Associated with Household Consumption

Yasushi Kondo,*[1]

[1]*Waseda University, Japan*
*Corresponding author: ykondo@waseda.jp

1. Background

The structure of a production network involved in supplying a given product is generally considered as quite complex. The transformation of a network into its simplified structure, or core structure, therefore, offers an effective tool for better understanding how the environmental impact associated with a product propagates throughout the entire economy. Further, the simplified structure may be useful in assessments regarding supply-chain GHG management like the Scope 3 Standard of the GHG Protocol Initiative.

2. Method

In this study, we applied PMDA [1], a method to extract a core structure entangled in a production network that we have elsewhere developed, to WIOD [2], an environmentally extended multi-regional input-output table, for understanding the international carbon network associated with household consumption. PMDA is based on structural path analysis (SPA) [3–5]. The utility provided by SPA is its ability to identify the individual paths and their impacts through the hierarchical sequences of sectors—each path goes from final demand to an impact-generating sector via intermediate products-producing sectors; for example, from household to agriculture via restaurant and food industry. A core structure extracted by PMDA is suitable to be visualized, for example, in a Sankey diagram.

3. Discussion

Widespread use of LCA and carbon footprint has highlighted consumer responsibility, i.e., accounting of environmental burden from consumer perspective. It provides a different point of view from producer responsibility, e.g., in accounting territorial emission for climate change mitigation. However, the reality is somewhere in-between, which is called shared responsibility in literature [6, 7]. A graphical visualization of the core structure allows us to get an insight into international carbon networks associated with household consumption from producer-, consumer- and shared-responsibility perspectives.

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Acknowledgments

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Life Cycle Inventory Database and Its Applications to Support Public Policy

Thumrongrut Mungcharoen*[1,2] and Saowalak Olarnrithinun[1]

[1]*National Science and Technology Development Agency, Thailand*; [2]*Kasetsart University, Thailand*
*Corresponding author: thumrongrut@nstda.or.th, fengtrm@ku.ac.th

1. Introduction

With the technical support from the Japanese government, Thailand has started a life cycle inventory (LCI) database project since 2005. The project was recognised as the national project in 2007 due to the support from several national organisations.

The applications of LCI database to support public policy have been promoted since 2009. In this paper, four case studies implemented by the National Science and Technology Development Agency (NSTDA) with the support of several national organisations will be mentioned.

2. Progress of the Thai LCI database

Up to now, more than 800 Thai LCI datasets, according to ILCD and ISO format, have been collected and maintained at the National Metal and Materials Technology Center (MTEC) under NSTDA. The list of datasets is shown in Table 1.

Table 1. Thai life cycle inventory datasets [1]

Substances (datasets)		Substances (datasets)	
Natural gas	6	Rice	17
Refinery	8	Pulp & paper	9
Petrochemical	19	Para-wood	17
Ferrous	9	Cassava & products	15
Non-ferrous	5	Longan + Agri-food	47
Electricity grid mix	1	Pineapple + Veg.frozen	11
Water	6	Plantation of plants	80
Road transportation	188	Oil palm & biodiesel	24
Ship & rail-transport	43	Coconut milk & Curry	3
Ceramics	7	Paints + Ind. Gases	9
Glass & mirror	7	Fertilizers & herbicides	16
Alt.mat. for wood	3	Chemicals & products	47
Construction mat.	8	Incineration	8
Feed mill	15	Landfill + recycle	20
Livestock & products	33	Wastewater treatment	9
Rubber	7	Others (textile, EE, etc.)	116
TOTAL		846	

3. Case studies of LCI applications to support public policy

Four case studies of LCI applications to support Thai public policy will be explained in this section.

For greenhouse gas (GHG) reduction policy, Thai national carbon footprint (CF) labelling scheme has been established since 2009 under the Thailand Greenhouse Gas Management Organisation (TGO). The GHG emission factors (EF), generated from the Thai LCI database, have been supplied to TGO every six months. The EFs are publicly available on the TGO website to be used for CF calculation of both products and organisations. Up to now, there are 1,207 products (from 282 companies) and 29 organisations certified with the CF labels.

For the promotion of biofuels according to the Thai alternative energy development plan 2012-2021 [2], LCI database and LC assessment (LCA) were used for GHG calculation of Thai Palm Oil Industry during 2011-2012. The results showed that biodiesel from Thai palm oil could reduce GHG by more than 60% comparing to the fossil diesel fuel. The more comprehensive study, including environmental social and economic indicators, is on-going with bioethanol from sugarcane-molasses and cassava using LCI database and LC sustainability assessment.

For the Thai green public procurement (GPP) policy, the LCI database has been used in LCA and LC costing study during 2012-2013 to quantify the benefit of this public policy during the 4-year implementation plan, 2008-2011. The results showed that, from the 930 million THB spending on green products, the government could reduce the GHG by 25,600 tons CO2e and save the external cost by 220 million THB. With this impressive results submitted together with the 2nd phase GPP plan, the national pollution control board was then endorsed the plan.

For the Green Growth and Green Industry policies promoted by the National Economics and Social Development Board and the Ministry of Industry, four pilot research projects (see Figure 1) have already been granted to the researchers, both scientists and economists. LCI database will be used with traditional GDP, economic input-output table and system of environmental-economic accounting (SEEA) [3] to quantify the green GDP on both national and specific sector levels. These research projects are expected to complete by the end of 2014.

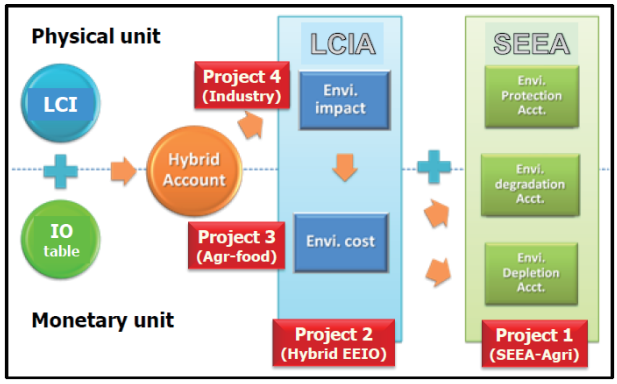


Figure 1. Framework of the green GDP research projects

4. Conclusions

Since 2009, LCI database have been used as one of the key infrastructures of Thailand to support public policy on green growth. The four success cases on carbon footprint, sustainable biofuels, government green procurement, and green GDP have been highlighted. It is expected that more applications of LCI database will be implemented to support policy justification in Thailand.

Acknowledgments

The authors gratefully acknowledge financial support from the Thai government and technical support from the Japanese government, especially professor Atsushi Inaba and his team.

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Thai CF Pro: a Web-based Program for Evaluating Carbon Footprint of Product

Chantana Yuvaniyama,*[1] Wanwisa Thanungkano,[1] Ruthairat Wisansuwannakorn,[1] Athiwatr Jirajariyavech,[1] Thepchai Supnithi,[2] Nattapol Kritsuthikul,[2] and Thumrongrut Mungcharoen,[3]

[1] *National Metal and Materials Technology Center, Thailand*; [2] *National Electronics and Computer Technology Center, Thailand*; [3] *National Science and Technology Development Agency, Thailand*
*Corresponding author: chantany@mtec.or.th

1. Introduction

Global warming resulted from emissions of excessive greenhouse gases (GHGs) is a matter of great concern for humanity nowadays. Various measures to raise public participation for GHG reduction have been promoted globally including the use of carbon footprint labels [1]. In 2009, National Metal and Materials Technology Center (MTEC) in collaboration with Thailand Greenhouse Gas Management Organization (Public Organization) or TGO have carried out the development of Carbon Footprint of Products (CFP) in Thailand [2]. Since then, Thai CFP label has gained popularity among Thai industries. However, to support these clients especially SMEs for CFP analysis, an effective CFP calculation tool is in strong demand. As a result, a new web-based program called **Thai CF Pro** has been developed to ease users for self-calculated CFP.

2. Features

Thai CF Pro is a web-based tool for evaluating the GHG emissions accumulated during the life cycle of a product in a unit of carbon dioxide equivalent ($CO_{2\text{-eq}}$). The program was developed using Drupal version 7.14 — an open-source content management system (CMS) [3]. **Thai CF Pro** has been designed to fulfill various functions as follows:

- It is free of charge, and can be accessible over the internet as shown in Figure 1. However, an account registration is required for each user before using the program.
- It operates with an individual user authentication system for data security.
- It can handle virtually any production processes, even with the highly complicated ones.
- It provides built-in Thai Emission Factor (EF) databases, mainly derived from Thai National Life Cycle Inventory database and announced on the website of TGO every 6-12 months [4]. In addition, users can input their own EF to customize their databases. Thai EF consider emissions of the six main GHGs covered by the Kyoto Protocol [5].
- It also offers automatic unit conversions which can reduce human errors in the CFP calculation process.
- Flow Diagram can be automatically created from the life cycle inventory database added by a user.
- Analysis results can be output as Table, Graph, and Picture (".png" file), and exported as Microsoft Excel ".xls" file for preparation of a CFP report as shown in Figure 2.



Figure 1. The first page of **Thai CF Pro** Website

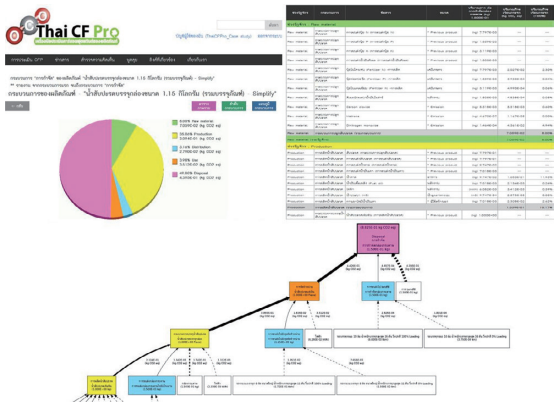


Figure 2. Analysis results by **Thai CF Pro** can be output as Table, Graph, and Flow Diagram

3. Results and Conclusion

Thai CF Pro was one of National Science and Technology Development Agency (NSTDA) Flagships in 2012. It has been well accepted and wildly used since the first launch to public. As of September 2014, there were 3,403 visits from 1,792 unique visitors to the **Thai CF Pro** website. Over 400 of these people were registered users working for governmental, industrial, or academic sectors. Their main uses of the program were for evaluation of CFP and for conducting research and development projects in the related areas.

Moreover, **Thai CF Pro** has been used for teaching of CFP evaluation in the LCA class at the Faculty of Environment and Resource Studies, Mahasarakham University located in the northeastern Thailand. The program benefits not only the students for their better understanding of the subject, but also the Faculty for financial saving on expensive commercial software.

Thai CF Pro is free, and can be accessible at the following URLs: http://www.thaicfpro.in.th or http://www.mtec.or.th. However, it is now available only in Thai language.

Acknowledgments

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Visualization of Comprehensive Environmental Impacts

Yoshinori Kobayashi*, Kiyoshi Sanehira

Toshiba Corporation, Japan
* yoshinori.kobayashi@toshiba.co.jp

1. Introduction

Recently, various framework related to life cycle management have been proposed and discussed globally. For example, environmental footprint in Europe has been discussed, in which environmental impacts throughout life cycle will be compared based on a multi-criteria, meaning, not only greenhouse gas emissions but also other environmental burdens should be quantified and compared. So it is essential to develop practical life cycle impact assessment (LCIA) method and establish a communication system with stakeholders based on LCA results.

In this paper, we will introduce a new concept to visualize the comprehensive environmental impact according to the global new trends mentioned above.

2. Concept

The new concept "T-COMPASS" has been introduced as Toshiba Group's compass for its environmental activities. It defines four domains for the group's environmental contributions and represents these domains as the symbols of the four cardinal compass points. The four points are 1) Reducing natural resource consumption (N; North), 2) Reducing energy consumption and greenhouse gas emissions (E; East), 3) Minimizing water consumption (W; West), and 4) Minimizing the risks involved in chemical substances (S; South).

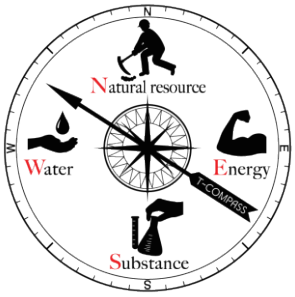


Figure.1 T-COMPASS

One of the features is to provide a visualization of life cycle impact assessment results. The unique radar chart is introduced in order to visualize the carbon, water and environmental footprint comprehensively and complicated LCIA results visualized with the several set of charts can be interpreted for especially non-experts. In addition to typical environmental indicators in the four major domains, other indicators are also defined in detail (up to eight or twelve points on the compass). Since highly relevant environmental indicators are arranged appropriately along different axes, the radar chart depicts the structure of life cycle impact assessments in a simplified way.

In addition, different environmental indicators are used for different regions in order to appropriately assess local environmental impacts, such as air pollution and water degradation. A global COMPASS system should be established to improve environmental impacts by reflecting the regional characteristics around the world.

3. Case Study

Environmental footprint of Toshiba group was evaluated as shown in Figure.1. Environmental impacts in the four domains were quantified to identify hot spots. Environmental burdens of its activities were quantified from life-cycle perspective, combining environmental performance data in group sites with product LCA and environmental accounting. Since energy-saving in use phase has been increasing, energy consumption, greenhouse gas emissions and other emissions have been decreasing. On the other hand, wood consumption from product packaging has increased. 3R of not only products but also their packaging should be improved. Various measures to enhance our environmental management with respect to products and manufacturing will be introduced based on the evaluation.

4. Conclusion

In this paper, the new concept for visualizing environmental impacts has been introduced. This concept is thought to be useful to understand and/or communicate the LCA studies among non-experts for LCA. It makes it possible to advance and expand an environmental management in industries. We have a plan to advance the method and apply to various businesses in Toshiba group.

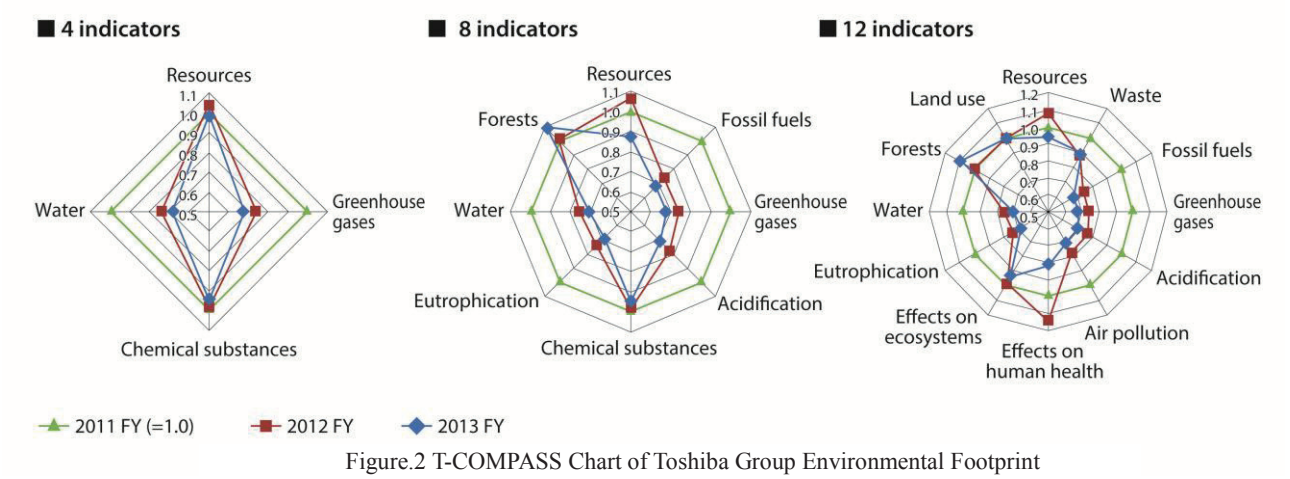


Figure.2 T-COMPASS Chart of Toshiba Group Environmental Footprint

Life cycle assessment of environmental impacts of crop residue management and manure application in Japanese rice cultivation

Ai Leon, Yasuhito Shirato, Shin-ichi Yoshimatsu, Seiya Tsushima, Kazuyuki Yagi, Kazunori Kohyama

National Institute for Agro-Environmental Sciences, Japan
*Corresponding author: kohyama@affrc.go.jp

1. Introduction

Agriculture in Asia covers more than 90% of the world's cultivated wetlands [1]. Increasing rice grain yields while maintaining or improving soil fertility and reducing environmental loads is a key to feed the rapidly increasing population in this area.

Applying crop residue or manure is a management practice that reduces soil erosion and mitigates climate change, by increasing soil carbon (C) which is an essential property for soil fertility. However, this practice will increase the nitrous oxide, nitrogen oxides, and ammonia emissions, and nitrate leaching. Moreover, it will also increase methane (CH_4) emissions in paddy soils [2]. Accordingly, benefits of C input through crop residue and manure will be offset against the global warming, acidification and eutrophication.

Few previous studies included soil C sequestration into their analyses when calculating the environmental impacts of rice cultivation. This study aims to compare the environmental impacts (global warming, acidification, and eutrophication) of differing scenarios in crop residue management and compost application while taking account of soil C sequestration.

2. Materials and Methods

The LCA approach is applied to rice cultivations to evaluate the following four scenarios: rice straw incorporation without application of compost (Scenario 1); rice straw removal without application of compost (Scenario 2); rice straw removal with 10 Mg ha^{-1} of fresh compost application (Scenario 3), and rice straw removal with 20 Mg ha^{-1} of fresh compost application (Scenario 4). The Rothamsted Carbon model (Roth-C) was modified for paddy soils [2]. A web-based Roth-C model is now available in the following web page to simulate soil C sequestration: http://soilco2.dc.affrc.go.jp. The soil C sequestration is estimated, assuming that the system reaches a new equilibrium after a 20 year time period. For the greenhouse gas emission calculation, global warming potentials were fixed for a 100 year time horizon: CO_2 : CH_4: N_2O = 1 : 34 : 298 [3]. For the acidification calculation, SO_2-equivalent factors were used for NO_2=0.506 and NH_3=1.598 [4]. For the eutrophication calculation, PO_4 equivalent factors were used for T-N=0.42, T-P=3.06 and COD=0.022 [4].

3. Results

Of the scenarios examined in this study, Scenario 4 has the smallest impact on GHG emissions (Table 1), owing to the greatest soil C sequestration, while it has the greatest impact on acidification and eutrophication. Despite having the greatest CH_4 emission, GHG emissions in Scenario 1 are the same as those in Scenario 2, while Scenario 1 has the smallest impact on acidification.

After the 20 years, when atmospheric CO_2 is no longer sequestered, total GHG emissions are the lowest in Scenario 2 (Table 1) and the largest with Scenarios 1 and 4.

4. Discussion

Due to a greater CH_4 emission, it has been recommended not to incorporate rice straw residue into paddy fields [5].

Table 1 Impact of different scenarios on climate change, acidification and eutrophication

			Scenario 1	Scenario 2	Scenario 3	Scenario 4
GHG emissions ($Mg\,CO_2$ eq. $ha^{-1}\,yr^{-1}$)	Agricultural machinery (a)		0.9	1.1	1.1	1.2
	Paddy soils (b)	N_2O emission	0.5	0.2	0.4	0.6
		CH_4 emission	6.1	3.7	4.7	5.6
	Soil C sequestration (C)		1.1	-1.2	0.7	2.6
	Total	1-20 year (a+b-c)	6.3	6.3	5.6	4.8
		> 20 year (a+b)	7.4	5.1	6.2	7.4
Acidification ($kg\,SOx$ eq. $ha^{-1}\,yr^{-1}$)	Agricultural machinery		3.8	5.1	5.4	5.6
	Fertilizer/Compost		3.4	3.4	6.5	9.5
	Total		7.2	8.6	11.9	15.2
Eutrophication ($kg\,PO_4$ eq. ha^{-1})	**Total**		12.4	12.4	20.9	29.5

In contrast to such recommendation, the present study, which considered soil C sequestration, found that rice straw residue incorporation (Scenario 1) is not the worst scenario.

Soil C sequestration is one of the crucial technologies to reduce the atmospheric CO_2 as a provisional step until new technologies are developed and implemented [6]. However, once soils reach a new equilibrium, the same management must continue to maintain the equilibrium soil C [6]. Thus, GHGs are continuously emitted, while no soil C is sequestered. Therefore, in the long-term, Scenario 2 seems to be a better management. However, a reduction of soil C for the first 20 years implies a reduction of rice yield [7], and of chemical, biological and physical properties [8], which in turn will hamper feeding the rapidly increasing population in the world.

Conclusions

This study explored the influences of differing scenarios of crop residue management and compost application on climate change. By taking account of the soil C sequestration, Scenario 1 seems a promising strategy since it is better environmental performance than scenario 2 in terms of acidification, and than Scenarios 3 and 4 in terms of both eutrophication and acidification. Moreover, it is the most common management over the last decades in Japanese paddy fields.

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Total Material Requirement of Food Production and Related Materials in Japan

Eiji Yamasue,*[1] Kazuyo Matsubae,[2] and Keiichi N Ishihara[1]

[1]*Kyoto University, Japan*; [2]*Tohoku University, Japan*
*Corresponding author: yamasue@energy.kyoto-u.ac.jp

1. Introduction

Increase in food productivity is an urgent issue in order to cope with population growth, and therefore, for example, fertilizing to supplement three major nutrients is indispensable in modern agriculture. Not only fertilizers but also agricultural chemicals are important substances for agricultural industry. Further, fishery, livestock industry and dairy farming also require various material and energy inputs for their products.

National Institute for Agro-Environmental science [1] reported life cycle assessments applied to agricultural industry. Such the detailed inventory data contributed to $LCCO_2$ analyses. However, it should be noted that although CO_2 emission by common soil input is thought to be relatively low, such the activities definitely disturb environment at source.

Matsubae et al. proposed a concept of "virtual phosphorus ore" and evaluated the amount of phosphorus ore required for food production in Japan [2]. The concept of virtual phosphorus ore is important because it can quantify impact that $LCCO_2$ analysis does not provide. Total material requirement (TMR) can be thought of as an extended concept of virtual phosphorus ore in terms of land use, since TMR includes not only direct and indirect material flows upstream of the process, but also hidden material flows, such as overburden and waste rock [3].

Although it is important to evaluate global warming in terms of CO_2 emission, the amount of land use as an initial source of resource utilization should not be ignored. Since many of the inputs for food production consist of various mineral components, they are expected to require great deal of land use, but no quantitative evaluation has been reported thus far. Thus, the aim of present study is to estimate and evaluate TMR of food production.

2. Method

In this abstract, the preliminarily estimated results for some crop production, meats, fishes, and beverages will be shown. Paddy rice, tomato, cabbage, wheat, potato, sweet potato, radish (daikon), orange, pear, beet, green tea leaf, silage, early-harvested maize, beef, squid, saury, salmon, tuna fish, tap water, some juices, milk, soy milk, and etc were chosen as targets. Functional unit was 1 kg of target fertilizer production.

System boundary was set as from mining to fertilizer production and all the direct and indirect inputs, and hidden flows such as tailings and waste rocks were considered, while any treatments of tailings such as de-toxification were regarded as being out of the system boundary.

Inventory data for crop production by National Institute for Agro-Environmental science were used. Authors have already reported the specific TMR value of various fertilizers. Specific TMRs of agricultural chemicals were estimated from the report by Kimura and Sugimoto.

3. Results and discussion

Figure 1 shows the results of estimation. The TMR of crop production range from 1.2 to 7 kg/kg, while fishery from 4 to 30 kg/kg. The TMR of beef is roughly estimated to be about 130 kg/kg. The TMR of milk is 2.6 kg/kg and that of soy milk is about half of milk.

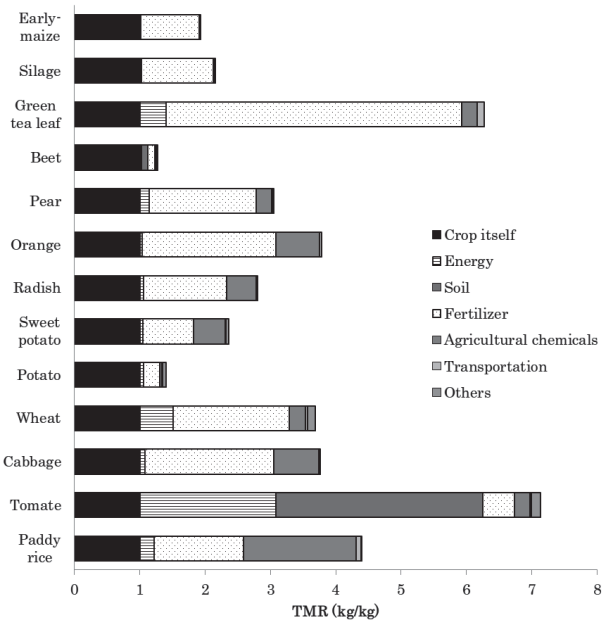


Figure 1. The TMR of crop production in Japan.

In case of crop production, large proportions of total TMR are inputs ascribed to fertilizer and agricultural chemicals, and in some crops, inputs due to soil and energy occupy cannot be negligible.

6. Conclusion

In this study, the TMR of various food production were estimated. large proportions of total TMR are inputs ascribed to fertilizer and agricultural chemicals, and in some crops, inputs due to soil and energy occupy cannot be negligible. These results will be compared with $LCCO_2$ for respective foods.

Acknowledgments

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Land use change related CO_2 emissions in the LCA of biofuel-based electrification in Mali

Joana Almeida[1], Jeroen Degerickx[1], Wouter MJ Achten[2] and Bart Muys[1]

[1]*KU Leuven, Belgium*; [2]*Université libre de Bruxelles, Belgium*
*Corresponding author: bart.muys@ees.kuleuven.be

1. Introduction and objectives

As with other renewable energy sources, bioenergy is expected to have lower GHG emissions than fossil energy, hence decreasing greenhouse gas (GHG) concentrations in the atmosphere. This assertion has been disputed on the grounds that, albeit emitting less GHG during the life cycle, bioenergy may have higher net emissions if land use change (LUC) is included in the life cycle assessments (LCA) [1].

In this study, we perform the cradle-to-cradle LCA of Jatropha oil-based electricity in Koulikoro, Mali. This analysis abandons the classical carbon neutrality assumption by including CO_2 fluxes of sequestration/release cycles in biomass and soil; and tailpipe emissions. Two direct LUC scenarios are evaluated, i.e. Jatropha establishment on former cropland or fallow land. We estimated the life cycle GHG emissions in annual time steps. Carbon stock changes in soil and biomass were amortized over a 20 year rotation time.

2. Methodology

System boundaries include the production of inputs to the system and direct emissions from fertilization and exhausts. The LCA model was parameterized with direct observations and data from literature, ecoinvent® v2.2 (Ecoinvent Center, Switzerland) and GREET 2013 (Argonne National Laboratory, USA). Due to high variability in Jatropha yields in the region, a yield of 1 ton ha^{-1} estimated by Trabucco et al. (2010) was used as a proxy [2,3]. Allocation to byproducts was avoided through system boundary expansion by including fertilizer and glycerol as the functional equivalents of seed cake and crude glycerine. The Global Warming Potential (GWP) was calculated with IPCC's Fourth Assessment Report GWP's for 100 years. The functional unit is 1 MJ of electricity generated from oil.

In order to estimate CO_2 emissions triggered by LUC, changes in C stocks in biomass and soil were estimated between Jatropha plantations and previous land uses. A negative difference was considered to be an emission. Biomass C stocks in cropland and fallow land in Koulikoro are based on field measurements [4]. Jatropha biomass C stocks were extracted from literature [5], whereas the SOC content was modeled with RothC. RothC was run with litterfall and climatological data from literature, starting from soil characteristics measured in the field under fallow land and cropland conditions [6].

3. Results and discussion

The generation of 1 MJ electrical energy emits 0.48 kg CO_2 eq if Jatropha replaces cropland, and 1.43 kg CO_2 eq if fallow land is converted (Figure 1). This difference is mainly driven by LUC. In fact, LUC is responsible for 58% to 86% of emissions (conversion of cropland and fallow respectively), mainly due to soil C loss over the years. This explains why cropland results in nearly 200% lower GWP, owing to lower initial biomass and soil C stocks which are lost.

Other relevant emission sources are N_2O release from manure application (11% to 33%) and electricity supply to the conversion facilities (3% to 9%). The remaining inputs to the system have a negligible contribution to GHG emissions.

Fossil diesel–based electricity emits 0.29 kg CO_2 eq MJ^{-1}. Although at par with Jatropha-based electricity when direct LUC is excluded, that figure is 1.7 to 4.9 times lower than when all biogenic emissions are taken into account. This comparison illustrates the relevance of LUC-related emissions for the LCA of biofuels as a tool to show their validity as a climate change mitigation practice.

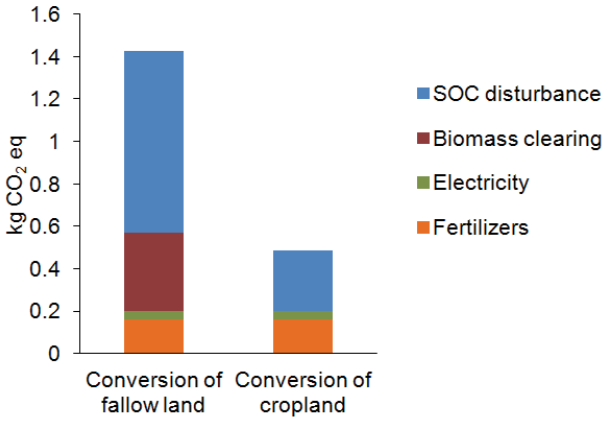


Figure 1. GWP of Jatropha-based electrification in Koulikoro when the plantations are established on fallow land or cropland. The stacked bars represent the main contributors to the GWP.

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Eco-efficiency analysis of integrated and non-integrated crop, forestry and livestock production systems in the Brazilian Cerrado

Marcela P. Costa[1,2], Sueli A. Oliveira[1], and Gerson A. de Medeiros[2]

[1]*Fundação Espaço ECO, BASF SA*; [2]*Universidade Estadual Paulista Julio de Mesquita Filho*
*Corresponding author: cmarcelaporto@gmail.com

1. Introduction

Despite the importance of Brazil as an exporter of agricultural and livestock products, the country has a considerable extension of low yield, degraded pasture land (Figure 1).

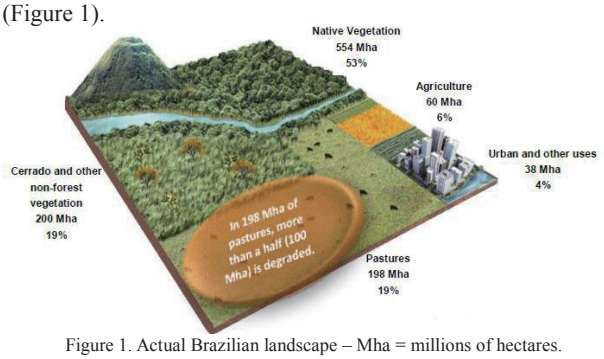


Figure 1. Actual Brazilian landscape – Mha = millions of hectares.

Technical improvement has been achieved aimed at recovering degraded pastures through integrated systems which consist on planting forage concomitant with a grain crop (CLi) and the possibility of planting tree species along spaced lines (CLFi).





Figure 2 and 3.(2) CLi System (Harvesting)(3):CLFi System(Pasture after crop + Forest)

When the crop is harvested, the forage and the residues of the crop generate a fresh pasture (Figure 2), livestock grazing in the dry season (Figure 4). The forest component can promote thermal comfort for the cattle, increasing weight gain.

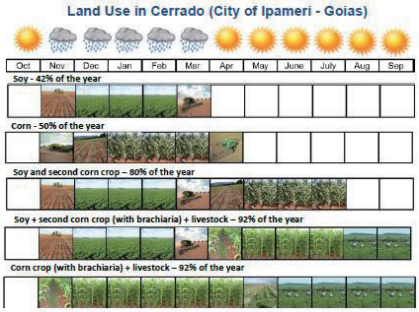


Figure 4:Land Use in different systems in Brazilian Cerrado.

2. Objective

Evaluate the eco-efficiency of five different combinations of agricultural (soy, corn, sorghum), forest (eucalyptus for energy supply) and cattle production systems, in order to meet the needs of 500 people in Brazil, in a period of seven years.

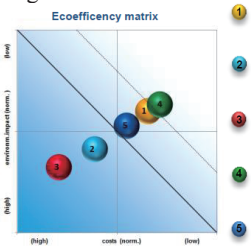
3. Methodology

The method used was the Eco-efficiency Analysis tool (EEA) developed by BASF SE, which consists on the economic and environmental life cycle assessment.

4. Results

Eco-efficiency Matrix

The most eco-efficient alternatives are positioned on the top right of the matrix.



Alternative 1. 0,88 of CLFi + 0,19 of Conventional Soy + 0,15 of Conventional Corn + 0,13 of Conventional Sorghum + 1,04 Conventional Livestock = 119 ha

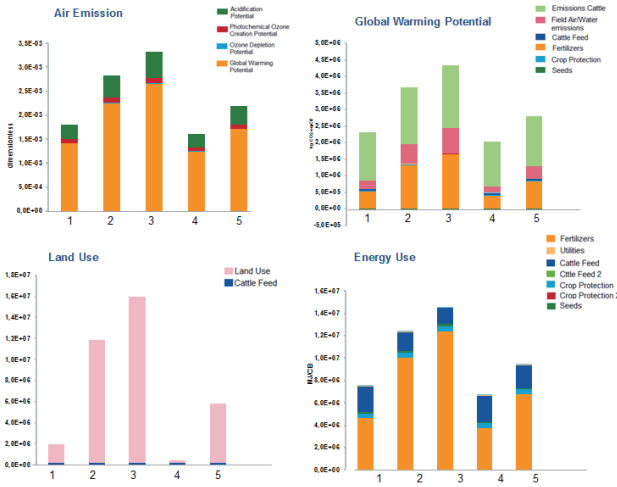
Alternative 2. 0,21 of CLi + 0,08 of Conventional Soy + 0,01 of Conventional Sorghum + 5,80 of Conventional Livestock + 0,27 of Conventional Forest = 319 ha

Alternative 3. 0,28 of Conventional Soy + 0,40 of Conventional Corn + 0,13 of Conventional Sorghum + 7,39 of Conventional Livestock + 0,27 Conventional Forest = 423 ha

Alternative 4. 0,88 of CLFi + 0,08 of CLi + 0,12 of Conventional Soy + 0,09 of Conventional Sorghum + 0,46 of Conventional Livestock = 81,15 ha

Alternative 5. 0,5 of CLFi + 0,11 of CLi + 0,13 Conventional Soy + 4,8 of Conventional Corn + 6,8 of Conventional Sorghum + 3,0 Conventional Livestock + 0,12 Conventional Forest = 197 ha

LCA Indicators of Environmental Impacts



5. Conclusion

- The combinations using more expressive amounts of CLFi system followed by CLi system presented the most eco-efficient results in comparison with the conventional systems.
- The most significant environmental advantages of adopting these integrated systems were on energy use, emissions and land use parameters.
- The impacts of costs on the integrated systems are lower due to the higher yields.

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Figure1 : redeagro.org.br/

Figure 3: Available on: http://ruralcentro.uol.com.br/noticias/mulheres-no-campo-marize-costa-sistema-ilpf-54526#y=2559

How much does Urban Mining reduce the environmental burden?

Kohmei Halada,*[1]

[1]*National Institute for Material Science, Japan*
*Corresponding author: HALADA.Kohmei@nims.go.jp

1. Introduction

The potential of urban mining to reduce the environmental burden is discussed. Reduction of resource-view weight, namely TMR (Total material requirement), and CO2 emission in processing are estimated for the potential of urban mining.

2. Procedure

Recycling has following three roles; 1) reduction of burden of acquisition of resources from the Eco-sphere, 2) reduction of burden to reassign waste to the Eco-sphere, reduction of 3) reduction of burden through the life stage in the Techno-sphere. In this work, reduction of resource-view weight is subjected as a parameter for the burden of acquisition. Reduction of CO2 emission through life-cycle is selected as a representative parameter through life stage in techno-sphere. While these two parameters are well established already[1], the parameter of reassign waste to eco-sphere has not been discussed. Newly developed parameter, waste-TMR, is introduced. Waste-TMR is the amount of soil which dilute wasted elements into acceptable concentration of eco-sphere. The acceptable concentration is estimated by the log-log relation of crust concentration with common soil concentrations of major elements and restriction concentrations of hazardous elements. These parameters are listed in the Table1.

3. Results and Discussion

The effects of recycling in Japan are analyzed with these three parameters for annual production and consumption of metals. The black part of each column is the reduction effect by practical recycling, obtained by comparing the practical material flow with the material which would be required if it is not recycled. The gray part means the difficult portion for recycling by reason of no-use in Japan and that of inappropriateness of application or composition for recycling. Then, the white part is the reduction potential of environmental burden by recycling.

Fe has reduced the burden by recycling already, and has further potential in TMR and CO2 emission. Pb has also reduced the burden and has further potential in waste-TMR. Cu has further potential in these three area. On the other hand, REE, which gives relatively higher burden, has less potential because of the difficulty of recycling.

Table 1 Environmental stresses of metals

		CO2 tCO2/tMetal	TMR coeff. −/−	waste-TMR			CO2 tCO2/tMetal	TMR coeff. −/−	waste-TMR −/−
3	Li	1.9E+01	1.5E+03	2.4E+04	50	Sn	5.1E+00	2.5E+03	9.8E+05
4	Be	7.4E+01	2.5E+03	1.3E+05	51	Sb	5.2E−01	5.6E+01	5.4E+06
5	B	6.0E+01	1.4E+02	5.4E+04	52	Te	2.9E−01	1.0E+04	5.0E+07
12	Mg	7.2E+00	7.1E+01	3.6E+02	55	Cs		1.1E+01	9.8E+05
13	Al	9.2E+00	4.8E+01	1.4E+02	56	Ba	4.6E+00	5.1E+02	2.3E+04
14	Si	7.2E+00	3.4E+01	6.0E+01	57	La	2.6E+02	8.2E+03	1.7E+05
20	Ca	4.8E+01	9.0E+01	3.5E+02	58	Ce	5.7E+02	1.8E+04	1.0E+05
21	Sc	2.3E+01	2.0E+03	9.1E+04	59	Pr	2.5E+02	7.9E+03	4.4E+05
22	Ti	6.9E+00	3.6E+01	1.9E+03	60	Nd	3.8E+02	1.2E+04	1.8E+05
23	V	2.5E+01	1.5E+03	2.6E+04	62	Sm	4.9E+02	1.6E+04	5.9E+05
24	Cr	7.9E+00	2.6E+01	3.3E+04	63	Eu	1.1E+03	3.3E+04	1.9E+06
25	Mn	2.8E+00	1.4E+01	6.6E+03	64	Gd	5.3E+02	1.7E+04	6.5E+05
26	Fe	8.4E−01	8.2E+00	3.5E+02	65	Tb	1.7E+03	5.5E+04	2.7E+06
27	Co	1.5E+01	6.1E+02	9.8E+04	66	Dy	5.1E+02	1.6E+04	7.3E+05
28	Ni	8.2E+00	2.6E+02	4.5E+04	67	Ho	9.4E+02	3.0E+04	2.1E+06
29	Cu	3.5E+00	3.6E+02	5.9E+04	68	Er	1.0E+03	1.2E+04	1.1E+06
30	Zn	2.8E+00	3.6E+01	5.1E+04	69	Tm	1.0E+03	3.2E+04	4.0E+06
31	Ga	2.6E+01	7.3E+03	1.8E+05	70	Yb	1.0E+03	3.2E+04	1.1E+06
32	Ge	3.7E+00	3.2E+04	9.8E+05	71	Lu	1.0E+03	3.2E+04	4.0E+06
33	As		2.9E+01	8.6E+05	72	Hf	1.3E+01	1.0E+04	9.8E+05
34	Se	2.3E+00	4.5E+02	1.5E+07	73	Ta	1.6E+01	6.8E+03	1.6E+06
37	Rb	1.9E+00	1.3E+02	5.1E+04	74	W	1.9E+00	1.9E+02	1.9E+06
38	Sr	7.9E+00	5.1E+02	1.9E+04	75	Re	2.0E+00	1.8E+04	8.3E+07
39	Y	1.1E+01	2.7E+03	1.1E+05	76	Os	9.5E+02	5.4E+05	8.3E+07
40	Zr	2.5E+00	5.5E+02	3.4E+04	77	Ir	3.9E+02	4.0E+05	8.3E+07
41	Nb	2.4E+01	6.4E+02	1.8E+05	78	Pt	9.0E+02	5.3E+05	8.3E+07
42	Mo	1.5E+01	7.5E+02	1.2E+06	79	Au	5.1E+02	1.1E+06	1.6E+08
44	Ru	1.6E+02	7.9E+04	5.0E+07	80	Hg		2.0E+03	1.8E+07
45	Rh	1.1E+03	2.3E+06	8.3E+07	81	Tl	1.3E+01	4.3E+02	5.4E+06
46	Pd	3.3E+02	8.1E+05	5.0E+07	82	Pb	3.4E+00	2.8E+01	4.4E+05
47	Ag	4.5E+00	4.8E+03	1.2E+07	83	Bi	5.3E−01	2.2E+02	9.0E+06
48	Cd	4.1E+00	6.8E+01	5.4E+06	92	U	2.0E+00	2.2E+04	
49	In	2.3E+00	1.2E+04	9.0E+06					

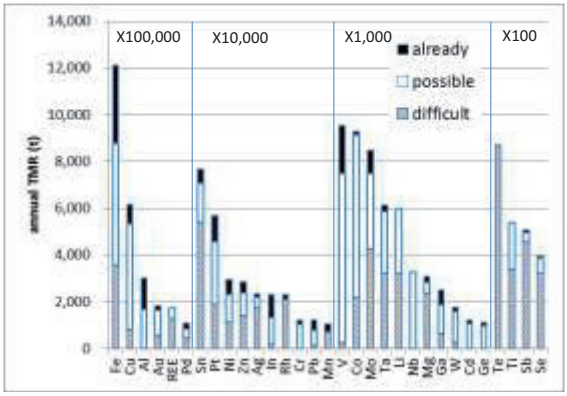


Figure 1 Effect of recycling in Japan on TMR

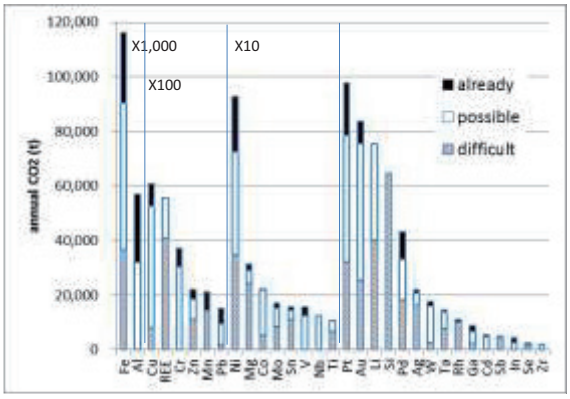


Figure 2 Effect of recycling in Japan on CO2 emission

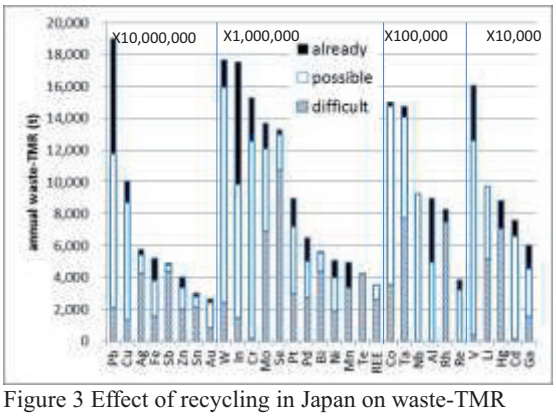


Figure 3 Effect of recycling in Japan on waste-TMR

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Designing Strategic Urban Mining in Japan for Criticality Mitigation

Hiroki Hatayama,*[1] Kiyotaka Tahara,[1] and Ichiro Daigo[2]

[1] *National Institute of Advanced Industrial Science and Technology, Japan*; [2]*The University of Tokyo, Japan*
*Corresponding author: h-hatayama@aist.go.jp

1. Introduction

Highly-developed industrial activities in Japan have been founded on a massive amount of metal consumption. Meanwhile, a large part of the metal supply is depending on the import from foreign countries. Therefore, Japan's governments and industries have been giving much importance on a security of metal resources. As mentioned in the governmental resource securement strategy, both common and minor metals are recognized to have a high criticality for Japan [1]. As well as a reinforcement of mineral supply from abroad, reducing dependence on imported metals by substitution and recycling are also recognized as the significant measures for criticality mitigation. All of these measures are more or less effective; however, adequate combination between mitigation measures and target metals should be explored in constructing a long-term resource strategy. The goal of this study is to represent how the effectiveness of recycling on criticality mitigation differs among metals and how it will change in future.

2. Methodology

Recovery from end-of-life products should be enhanced for metals that meet the following conditions:
(1) There is a high risk in supplying necessary amount of metals to the domestic industries.
(2) Mineral demand can largely be reduced by recycling promotion.
One possible index for representing the first point is a criticality score that integrates several sub-scores provided to various criticality components such as production concentration and future demand growth. The index that represents the second point could be evaluated from a comparison between the amount of metal demand and discard which are provided by substance flow analysis (SFA).

The effectiveness of recycling promotion in the future will be affected by the change in metal demand and discard. As well, criticality of metals would change in the future in tandem with increase/decrease in geological reserves, metal demands, prices and so forth. The transition can be illustrated as 3D chart shown in Fig.1. Some measures to mitigate criticality should be taken for the metals placed at the left side in Fig.1. For metals placed at the upper left, recycling promotion becomes one of the significant measures for criticality mitigation. Conversely, recycling cannot fully mitigate the criticality when metals are at the bottom left area. For these metals, other measures such as substitution must be rather effective.

Seeing the snapshot in the present year, a necessity for securing resources is relatively small for the metal placed at the bottom right area. However, criticality of the metal could rise in the future. At the same time, potential of urban mining may also increase due to the spread of products containing metal. By depicting the time change of the position in the Fig.1, effective timing for developing urban-mining technologies would be indicated. Furthermore, cross-metal evaluation can suggest the comprehensive strategy for domestic recycling and resource management.

Japan's criticality assessment was done by NEDO in 2009, where the criticality of 39 minor metals were evaluated [2]. However, common metals like steel and copper, which are also designated as "strategic minerals" in Japan's resource strategy [1], were not focused on. On the other hand, there have not been enough dynamic SFA studies for minor metals. To build the chart in Fig.1 for Japan, we conducted the criticality assessment and dynamic SFA of several common and minor metals. The method of criticality assessment basically followed the NEDO approach, but a criticality component that represents the sufficiency of resource entitlements [3] were additionally considered.

3. Summary of the Results

The results of criticality assessment and dynamic SFA are presented by 2030 for several metals e.g. steel, aluminum, copper, lead, cobalt, tantalum, dysprosium. etc. As with NEDO assessment in 2009, our criticality assessment also show high criticality scores for minor metals like indium and dysprosium under the conditions prevailing in 2012. Furthermore, our assessment clarified that the criticality of steel and some common metals are nearly at high level compared to minor metals. The results of criticality assessment and SFA led to the suggestion of metals that recycling should be promoted at the present situation. Furthermore, adequate measures in the future were also indicated based on the dynamic analysis.

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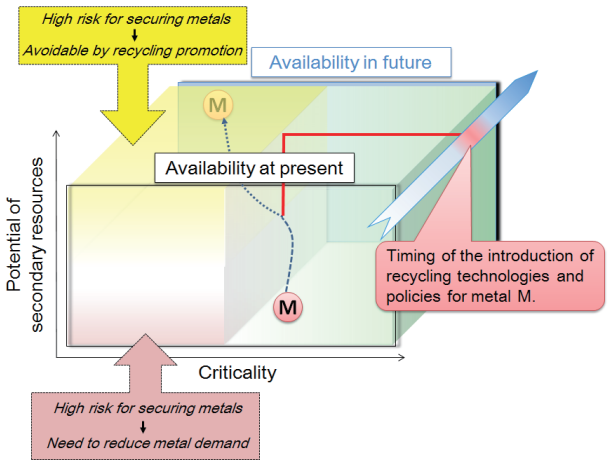


Figure 1. Conceptual chart for long-term strategy of urban mining.

Comparison of End-of-Life Recycling Rates of Common Metals in Japan

Ichiro Daigo [*1], Kohei Iwata [1] and Yoshikazu Goto [1]

[1] *Graduate School of Engineering, The University of Tokyo, Japan*
*Corresponding author: daigo@material.t.u-tokyo.ac.jp

1. Introduction

Material recycling is a measure to conserve natural resources. An efficiency of material recycling from recovered end-of-life products can be evaluated by end-of-life recycling rate (EoL-RR). The EoL-RR has been defined in the report from International Resource Panel, UNEP[1], i.e. the amount of recycled EoL materials divided by the amount of the materials contained in discarded EoL products. In addition, significance of evaluating EoL-RR has been pointe out by Reck and Graedel[2]. Several EoL-RRs for specific regions in specific time points could be obtained by results of MFA studies[1]. On the other hand, time-series change of EoL-RR has not been evaluated, except for the case of aluminum in the U.S. [3]. Furthermore, EoL-RRs have not been compared among different materials due to a lack of availability on flux in recycling chain[2], especially due to difficulty of observing the denominator of the rate.

The goal of this study is to estimate time-series EoL-RRs on the basis of the same definition and calculation method and compare them.

2. Methodology

In this study, we focused on recycling of six metallic materials; such as steel, aluminum, copper, austenitic stainless steel, ferritic stainless steel and zinc in galvanized steel in Japan. In general, it is difficult to estimate the amount of the materials contained in discarded EoL products. A possible method to estimate the amount is a dynamic material flow analysis (dMFA) which requires lifetime distributions of products. The lifetime distributions adopted in the previous studies employing dMFA were generally constant over time due to insufficient information on chronological change of the lifetime. In order to reduce uncertainties of estimated EoL-RRs, time-series change of products' lifetime distribution was investigated. Time-series change of lifetime distribution could be obtained for automobiles and buildings, which account for more than a half of consumption in every metal evaluated here. Time-series change of lifetime for other end uses have been remained as a factor of uncertainty in the results.

Using the lifetime for each end use and time-series consumption for each end use in the past, the time-series EoL-RRs were estimated. The numerators of the rates, i.e. the amount of recycled obsolete scrap, were estimated by combination of some statistics. Due to restriction of data availability, the numbers of end uses classified for six metals are different as shown in table 1.

3. Results and Discussions

Estimated EoL-RRs for the six metals are shown in figure 1. EoL-RRs have been changed over time in quite large ranges; 25, 52, 53, 40, 47 and 35 %-points for steel, aluminum, copper, austenitic stainless steel, ferritic stainless steel and zinc, respectively. At least during the evaluated period, EoL-RR of steel has been the highest in almost every year, followed by copper and austenitic stainless steel. EoL-RRs for steel, copper and stainless steels indicated relatively high values during the year 2005 to 2008, which is considered due to high prices of resources which include scraps of the metals. This results are in agreement with the results on aluminum in the U.S. reported by Chen[3]. Especially, the rates for steel, copper and austenitic stainless steel exceeded more than 100%. Even if the results would have uncertainties to some extent, the results implies that a certain amount of disused metals can remain in anthroposphere as hibernating stock[4] during a period in low metal prices and will be drawn to the market in high metal prices. Our results might be the first evidence which indirectly observe the phenomena of hibernation from a macroscopic view. On the other hand, chronological changes of EoL-RRs of aluminum and zinc have no relation with prices of those metals. In spite of the same material to ref.[3], the relations with prices were different in Japan and the U.S.

Table 1. Data used for estimation on EoL-RRs

Metals	Number of end uses
Steel	11
Aluminum	11
Copper	6
Austenitic stainless steel	10
Ferritic stainless steel	10
Zinc in galvanized steel	11

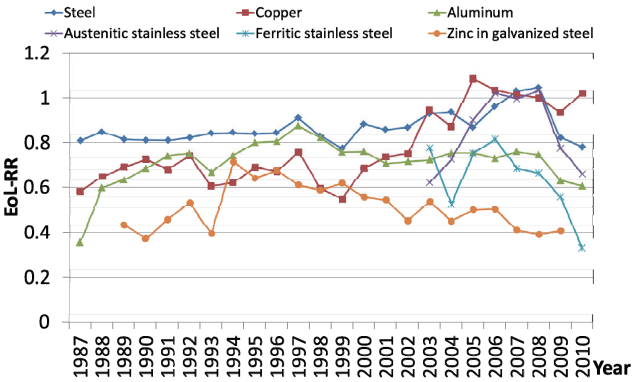


Figure 1. Time-series change of EoL-RRs for the six metals in Japan

Acknowledgments

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Framework and Applications of Time-Series Material Flow and Stock Analysis

Shotaro Nakanishi,*[1] Jun Nakatani,[1] and Yuichi Moriguchi[1]

[1]*University of Tokyo, Japan*
*Corresponding author: nakanishi@env.t.u-tokyo.ac.jp

1. Introduction

It is considered that many fixed capital in Japan will become superannuated in several decades. At the same time, aging and depopulation will progress in the nation. These two conditions make the nation manage superannuated fixed capital with decreasing social vitality. Therefore, the information on future fixed capital is important. Murakami et al. [1] states that the number of studies using material flow and stock analysis has increased, however few researchers study about social overhead capital (SOC), namely, infrastructure. Moreover, most studies have not focused on both SOC and durable goods, such as cars and machineries.

The objective of this study is to develop a framework and comprehensive database of fixed capital, which contributes material flow and stock management in Japan.

2. Method

We used the Japanese Input-Output Tables (IOT) from 1990 to 2005 [2] as basic datasets. We calculated $(I-A)^{-1}$ type inverse matrix from input tables with original 105 sectors, and defined these tables as b [-]. We rearranged value and quantity tables with the 105 sectors, divided them by domestic production, and defined them as m [ton/million yen]. We rearranged fixed capital matrixes with the 105 sectors, and defined them as f [million yen]. Finally, we defined l as lifespan curve of each fixed capital as in Table 1.

Table 1. Lifespan curve of fixed capital [3]

Fixed capital	Type of function, parameter
Machinery	Weibull, m=2.9, μ=10
Construction (wooden)	log-normal, μ=3.7, σ=0.6
Construction (nonwooden)	Weibull, m=14, σ=-112.4
Civil engineering structure	normal, μ=70, σ=4.8
Others	normal, μ=5, σ=1.3

Using these matrixes, we calculated $\mathbf{s}$ [ton], the amount of each fixed capital stock in Japan.

$$\mathbf{s}(\hat{t},t,p,i,j,k) = b(t,i,j)\times m(t,p,i)\times f(t,j,k)\times l(\hat{t},t,j) \quad (1)$$

where, k denotes final demand sectors of fixed capital, j denotes the types of fixed capital, i denotes the types of intermediate input, and p denotes the types of material. t denotes the year of manufacture of fixed capital, and $\hat{t}$ denotes the year of observation. Using Equation 1, we calculated $S[\hat{t},t_0,t](p,i,j,k)$, gross stock of fixed capital.

$$S[\hat{t},t_0,t](p,i,j,k) = \sum_{t=t_0}^{t}\sum_{p,i,j,k} s \quad (2)$$

where, t_0 denotes the oldest year of manufacturing. In general, t_0 should be sufficiently older than $\hat{t}$.

3. Result and Discussion

Figure 1 shows the fixed capital input of the 4year when IOTs exist. Compared with the estimation of the White Paper [4], our value was 40% larger in 1990, but became a close value in other years. Because the demand of mineral was overestimated in 1990, we should review b matrixes. Figure 2 shows the fixed capital stock, and Figure 3 shows the obsolete fixed capital. Figure 2 and 3 used the 15-years input data obtained from the result of Figure 1 with interpolation. Figure 3 shows that the type and amount of capital was significantly different depending on the $\hat{t}$.

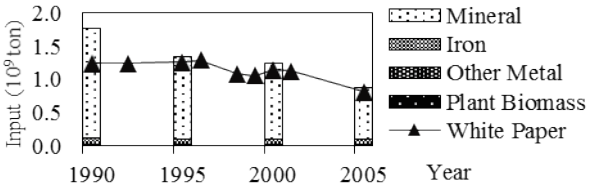


Figure 1.Produced fixed capital

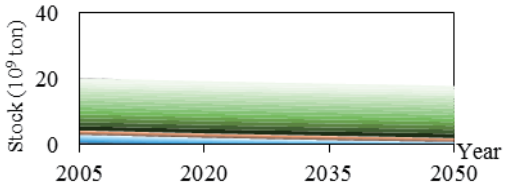


Figure 2.Stocked fixed capital (produced in 1990-2005)

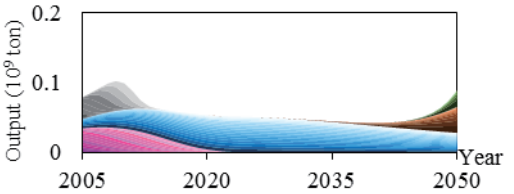


Figure 3. Obsolete fixed capital (produced in 1990-2005)



Figure 4. The legend of Figure 2 and 3,

4. Conclusion

This study developed the framework that contributes to material stock and flow management in Japan. Input, stock and output of fixed capital, produced from 1990 to 2005 were estimated. To improve the utility of the framework, we have to use older data, and estimate future input.

Acknowledgments

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Value added Material Flow Analysis of NdFeB magnets in Denmark

Komal Habib,*[1] and Henrik Wenzel[1]

[1]*University of Southern Denmark. Niels Bohrs Alle 1, DK-5230, Odense M, Denmark.*
*Corresponding author: koh@kbm.sdu.dk

1. Introduction

Neodymium-iron-boron (NdFeB) magnets have become highly desirable for modern high-tech applications. These magnets contain two key Rare Earth Elements (REEs) i.e. neodymium (Nd) and dysprosium (Dy), which are considered as critical resources by a number of governing bodies including the European Commission. These magnets are used in products ranging from electricity generators and medical equipment to the household appliances and personal care products [1, 2].

This study is aimed at mapping the stocks and flows of Nd and Dy contained in the NdFeB magnets in Denmark, where the reference year is 2012.

2. Methods

In order to estimate the in-use stocks of NdFeB magnets in Denmark, both top-down and bottom-up approaches are used [3]. The inflow of these magnets to Denmark in the form of magnetic alloy or finished goods is estimated based on trade and sales statistics [4-8]. To know the NdFeB magnets composition for various products, a total of 157 different electronic products representing 7 various product categories were dismantled. After dismantling, the NdFeB magnets were taken out to perform the elemental analysis with the help of Electron Dispersive X-ray spectroscopy (EDX) system to reveal their composition. For the products which could not be dismantled e.g., home appliances, data regarding the magnet weight and composition was collected from leading NdFeB magnet and final product manufacturers.

3. Results

Our results show that in 2012, nearly 975 Mg of NdFeB magnets were imported to Denmark, either contained in the end-use products such as Information Technology (IT) applications or in the form of magnetic alloy to be further used in finished goods. This value corresponds to almost 283 Mg of Nd and 17 Mg of Dy. The largest import category is wind turbines, which alone represents almost half of the total NdFeB magnets import to Denmark in 2012. The remaining half of the imports comprise passenger vehicles, home appliances, IT & telecommunication products, medical equipment such as Magnetic Resonance Imaging (MRI) machines, personal care products, industrial motors and circulator pumps. Figure 1 presents the simplified results for the Material Flow Analysis (MFA) of NdFeB magnets in Denmark in 2012.

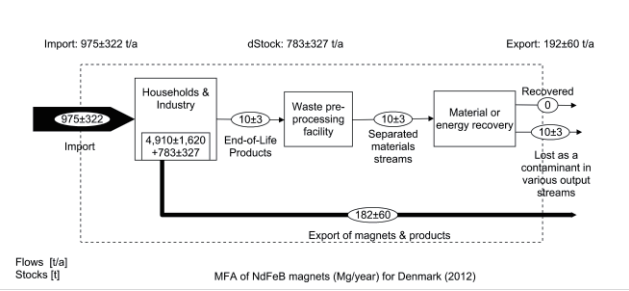


Figure 1. MFA of NdFeB magnets for Denmark (2012)

The results further reveal that the in-use stocks of NdFeB magnets in Denmark are approximately 5000 Mg, which corresponds to 1400 Mg of Nd and 100 Mg of Dy. Nearly 38% of the in-use stocks of NdFeB magnets are contained in the wind turbines, followed by home appliances (28%) and passenger vehicles (18%). The remaining 16% of the in-use stocks of NdFeB magnets consist of IT & telecommunication products, personal care products, medical appliances and others.

Our estimates show that in 2012, only 10 Mg of NdFeB magnets appeared in the Danish waste stream. This corresponded to almost 3 Mg of Nd and 0.2 Mg of Dy. The dominant category is IT & telecommunication which represents nearly 65% of total NdFeB magnets appearing in the waste, followed by MRI machines (35%).

The estimated amount of NdFeB magnets appearing in the waste stream (10 Mg) is quite low compared to what was imported to Denmark (975 Mg) in 2012. This is mainly because of the long lifetimes of key end-use products such as wind turbines (25 years) and passenger vehicles (16 years) etc.

4. Conclusion

The NdFeB magnets are currently not recycled in Denmark to recover the critical resources i.e. Nd and Dy contained in them. This is primarily because of the challenges attached to isolate the small amount of magnets contained in a large variety of end-of-life products found in waste flows, making their efficient recovery unattractive at the moment considering the economic feasibility.

Acknowledgments

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Ultra-High Temperature Materials for Higher-Efficiency Energy Conversion of Heat Engines

Kyosuke Yoshimi

Tohoku University, Japan
yoshimi@material.tohoku.ac.jp

1. Introduction

Since the Great Eastern Japan Earthquake on March 11th, 2011, the world has reaffirmed the significance of energy conversion by heat engines. High-temperature and high-strength materials are one of the most important technological components in achieving more efficient heat engines and attaining more stable energy supplies. Basically, the hotter the operating temperature of heat engines is, the better its energy conversion efficiency is improved [1]. Unfortunately, the operating temperature of the heat engines such as gas turbines and jet engines exceeds the melting point of nickel-base superalloys which are a main and key heat-resistant material in the engine system, and thus their energy conversion efficiency has almost peaked these days. If the nickel-base superalloys are replaced with better heat-resistant materials, the efficiency will be dramatically improved.

In this paper, the current situation of the engines is briefly reviewed. And then, their future prospects are discussed involving ultra-high temperature materials such as SiC/SiC composites (CMC), Ti-based alloys and Mosibtic alloy which have been developed in our recent project.

2. Current situation of the energy conversion efficiency of gas turbines and jet engines.

To improve the energy conversion efficiency of the heat engines, gas pressure in compressor and turbine inlet temperature are increasing with development. The turbine inlet temperature of a land-based gas turbine for power generation has reached approx. 1600°C [1]. However, as Perepezko pointed out [2], the deviation of the specific core power of actual equipment from the ideal performance has become larger with increase in turbine inlet temperature (Figure 1). It has been considered that the inefficiency losses are induced by cooling system in turbine blades since the system enhances internal stress due to stress concentration. Weight reduction is one of the ways to solve the trade-off problem. The other way is to enhance the heat-resistant properties of the turbine blades by replacing nickel-base superalloys with ultra-high temperature materials.

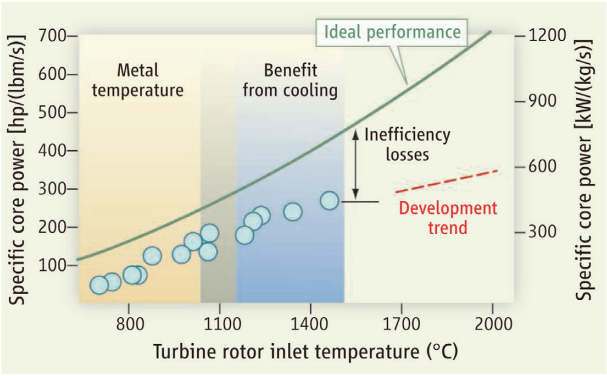


Figure 1. Specific core power output of gas turbines vs. turbine inlet temperature reported by Perepezko [2].

3. Novel ultra-high temperature of TiC-added Mo-Si-B alloys beyond nickel-base superalloys

Mo-Si-B-based alloys are a leading candidate for ultrahigh-temperature materials available above the operating temperature of nickel-base superalloys because of their high melting point, excellent high-temperature (creep) strength and moderate oxidation resistance in the ultrahigh temperature range [2–4]. However, as these alloys have a higher density than nickel-base superalloys and poor room-temperature fracture toughness [5], their practical use is limited. To improve the physical properties of Mo-Si-B-based alloys, attempts have been made to include a fourth element and control their microstructure.

We recently developed novel TiC-added Mo-Si-B alloys using a conventional arc-melting technique. Through the process, fine microstructures of three- and four-component eutectic phases such as Mo_{ss} + Mo_5SiB_2 (T_2) + (Ti,Mo)C + $(Mo,Ti)_2C$, Mo_{ss} + T_2 + (Ti,Mo)C, and Mo_{ss} + T_2 + $(Mo,Ti)_2C$ with a primary phase of Mo_{ss}, T_2 or (Ti,Mo)C depending on the composition are created [6]. The density reduces to ≤9.0 g/cm^3 as a result of the TiC addition, even though the volume fraction of Mo_{ss} is over 60%. Alloys containing an elongated coarse T_2 primary phase has low deformability at 1400 °C, whereas alloys containing a Mo_{ss} or TiC primary phase has good deformability and high strength of 800 MPa at 1400 °C along with a strain rate of 2.1 × 10^{-4} s^{-1}. TiC-added Mo-Si-B-based alloys thus have a high potential to be used as ultrahigh-temperature materials.

Acknowledgments

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Advanced Green Innovation Discovered by Self-healing Ceramics

Wataru Nakao

[1]*Yokohama National University, Japan*
*Corresponding author: wnakao@ynu.ac.jp

1. Introduction of fiber reinforced self-healing ceramics

Self-healing is the capability (or function) for material to restore autonomically the damage, similarly as the living thing, thereby adapting the function to the materials for structural and mechanical use gives rise to the huge enhancement in its lifetime and reliability. The self-healing materials for structural and mechanical use usually include the healing agent which acts as adhesives to re-bond the crack surfaces, because the self-healing target should be the cracks. The healing agent is flowed into the space between the cracks at the crack initiation and propagation, thereby reacts at the crack surface to re-bond the crack surfaces.

Oxide based fiber reinforced self-healing ceramic composite (shFRC) developed by the present authors has human bone-like structure (Figure 1), which consists of oxide fiber bundles, oxide matrix and non-oxide interlayer. Especially non-oxide interlayer is most important and characteristic consistent. Crack initiation and propagation allows the non-oxide interlayer react with the oxygen in the surrounding atmosphere, and then the formed oxide and the reaction heat bond the branched crack. Furthermore, the interlayer possesses the function to branch the crack propagation. The crack branching leads to the huge resistance to crack propagation and the conducts the crack to the healing agent. Due to these functions, shFRC can exhibit the high self-healing ability.

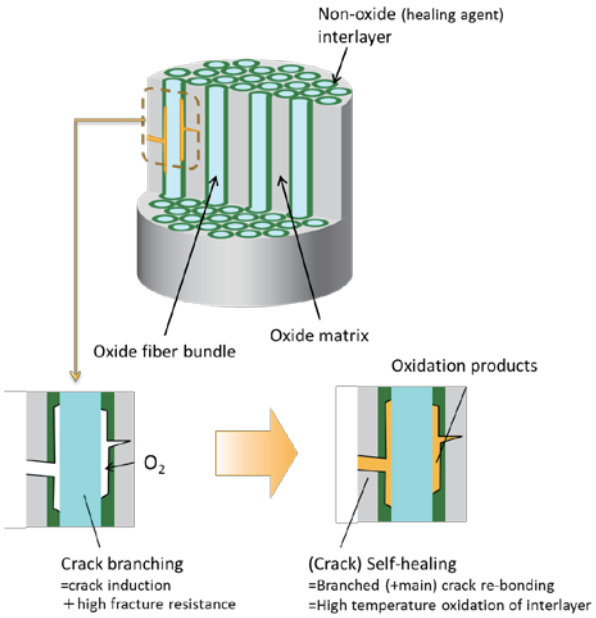


Figure 1 Schematic of fiber-reinforced self-healing ceramics

2. Most attractive feature of shFRC

The life time of shFRC can be considered to be the same time-dependent type (Fig. 2) as metal material, although the life time of the ordinary ceramics must be considered to take into consideration the probability of occurrence of excessive load. Ceramic materials, which are well-known as brittle materials, are easily fractured by the excessive loads due to crush of foreign objects and thermal shock. The fracture resistance of ceramic materials is quite low so that the cracks introduced by the excessive load propagate to the opposite side in an instant. Therefore, the life time of ceramic components is exhausted abruptly by generating of excessive load. Similarly silicon carbide based fiber reinforced ceramics reach the final fracture by repeating the excessive loads although the composites have the high fracture resistance. On the other hand, shFRC can autonomically recover the strength degraded by the excessive load, so that one can use the shFRC components with high mechanical reliability until the self-healing capability is exhausted.

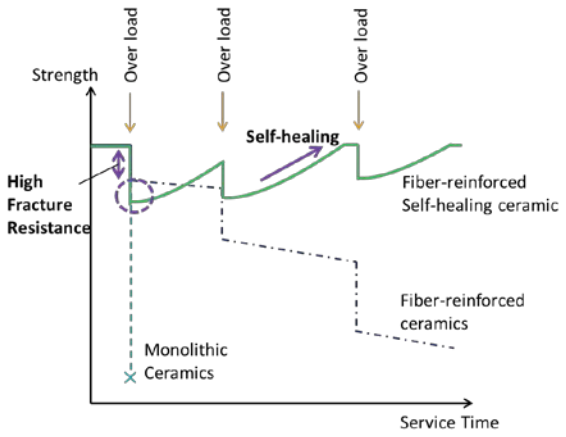


Figure 2 Time dependent deterioration in strength of fiber-reinforced self-healing ceramic

3. Environmental effects

Large green innovation which is to develop an advanced jet engine with ultrahigh fuel efficiency can be achieved by using shFRC. The enhancement in fuel efficiency of jet engine has been attained by the increment in the combustion gas temperature (turbine inlet temperature) with the aids of the heat-resistant improvement in a base material as well as the development of cooling technology, such as adapting air cooling blade and thermal barrier coating. Alternatively the increment of the combustion gas temperature gives rise to the increase in NOx concentration in combustion gas. Thus, it is hard to further increase the combustion gas temperature, based on the view of environmental protection. If one substitutes the shFRC turbine blade for the ordinary blade, the advanced jet engine with non-cooling of turbine blade and ~22% weight reduction can be actualized. The advanced engine can exhibit ~15% higher fuel efficiency than the latest jet engine, and the fuel efficiency enhancement corresponds to the reduction of the CO_2 exhaust by half of the total CO_2 emission equivalency of our country.

shFRC possesses large potential to adapt many application except turbine blade. The present author wishes that the readers will be interested in the self-healing materials.

Environmental Barrier Coating on SiC Fiber-Reinforced SiC Matrix Composites for Low Pressure Turbine in Jet Engine

Hideki Kakisawa

The University of Tokyo, Japan
kakisawa@hyper.rcast.u-tokyo.ac.jp

1. Introduction

SiC fiber-reinforced SiC matrix composites (SiC/SiCs) are the promising candidate structural materials for the hot sections in the next generation jet engines [1]. In dry oxygen atmosphere, a protective SiO_2 layer is formed on the SiC surface preventing further oxidation. However, when the SiO_2 is exposed to water vapor in combustion gas, it reacts to form gaseous silicon hydroxide as [2]

$$SiO_2\ (s) + 2H_2O\ (g) = Si(OH)_4\ (g). \qquad (1)$$

This oxidation and the following volatilization in the combustion environment cause weight loss of SiC which decreases the lifetime. Thus environmental barrier coatings (EBCs) have been developed to protect the surface of SiC based materials from such corrosive behaviors [3-5].

Mullite EBCs has been developed because of its high temperature stability, coefficient of thermal expansion (CTE) close to SiC and chemical compatibility. Then for further protection performance at higher temperatures, YSZ, $Ba_{1-x}Sr_xAl_2Si_2O_8$ (BSAS) and rare earth silicates ($RESi_2O_7$ and $RESiO_5$) (RE: rare earth element like Y, Sc and Yb) have been considered as protective materials. However, mullite is still an important material for lower temperature EBCs and for an intermediate layer material in BSAS EBCs.

In the EBCs, cracking through the coating thickness often occur and reaches to the substrate. CTEs of most oxide materials used for EBCs, including mullite, are larger than that of SiC and thus in-plane tensile stress is induced in the coating during cooling in the fabrication process and in service. The thermal tensile stress reaches several hundred MPa at maximum and causes mode I cracking across the coating[14-15]. Such cracks through the thickness make paths of oxygen and water vapor to the substrate, which may cause significant damage of substrate materials.

In this study, to prevent cracking through the thickness and to enhance the gas shielding properties, Al_2O_3 flake is dispersed in mullite EBC. Design of the flake-dispersed structure is done for an inexpensive, damage tolerant and repairable EBC and based on the design, Al_2O_3 flake-dispersed mullite matrix composite coating is developed by sol-gel and slurry techniques.

2. Structural design

Crack propagation resistance through the coating thickness was discussed in terms of the dimensionless cracking number,

$$\Omega \equiv \frac{K_c}{\sigma^T\sqrt{h}} \qquad (2)$$

where σ_T is in-plane thermal stress, K_c is fracture resistance and h is coating thickness. The cracking number Ω is calculated as a function of flake volume fraction and flake size. An optimum structure for maximizing fracture resistance is suggested through the discussion.

3. Experimental procedure

Based on the structural design, Al_2O_3 flake-dispersed mullite matrix composite coating was fabricated on SiC discs synthesized by melt infiltration process. The disc was 12.7mm in diameter and 1.8 mm in thickness. α-Al_2O_3 flake powder (Serath 10030, Kinsei Matec Co., Ltd., Osaka, Japan) was used as the dispersed flake material. It had a nominal diameter of 10μm and a thickness of 300nm (aspect ratio: 33). Raw material of mullite matrix was a mixture of mullite powder (KM101, KCM Corporation Co., Ltd., Nagoya, Japan), Al_2O_3 sol and SiO_2 sol. The Al_2O_3 flake powder and mullite powder were put in the mixture of Al_2O_3 and SiO_2 sols with the ratio of 5.5:1.2:1 (sol mixture : flake powder : mullite powder). The expected final volume fraction was ~30%.

The prepared slurries were coated on the SiC substrate by doctor blade technique. The gap between the blade edge and the substrate surface was set 200μm. The coatings were dried in air for 24h and sintered with a tubular furnace at 1200˚C or 1400˚C for 2h in flowing N_2 gas atmosphere with a heating rate of 2˚C/min. After the heating the coatings were furnace cooled.

4. Results and discussion

The coating was bonded to the substrate through the drying, sintering and polishing process, although a partial delamination was observed at the interface. The thickness of the coating was 64μm at 1200˚C and 59 μm at 1400˚C; they were almost the same despite the difference of the sintering temperature of 200˚C.

The flakes remained in the mullite matrix, keeping a distinguishable interface without significant reaction or diffusion. The flakes were aligned fairly parallel to the substrate surface by shear force induced by the blade in the coating process. Pores of ~1-3μm were distributed mainly between the flake planes. Cracks with opening displacement of ~2μm were propagated in the matrix and connected to the pores. The cracks were arrested at the pore or the interface between the flake and matrix; no network of cracks and pores seemed to make an open path from the surface to the substrate.

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Metal Recovery from Urban Mines by Hydrometallurgical Methods

Mikiya Tanaka*[1], Hirokazu Narita[1], Tetsuo Oishi[1], Takeshi Ogata[1], Yuiko Tasaki-Handa[1], and Kazuya Koyama[1,2]

[1]*National Institute of Advanced Industrial Science and Technology, (AIST), Japan*; [2]*Chiba Institute of Technology, Japan*
*Corresponding author: mky-tanaka@aist.go.jp

1. Introduction

Recently the recovery of valuable metals from urban mines is receiving more and more attention to stabilize their supply chains. Hydrometallurgical processes, consisting of leaching, purification, and metal winning, are suitable for fine separation and small scale operation and have wide applicability to the metal recovery from urban mines. In this presentation, we will outline our studies on the hydrometallurgical processes and related unit operations.

2. Recovery of rare earth elements from scrap magnets by an oxidative roasting - acid leaching - solvent extraction process

Neodymium magnets, indispensable in electronic and electric appliances, automobiles and other industrial products, contain neodymium and a small amount of dysprosium as the additive. Because no rare-earth metal resources exist in Japan, exploration, stockpiling, and recycling should be promoted in order to secure the stable supply of these rare-earth metals.

The hydrometallurgical route would be one option for the neodymium magnet recycling, particularly, from the end-of-life scrap of which the composition is rather diverse. For the hydrometallurgical process of neodymium magnet scrap, one has to consider that iron amounts to more than 70 wt% of the magnet. When all the iron is dissolved in the acid, not only excess acid, but also a significant amount of alkaline for neutralization of the leach solution are required, which would be quite uneconomical.

From this viewpoint, we showed that the dissolution of iron can be controlled, and, at the same time, rare-earth elements can be efficiently dissolved by acid leaching at 453K after oxidative roasting, in which both nickel and boron are also dissolved [1].

A method to mutually separate dysprosium and neodymium from this selective leach solution using solvent extraction was then investigated. A process using acidic organophosphorous extractant is proposed on the basis of the experimental data.

Figure 1 shows the effect of the equilibrium pH on the percentage extraction of neodymium and dysprosium with 5 vol% PC88A (active component: 2-ethylhexylphosphonic acid mono-2-ethylhexyl ester) at the unit phase volume ratio. The separation factor, *SF*(Dy/Nd), is also shown, where *SF*(Dy/Nd) is equal to *D*(Dy)/*D*(Nd) and *D* is the distribution ratio defined as the ratio of the metal concentration in the organic phase to that in the aqueous phase. From this figure, it is understood that dysprosium is selectively extracted at a pH 1 - 1.2.

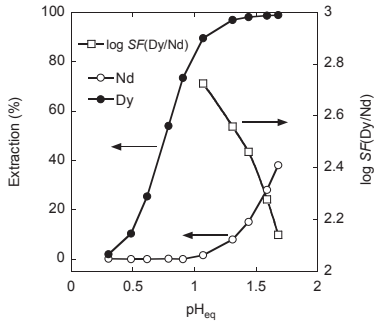


Figure 1. Effect of the equilibrium pH on the extraction of neodymium and dysprosium by 5 vol% PC88A.

3. Nickel recovery from spent electroless nickel plating baths

Electroless nickel plating is now an important surface finishing technology in many fields such as the electronic and automobile industries. However, the treatment of the spent baths is becoming a serious problem. We proposed a nickel recovery process from the spent electroless nickel plating baths using solvent extraction, where the impurity metal ions such as iron and zinc are initially removed by solvent extraction with acidic organophosphorous reagent and then the nickel in the aqueous raffinate is separated by solvent extraction using a chelating extractant, LIX84I (active component: 2-hydroxy-5-nonylacetophenone oxime). The extracted nickel is stripped with sulfuric acid in order to obtain nickel sulfate which is reused in the plating process [2].

Recently, we have done some fundamental studies related to the solvent extraction involved in this process. One of them is to study the effect of aqueous organic acid on the extraction equilibrium of nickel. This is because the electroless nickel plating baths contain considerable amounts of organic acids such as lactic, malic, propionic, and succinic acids as complexants and buffers, and quantitative prediction is necessary to predict the nickel extraction behavior in order to design and control the process.

Figure 2 shows the log *D* values as a function of the equilibrium pH of the aqueous phase at various lactic acid concentrations. The log *D* values monotonically increase with pH and decrease with the lactic acid concentration.

Equilibrium analysis revealed that the decrease in log *D* with lactic acid concentration is due to the masking effect caused by the complexation of nickel(II) ion with lactate anion. It was found that log β_1 = 1.52 ± 0.12 and log β_2 = 2.46 ± 0.12. Here β_1 and β_2 are the overall stability constants for Ni-lactate and Ni-(lactate)$_2$ complexes, respectively. Solid curves in Figure 2 present the fitted values and are in good agreement with the experimental data.

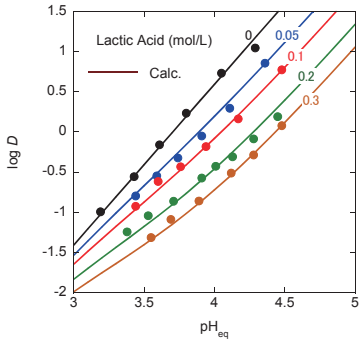


Figure 2. Extraction of nickel with LIX84I in the presence of lactic acid at ionic strength of 1 mol/L.

Acknowledgments

We are deeply indebted to NEDO and JOGMEC for their financial supports.

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Evaluation of novel processes for precious metals recovery using organic aqua regius

Kana Umehara, Akihiro Yoshimura and Yasunari Matsuno*

The University of Tokyo, Japan
*Corresponding author: matsuno@material.t.u-tokyo.ac.jp

1. Introduction

The recovery of precious metals from secondary sources like waste of electric and electronic equipments has received much attention, and various recovery techniques have been developed, e.g. pyrometallurgy, hydrometallurgy and bio-hydrometallurgy techniques. Among these methods, with their relatively low capital cost, reduced environmental impact (e.g., no hazardous gases/dusts), potential for high metal recoveries and suitability for small-scale applications, hydrometallurgical processes are recognized as promising options for the treatment of secondary sources [1]. However, restrictions on waste disposal, safety concerns, and stringent environmental regulations have motivated the further development of economically, eco-friendly and fewer health risk technologies.

Therefore, we have developed a novel method for the recovery of gold using "organic aqua regius": the leaching of gold by dimethyl sulfoxide (DMSO) solutions containing $CuBr_2$ and precipitation by water [2]. We have also investigated the use of a more environmentally benign solvent, Propylene Carbonate (PC) with $CuBr_2$ and KBr for leaching and recovery of precious metals [3]. Our methods offer a number of advantages, including eco-friendliness, ease of operation, low cost and the minimization of chemical sludge production.

2. Characteristics of the precious metals recovery using organic aqua regius

2.1 Leaching of precious metals

In the organic aqua regius, the high redox potentials of precious metals are significantly lowered in the presence of halogens and corresponding halides. In addition, copper (II) ions act as an oxidizing agent and are reduced to copper (I) ions by oxidizing precious metals. It was found that the dissolution rate of gold is relatively large compared with those obtained with other leaching methods [2].

2.2 Recovery of precious metals

2.2.2 DMSO solutions with $CuBr_2$ and KBr

DMSO solvates water in any concentration. The addition of water in DMSO solutions drastically changes the solution characteristics, in particular resulting in high redox potentials of gold in mixed solutions. So, water can be used for the precipitation of gold. Furthermore, DMSO does not form an azeotrope with water and can be separated by distillation, which enables the repeated use of the solutions (Fig. 1).

2.2.3 PC solutions with $CuBr_2$ and KBr

When PC is used instead of DMSO, the dissolved Au and Pd can be effectively separated from other metals by the biphasic separation with sulfuric acid. Then the dissolved Au in the PC solution can be recovered by reduction with ascorbic acid, or calcination (Fig. 2).

3. Cost analysis and LCA

Preliminary cost analyses and LCA were conducted to evaluate the cost and CO_2 emissions for the proposed system of precious metal recovery. Solvents (DMSO, PC), solutes ($CuBr_2$ and KBr), energy required for the processes were taken into account. The results will be presented in the session.

Acknowledgments

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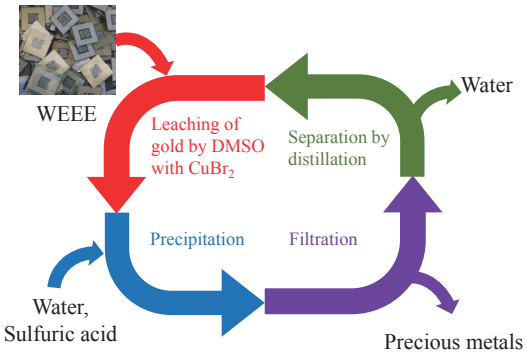


Figure 1 Precious metal recovery system using DMOS solutions with $CuBr_2$

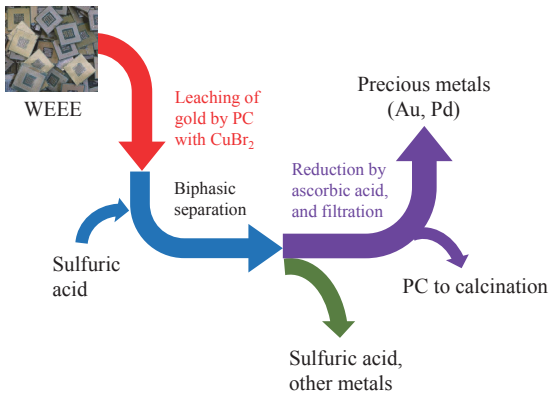


Figure 2 Precious metal recovery system using PC solutions with $CuBr_2$

A recycling system for poly (methyl methacrylate) in Japan

Yasunori Kikuchi,[*1] Masahiko Hirao,[1] Hirokazu Sugiyam,[1]
Stavros Papadokonstantakis,[2] Konrad Hungerbühler,[2] Takashi Ookubo,[3] Akinobu Sasaki[3]

[1]*The University of Tokyo, Japan*;
[2]*Swiss federal institute of technology (ETH) Zurich, Switzerland*; [3] *Mitsubishi Rayon, co., Ltd., Japan*
*Corresponding author: kikuchi@platinum.u-tokyo.ac.jp

1. Introduction

Recycling systems for highly functional plastics such as poly (methyl methacrylate) (PMMA) have not been studied sufficiently. Along with the popularization of PMMA-containing products such as liquid crystal displays (LCDs), the use of PMMA is steadily increasing, which will result in more waste of PMMA in the next decades.

In this study, pyrolysis process for recycling waste PMMA into methyl methacrylate (MMA) monomer was examined considering environmental impacts, chemical hazards and resource availability. We applied life cycle assessment (LCA), environment, health, and safety (EHS) assessment as well as material flow analysis (MFA) to the evaluation of the recycling system as discussed in the previous researches [1, 2]. In this paper, the statistical data is updated on the latest one [3] and further discussion regarding the scenario analyses of the multiple aspects of a process system is performed.

2. Materials and method

A process system has multiple aspects to be examined carefully and designed through adequate analyses of them as shown in the center of Figure 1. Although their importance is different on a case-by-case base, all aspects should be checked by some methods. Especially for recycling system, the environmental performance and the feasibility of the collection of waste with quality enough for utilized technology must be examined. As an industrial process, the safety aspects must be also taken into account in the decision making. Through these analyses, the process system for PMMA recycling is proposed in this study.

Based on the differences between PMMA grades and their life cycles, we developed a life cycle model and designed a range of scenarios for PMMA recycling. We obtained monomer recycling process inventory data based on the operational results of a pilot plant. Using this process inventory data, we quantified life cycle greenhouse gas (LC-GHG) emissions, fossil resource consumption, and the LIME single index. Additionally, process EHS hazards assessment was conducted to quantify the local effects of the PMMA monomer recycling process. Besides the process hazard, the availability of waste PMMA was quantified by analyzing the material flow of PMMA-containing products. PMMA contained in LCDs as light guide panels was selected as a feasible source of waste PMMA and the quantity of PMMA flows in the society was evaluated.

4. Results

Through scenario and sensitivity analyses, we demonstrated that PMMA monomer recycling is more effective than mechanical recycling on environmental impacts evaluated by LCA. EHS hazard assessment results showed the less process hazard of monomer recycling than the production of fresh MMA from crude oil. The implementation of circulated cooling water could significantly decrease the process hazard in PMMA pyrolysis attributable to chemical hazards. MFA revealed that the availability of waste PMMA shows a fluctuating trend in the next 20 years because of the sharp peak demand for LCD television sets around 2010. In fact, the shipment of television sets has been significantly decreased after 2011 July, when the switch over to terrestrial digital broadcasting was implemented.

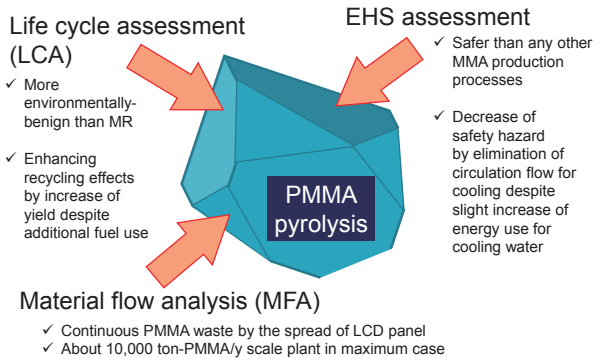


Figure 1. Analyses of multiple aspects of PMMA pyrolysis

6. Conclusion

Through the multiple analyses organized in Figure 1, the PMMA monomer recycling has a potential to achieve a closed-loop recycling of PMMA reducing environmental impacts with a less process hazards than fresh MMA production from crude oil. The availability of waste PMMA has a strong relationship with the lifetime of LCD television sets. The multiple and comprehensive assessments can reveal various aspects of a process technology.

Acknowledgments

A productive discussion on MFA with Dr. Ichiro Daigo is appreciated. Part of this study was supported by a grant-in-aid for scientific research (B) (no. 23360404) and scientific research (A) (no. 24246150) from the Japan Society for the Promotion of Science.

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Life cycle assessment inventory of energy technologies – survey and application to energy technologies

Andrew J. Chapman[1], Benjamin C. McLellan*[1], Tetsuo Tezuka [1]

[1]*Graduate School of Energy Science, Kyoto University, Japan*
*Corresponding author: b-mclellan@energy.kyoto-u.ac.jp

1. Introduction

In the context of future scenarios for energy systems, the operational emissions from a given energy mix are typically cited as the critical environmental criterion. By comparison, when the comparative benefits of alternative technologies are identified, the operational and construction-related emissions are often accumulated into a levelised emissions rate (g CO_2-eq / kWh) across the lifecycle of the technology. The results of such studies often indicate that low-carbon technologies may not be as ideal as their operational impacts imply. Many LCA studies have been produced – often with widely varying results depending on the underlying assumptions utilized.

This study reviewed a wide range of LCA's on energy technologies, and identified important factors for harmonizing alternative studies so that the results could be readily integrated and later adapted to studies of different alternative energy futures. The importance of this harmonization is to create a common basis for comparison, and to thereby enable non-identical conditions to be applied for scenario-building.

In this study, solar (PV), wind, nuclear, geothermal, hydropower and carbon capture and storage technologies were reviewed. Each study was analysed against a set of criteria including: date of study; level of detail; and completeness, and those studies not complying with the requirements were eliminated. The final set of results was compared on an as-presented basis as well as post-harmonisation.

2. Results

Table 1 shows the number of studies considered for each technology, and the initial range (pre-harmonisation) of alternative emissions intensities. These studies were selected from a review of more than 300 studies, but only those capable of being adequately harmonized, recent and sufficiently detailed were chosen. Geothermal and Carbon Capture and Storage (CCS) technologies were also examined, but not presented due to lack of sufficient samples. Harmonisation was undertaken using technology specific factors, particularly the lifetime and capacity factor for most technologies.

Table 1. Technology un-harmonized emissions intensities

Technology and types	Final accepted studies	Emission intensity (g CO_2-eq / kWh)
Photovoltaics (Mono-Si, Poly-Si, Cd-Te thin film)	10	16 - 61
Wind (Onshore, Offshore)	10	6 - 31
Hydro (run-of-river, dam, pumped-storage)	8	4 - 610
Nuclear	10	7 - 527

The wide range of emissions intensity was particularly apparent in the hydropower and nuclear power studies. In the former, the contribution of power mix attributed to pumped storage was the main factor that exacerbated the upper end of the range. In the latter, the assumptions of ore grade, mining and milling energy and mine decommissioning were the largest factors. These are indicative of the challenges to appropriate harmonization of the emissions factors. Further, harmonized factors were presented, and will be described in a full paper.

3. Discussion

Considering the wide disparity between the raw study results for LCA-based emissions factors for global warming potential, the alternative scenarios for sustainable energy systems, and the optimization of such systems on lowest-emissions bases can be drastically altered. As shown in Figure 1, the range of emissions that would be predicted under scenarios for the Japanese energy future would drastically change according to the emissions factors applied. Here we use the emissions factors representing the maximum range for each of the technologies surveyed (assuming that the renewable energy technologies are used in equal proportion) to the scenarios of the Japanese government [1] tested by McLellan et al. [2]. The harmonized figures use the range considered most representative (with the elimination of extreme outliers in the nuclear and hydropower cases).

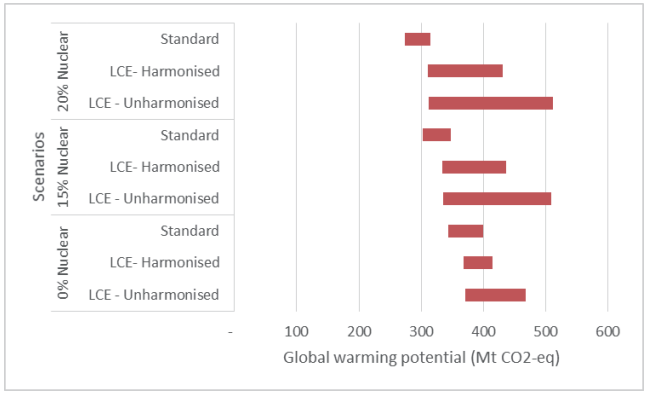


Figure 1. Emissions ranges for Japan – 2030 scenarios (standard values from [2], LCE is the Life Cycle Emissions)

The important conclusions from Figure 1 are that the LCE exacerbates the emissions of each scenario (as expected), but the impact of increasing nuclear is to increase the uncertainty (range) in the emissions, due to the large range of emissions intensities in the studies assessed.

Acknowledgments

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Network Theory Integrated Life Cycle Assessment for an Electric Power System

Heetae Kim and Petter Holme*

Department of Energy Science, Sungkyunkwan University, South Korea
*Corresponding author: holme@skku.edu

1. Introduction

Electricity consumers utilize transmission facilities differently according to their own location and the topological structure of electric power grid. For example, when a consumer lives far from a power plant, he or she requires longer transmission lines than others who live near the power plant. It implies that the formers are more responsible for the environmental impacts of transmission system than the latter.

However, the environmental impacts of transmission facilities are yet to be considered separately. In other words, conversion factors for environmental impact of electric power are set based not on the transmission load as a whole but on the amount of electricity consumption alone. The reasons are twofold. First, the transmission impacts are considerably less than the one of primary resources combustion [1]. In addition, it is methodologically nontrivial to fully reflect complex supply-demand paths on the power grid. Therefore, the environmental impacts of electric power are currently allocated to the users regardless of their transmission facility load.

To circumvent such as discrepancy, in this study, we develop a method in order to properly allocate environmental impacts of electricity to the electricity consumers considering the transmission load. We incorporate network theory [2] to analyze the electricity transmission flow in the electric power grid. We introduce energy distance as an index representing both the amount of electricity consumption and the electricity transmission distance. As a case study, we estimate regional life cycle greenhouse gas emissions caused by electricity consumption in Chile. We show that network-theory-based energy distance is a useful complement to the conventional life cycle assessment (LCA).

2. Method: network theory integration into LCA

We follow the standard LCA protocol [3] to estimate the total greenhouse gas (GHG) emissions caused by the Chilean electric power system. In order to analyze the regional GHG emissions of each substation, we allocate the total GHG emissions according to the functional load of the substation. As a quantitative approach, we introduce *energy distance* as the allocation standard. Figure 1 illustrates our scheme of network integration (gray boxes) added to the standard LCA process (white boxes).

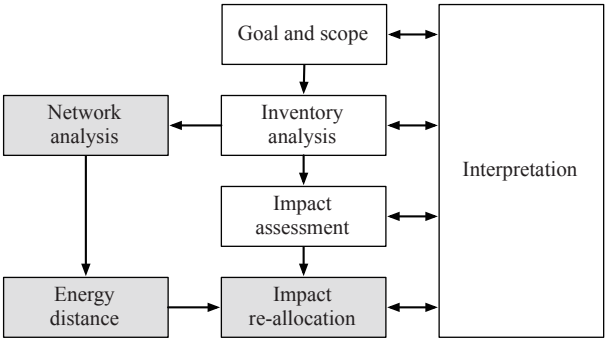


Figure 1. Scheme of network theory integration into LCA

3. Energy distance

Energy distance is a nodal index that enables us to consider transmission distance in addition to the amount of electricity consumption. Given network structure, we analyze the electricity supply and demand pairs, transfer quantity, and transmission path length. The standardized energy distance Ed_i of node i [between 0(no contribution by i) and 1(the entire contribution by i)] is defined as

$$Ed_i = \frac{\sum_{j \in nhd(i)}^{k} f(a_{ij}, d_{ij})}{\sum_{i=1}^{n} \sum_{j \in nhd(i)} f(a_{ij}, d_{ij})} \quad (1)$$

where a_{ij} is amount of electricity transmission and d_{ij} is transmission distance between nodes i and j, $nhd(i)$ is the set of neighbors of node i, n is the total number of nodes, and $f(a,d)$ is the function representing systemic load calculated from the input variables the nodal consumption (a) and the transmission distance (d).

4. Results

The total GHG emissions of Chilean electric power system are 23.07 Mt CO_{2eq}. We reallocate the total GHG emissions to each region according to the energy distance. We confirm that the energy-distance-based allocation reflects real situations of Chilean electric power system. For instance, as a heavy consumer Santiago needs to be supplied through faraway power plants, so that the regional GHG emissions of Santiago are effectively larger than the one solely from energy consumption. In contrast, even though Conception (the largest industrial city in Chile) consumes a large amount of electricity, the transmission loads are not so significant thanks to many local power plants around the city. As a result, the GHG emissions for Conception are effectively smaller than consumption-only-based ones.

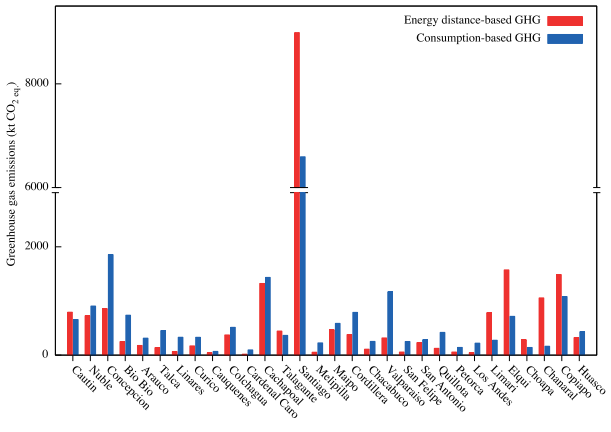


Figure 2. Regional GHG emissions of Chilean electric power

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Life Cycle Greenhouse Gas Emission and Land Use Change Impact on Compressed Natural Gas as Alternative Vehicle Fuel in Thailand

Worayut Saibuatrong, Viganda Varabuntoonvit and Thumrongrut Mungcharoen*

Chemical Engineering Department, Faculty of Engineering, Kasetsart University, Bangkok 10900, Thailand
* Corresponding author: fengtrm@ku.ac.th

1. Introduction

The growth of the natural gas consumption will be driven by increased own production, the development of distribution pipeline network and the need to reduce emissions of Greenhouse gases (GHG) [1]. Natural is gas is a less carbon intensive fuel than diesel and GHG emission reductions can be expected by the use of CNG instead of diesel in vehicle. On the other hand, some of the emissions of interest are in fact higher in the CNG case than their counterparts in the diesel case even though the major items are typically lower. For this reason our comparative analysis of CNG and conventional diesel was conducted using the Life-Cycle Assessment (LCA) method and considering all the GHG emissions produced throughout the fuel's life cycle. The LCA study of Compressed Natural Gas for Vehicles (CNG) production covered the inventory data collection throughout the entire life cycle based on the Well-to-Wheel approach. This study illustrates the change in the carbon balances of LUC for pipeline transportation, using methodology and data from the IPCC Guidelines for National Greenhouse Gas Inventories.

2. Methodology

The LCA study of CNG production covered the inventory data collection throughout the entire life cycle based on the Well-to-Tank approach. This included the natural gas extraction, production and separation, transport and gas service stations, as shown in Figure 1. Since the natural gas extraction, production and separation had already been done by National LCI database [2] and Ecoinvent 2.0 database [3]. Therefore, the scope of this study covered mainly on the natural gas compression process, CNG distribution and the operation at the service stations. Finally, the impact of transportation of CNG distribution to the emission of GHG by both transportations (truck and pipeline) was compared. For pipeline transportation, the land used change (LUC) of the area planned to construct the pipeline was considered. The major sources of information for assessing the GHG emission from LUC are the IPCC methodologies used for the national GHG inventories [4].

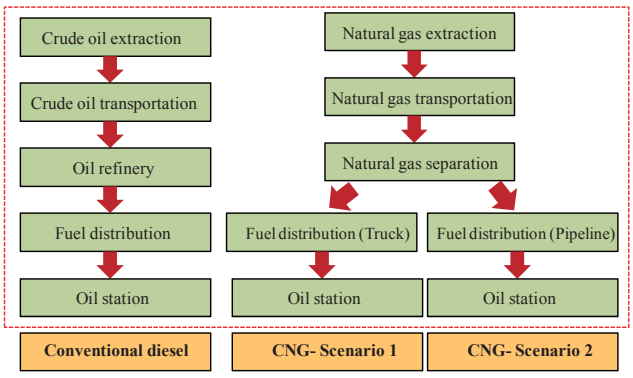


Figure 1. System boundary of this study

3. Results and discussion

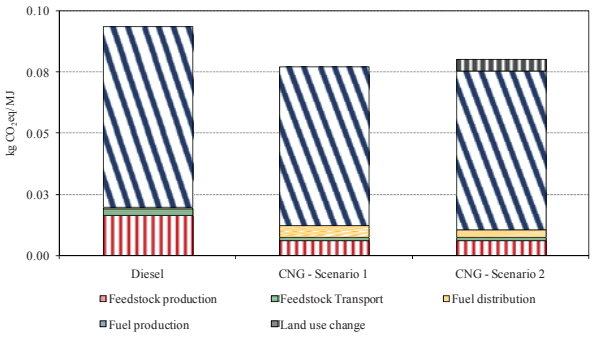


Figure 2. Life cycle GHG emission of diesel and CNG

Life cycle GHG emissions of transportation fuel are shown in Figure 2. The results indicate that life cycle GHG emissions of CNG have 12% lower than conventional diesel, the majority of which was attributable to the fuel production phase. The distribution of CNG by pipeline has increased GHG emission due to GHG emission from LUC.

4. Conclusion

This study compared diesel and CNG fuels for use in vehicles in terms of GHG emissions throughout their life-cycle. The GHG emissions of the CNG distribution have 2 scenario were comparable with those of the diesel cycle. It emerged that CNG afforded a reduction in GHG emissions by comparison with diesel. The distribution of CNG by truck has GHG emission lower than pipeline distribution.

Acknowledgments

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Life Cycle Assessment of Biodiesel in Hong Kong

Ya Hong Dong,[1] and S. Thomas Ng*[2]

[1,2]*The University of Hong Kong, Hong Kong*
*Corresponding author: tstng@hku.hk

1. Introduction

Biodiesel is an environmental-friendly alternative of petroleum diesel. Biomasses, such as soy bean, rape seed, sunflower, palm oil, are usually the sources of biodiesel [1]. It is believed that biodiesel is a carbon-neutral solution, since the combustion of biodiesel generates the same amount of greenhouse gases (GHGs) as those which have been absorbed by plants [2]. Petroleum diesel, produced from fossil fuel that stocks carbon for millions of years, is generally not recyclable. In Hong Kong, biodiesel is made from a multi-feedstock that includes waste cooling oil, grease waste, palm fatty acid and animal fat. About 100,000 tons of low carbon fuel is manufactured in the biodiesel factory and this can lead to 3.6% of GHG reduction in Hong Kong [3].

In this study, a life cycle assessment (LCA) is carried out to evaluate the environmental performance of biodiesel in Hong Kong. The inventory is established based on the material and energy consumed in a local biodiesel factory. Results of biodiesel are further compared with petroleum diesel.

2. Life cycle inventory

The LCA model considers the 'cradle-to-grave' processes, including raw material extraction, in-plant manufacturing, transportation, waste treatment, combustion in engines, etc. In order to analyze the environmental impacts of biodiesel before combustion, 'cradle-to-delivery' processes are studied as well to exclude fuel combustion. The manufacturing process flow chart of the biodiesel plant in Hong Kong is given in Figure 1. The inventory data are mainly acquired from the Project Profile [4]. The Ecoinvent database [5] is adopted to provide the background data of environmental impacts of the processes. The functional unit of biodiesel is 1 kilogram (kg) of biodiesel produced in the Hong Kong plant. As shown in Figure 1, the plant generates three products: biodiesel, glycerin and bioheating oil. The allocation percentages of the three products are proportional to their weights. When establishing the model, it is assumed that carbon dioxide is captured by the biomass, so that carbon sink is calculated to close the carbon balance. No environmental burden is accounted in the waste oil feedstock. Besides, infrastructure is not considered in the model.

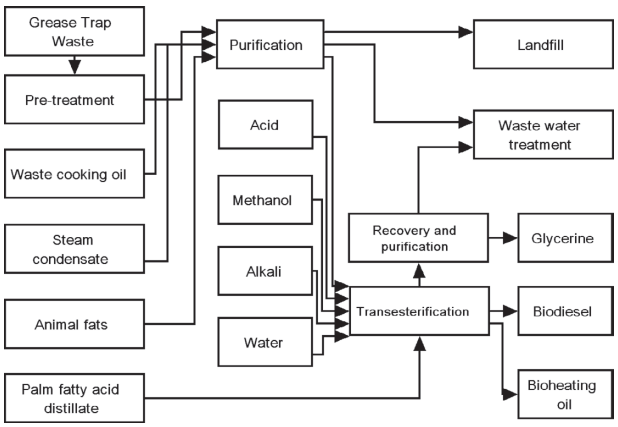


Figure 1. Manufacturing process of a biodiesel plant in Hong Kong (Adapted from [4])

3. Life cycle impact assessment

The impact assessment is carried out using 'ReCiPe' [6] and the results are computed in SimaPro 7. It is found that the carbon emissions to produce 1 kg of biodiesel is 0.32 kg. By considering the carbon sink to biomass, the net carbon balance is -2.2 kg, indicating that the carbon emitted to produce biodiesel is less than the carbon captured in the biomass. The results show that the carbon emission is 33.2% originated from material manufacturing and 47.6% due to in-plant processes.

The LCA model also considers other impact categories of ozone depletion, human toxicity, particulate matter formation, eutrophication, ecotoxicity, metal depletion, etc.

4. Comparison with petroleum diesel

The environmental impact of biodiesel is further compared with the impact of petroleum diesel. It is found that biodiesel performs much better than petroleum diesel in most impact categories, except agriculture land occupation. The endpoint score of biodiesel is -0.069 (combustion excluded), indicating that by considering the processes from 'cradle-to-delivery', biodiesel has positive environmental impact and can considerably reduce the carbon emissions as compared with petroleum diesel. If the combustion process is included (i.e. 'cradle-to-grave'), the environmental impact of biodiesel is much less than that of petroleum diesel. Single score of biodiesel becomes 0.16, which is much less than 0.53 of petroleum diesel. This indicates that the environmental impact of biodiesel is only about 30% of petroleum diesel.

5. Conclusions

Environmental impacts of biodiesel produced in the biodiesel plant in Hong Kong were studied using LCA. The impact assessment results were compared to petroleum diesel. The results indicated that petroleum diesel can lead to about three-fold of environmental influence of biodiesel when 'cradle-to-grave' life cycle processes are considered.

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Ecological Effects from Operating a Biomass Power Plant

Akito Murano, [1] Satoshi Nakano,[2] and Ayu Washizu*[3]

[1]*Toyo University, Japan*; [2]*The Japan Institute for Labour Policy and Training, Japan*; [3]*Waseda University, Japan*
*Corresponding author: washizu@waseda.jp

1. Introduction

Introducing renewable energy sources is indispensable to construction of an energy system that is not only sustainable but also resilient. Toward these ends, we have studied the effect of the spread of power generation using renewable energy using input-output analysis. As the existing Japanese input-output table doesn't include renewable energy activities, we construct an extended input-output table for the analysis of renewable energy based on technical literatures and interviews. (See Nakano and Washizu [1].) In this study, we focus in particular on the effects of constructing and operating a biomass power plant with a capacity of 5700 kW. The operation of such a power plant may result in preservation of the nearby forests, so we also estimate the amount of public benefit from preservation.

In the following sections, by using our input-output table, we first estimated output and CO_2 emissions induced by construction and operation of a woody biomass power plant, and the amount of CO_2 reduction from reducing the amount of fossil fuel used in thermal power plants. Then, we estimated increased CO_2 storage from forest preservation domestically and overseas, and calculated reducing fuel used for marine timber import. Finally we estimated public benefit from the preserved forest as a monetary amount using a method of cost-benefit analysis on public works projects.

2. Method

We calculated the direct and indirect effects of constructing and operating a biomass power plant by using a conventional static open IO model. For estimation of increased CO_2 storage from forest preservation, we calculated CO_2 absorbed by photosynthesis. Figure1 summarizes the using method of cost-benefit analysis. See Nakano, Murano and Washizu [2] for details.

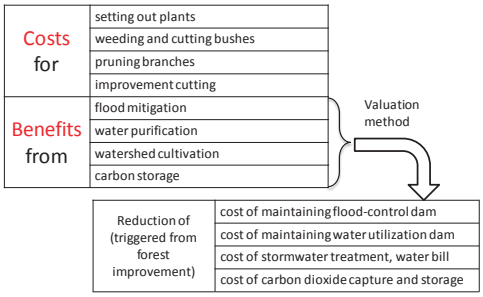


Figure 1. Cost and benefit analysis for forest preservation by Forestry agency (MAFF)

3. Results

Table 1 shows annual monetary effect induced by construction and operation of a woody biomass power plant. The total annual monetary effect of a biomass power plant is 4.822 billion yen. A plant of 5700kW can generate 46.4GWh of electricity per year. The procurement cost of electricity generated from unused woody biomass is 34.56 yen (after tax) per kWh under the current feed-in tariff, so 46.4GWh of electricity earns about 1.6 billion yen. We can see the monetary effect of a biomass power plant is 3 times as large as the amount spent.

Table 2 shows annual environmental effect of a woody biomass power plant. The total environmental effect of a constructing a woody biomass power plant is a reduction of 52,881 t-CO_2. In our previous study [3], we found that annual household CO_2 emissions total about 7.5 t-CO_2, so this amount corresponds to CO_2 emitted by 6,500households.

Table 1. Annual monetary effect of a biomass power plant (5700kW) (billion yen)Page dimensions

*Service life:15 years

	Construction*	Operation	Increase in public benefit
Direct	0.184	1.560	1.920
Direct +Indirect	0.436	2.466	

Total inducement 4.822 billion yen

Table 2. Annual environmental effect of a biomass power plant (5700kW) (t-CO_2)

	CO_2 emission	
	construction*	operation
Direct	16	339
Direct + Indirect	503	1,261
Total	(a) 1,764	

*Service life: 15 years

	CO_2 storage or reduction			
	Substitution effects for thermal generation	Increase in CO_2 storage by domestic forest	CO_2 storage by preserved foreign forest	Reduction of CO_2 from ocean transport of timber
Direct	-30,485	-3.76	-5,200	-18,508
Direct +Indirect	-30,934			
Total	(b) -54,645			

4. Discussions

Woody power generation brings favorable effects to Japanese forest areas, so we should encourage construction of power plants like these using a feed-in tariff, which are subsidies that stimulate plant investment. However, in the case of woody biomass generation, the operational cost, namely the fuel cost, is considerably high, so a feed-in tariff or similar subsidy is needed after capital depreciation. From there, the subsidy can triggers many favorable effects for the local economy and environment.

Acknowledgments

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Load flexible power plant concepts – a comparative analysis from a life-cycle perspective

Witold-Roger Poganietz,*[1] Yasushi Kondo,[2] Hans-Joachim Gehrmann,[1] and Shinichiro Nakamura [2]

[1]*Karlsruhe Institute of Technology, Germany*; [2]*Waseda University, Japan*
*Corresponding author: poganietz@kit.edu

1. Introduction

The strategic goal of the German government is to establish a sustainable energy system. The keystone of such a system is the use of renewable energy carriers [1], whereas solar and wind energy will dominate power generation (e.g. [2]). These renewables are characterized by the intermittency of supply. A possible way to bridge diverging demand and supply pattern are load flexible power plants, like gas power plants. An alternative could be to increase the flexibility of grate stoker furnaces by combining them with dust furnaces. Depending on the used feedstock the environmental impacts of energy conversion could be reduced. Furthermore, the international dependency of Germany on imported energy carriers could decline either, increasing the internal energy supply security.

In the following the economy wide environmental impacts are discussed, when load flexible power plant concepts could enter the market of electricity. Furthermore potential impacts on energy carrier imports will be analyzed.

2. Load flexible power plant concept

The proposed plant concept consists of a grate firing which is operated in base load mode and a dust burner which is operated in peak load mode (s. Figure 1).

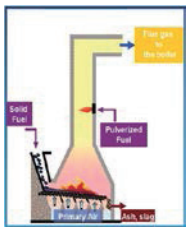


Figure 1. Scheme of a load flexible power plant concept [own compilation]

The feedstock of the grate firing is hard coal. The flexible burner will be fed either with pulverized biomass (variant I) or with pulverized reduced derived fuels (RDF) (variant II).

3. Method

To assess the economy wide environmental impacts of establishing load flexible power plants in a first step a physical Input-Output model of Germany, named Carbon-PIOT, is combined with ReCiPe methodology.

Carbon-PIOT depicts the carbon relevant material flows in Germany in a setting of a physical input-output table. The approach makes use of CarboMoG [3]. CarboMoG (short for carbon flow model of Germany) is a dynamic process-based material flow model of the German carbon system, which links carbon flows on the scale of production processes. The backbone of Carbon-PIOT is 369 production processes with about 332 carbon-related material and energy flows. In contrast, the German Input-Output Table consists of just 71 processes on the scale of sectors. The reference year is 2005.

In a second step scenarios is created and calculated. A reference scenario with no load flexible power plants will be compared with a scenario with this type of power plants. In the latter scenario load flexible power plants will experience a market share of 6.75%. Assuming that load flexible power plants will crowd out about 50% of gas and oil power plants, their market shares will decline respectively. Since the impacts depend crucially on the assumed power mix, two different cases are analyzed. The first case depicts the power mix in 2005; the second one considers a power mix, which is dominated by solar and wind energy [2].

The assessment of the reliability of imports makes use of the REES index, which also considers political and institutional stability of export countries [4].

4. Discussion of the results

The environmental impacts of substituting mainly gas power plants by load flexible power plants are not clear. On the one hand, mainly methane emissions would decline in any case analyzed. On the other hand, coal induced carbon emissions and RDF induced emissions (variant II) will increase. Depending how biogenic emissions are valued, additional emissions could occur in variant I. All in all, the global warming potential shall increase; but the entire impact depends on the chosen time horizon and on the power mix.

The market entry of load flexible power plants will change the import mix of energy carriers. The share of gas and oil will decline. On the other hand, imports of coal and to some extent biomass shall increase; RDF is assumed not to be traded internationally. With the change of the import mix the relevance of specific export countries will alter, too. The main supplier of gas is Russia, whereas the main suppliers of coal are amongst others Colombia, Russia and USA. Depending on how the political stability is assessed the switch in the export countries could lead to an increased security of supply.

5. Concluding remarks

Balancing power supply and demand in a system with dominant solar and wind energy is demanding. Convincing solutions are still not available, but different options are discussed. Whether load flexible power plants could fulfill the expectations depends crucially on the success of competing technologies, like storage systems. But also whether technological problems of the concept, like controlling or combustion behavior of biogenic inputs, could be solved is relevant.

Acknowledgments

Funds of the Japan Society for the Promotion of Science are gratefully acknowledged.

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Small Hydro Power Plants: A Modular LCA Approach for Optimization

Beatrix F. Becker,* Liselotte Schebek

Technische Universität Darmstadt, Germany
*Corresponding author: b.becker@iwar.tu-darmstadt.de

1. Introduction

Small Hydro Power Plants (SHPP) do interest as renewable energy technology for mitigating climate change. There is a large variety of sites for SHPP, resulting in a large variety of possible individual technological solutions: SHPP combine different components and their variants like rake and hydraulic machinery. Yet nature conservation also has to be considered, notably as to the inclusion of fish passes. As to ecological assessment, several LCA studies are available [1][2][3][4], however they don't display current developments in technology nor river continuity, which is requested by the EU commission. So, in order to support the ecological assessment and optimization for future SHPP, a novel approach for LCA and an appropriate database are needed.

The lay-out of SHPP requires the technological approach a hydraulic dimensioning as a first step. Further an economic evaluation is performed, which may change the first outline of components. In addition, specific local framework conditions have to be met, usually leading to individual solutions. This technological approach is costly reverted to the energetic output of SHPP which is rather low. So, different technological components and all their variants have to be analyzed regarding their ecological assessment in consideration of the efforts needed for different locations. Therefore, the following approach aimed for a parameterized procedure.

2. Method

Modular LCA follows the technological approach described above. Parameterized unit modules provide the database from which the product system for a specific plant is generated. To develop this database, datasets for components of SHPP have been developed from literature evaluation, producer information and site investigations. This modular database uses open source software developed in a project for LCA of bioenergy *(BioEnergieDat)*. So, datasets are compatible and convertible. Based on this database, our methodology for optimization combines the following steps:

1. *Input of parameter by user*: specific local framework conditions (head, flow rate, fish species, natural requirements)
2. *Automatized generation of combinations and their LCI-Data by program*: definition of variants with input parameters and background information within the program, combinations added by LCI-Data, based on existing and newly generated datasets for technological components
3. *Generation and optimization of LCIA results of variations by program*: evaluation of all combinations by impact categories (global warming potential (GWP) and cumulated energy demand (CED)), optimization by input parameters

3. Results

Following the aforementioned methodological approach, a case example is displayed, wherein all technological combinations were estimated and the best and worst combinations were calculated for the LCIA category GWP_{100}. As input parameter in Table 1 the values are shown. With the input parameter the parameterized LCI-datasets of technological components will be calculated. Here the number of technological variants varies: Rake (10), bypass (7), fish pass facility (2), hydraulic machinery (3) and generator (1). Figure 1 shows the result of the variations of components for the case example. These range from 0,062 $kgCO_{2eq}$/kWh up to 0,082 $kgCO_{2eq}$/kWh.

Table 1: Input parameter in case example

Parameters	Value
Head	2 m
Flow rate	0.5 m³/s
Fish species	Zander
Intake sizes	5m x 4m
Natural requirements	River continuity

Here, the characteristic picture of the variants results from the high influence of the fish passes facility on the total emissions. But, it is also obvious, that the percentage share of technological component varies depending on each variation. For example the share of hydraulic machinery on total emissions varies from 1% (in minimum) up to 12% (in maximum).

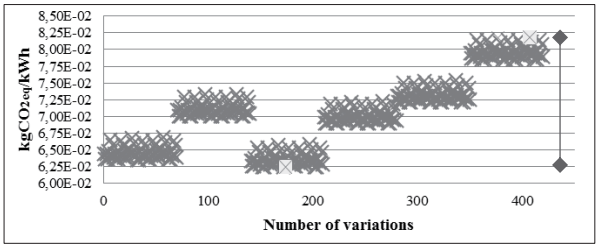


Figure 1. The GWP_{100} of variation of technological components of SHPP

With this methodological approach and implementation in a program structure, it is possible to calculate a high number of technological component variations (here: 420) very easily.

5. Discussion

The open modular programming structure ensures the extension of this methodological approach for more component variants, impact categories and for the transition of other energy technologies. So, the currently existing datasets do not display all components of SHPP neither all existing technological variants yet. More datasets will be created, parameterized and validated in the future. So more studies will be analyzed for a more detail view of total emission and the influence of technological components depending on input parameters.

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Global flow of nickel: Identifying its supply chain and implication for sustainable resource management

Kenichi Nakajima*[1], Keisuke Nansai[1], Hiroya Yamano[1], Kazuyo Matsubae[2], Shinsuke Murakami[3], Yuto Ohtsuka[2], Yasunori Iwatsuki[3], and Tetsuya Nagasaka[2]

[1] *National Institute for Environmental Studies, Japan*; [2] *Tohoku University, Japan*; [3]*The University of Tokyo, Japan*
*Corresponding author: nakajima.kenichi@nies.go.jp

1. Introduction

The UNEP International Resource Panel pointed out the importance of decoupling resource use and negative environmental impacts from economic activity. The economic growth also induced a rapid rise of metals, and sometimes the green technology, such as low carbon power generation, triggered the rapid rise of metals and minerals. Nickel and nickel-containing materials play a major role in modern society, which are also key materials for low-carbon technologies. At the same time, environmental risks and challenges are always attaching through the life cycle of nickel-containing materials, and the biodiversity impact by nickel ore mining has also received attention in recent years [1]. In this study, we present the results of global material flow analysis of nickel, and discuss the importance and possibility to control its resource logistics. This study also introduces the challenge to identify the land-use changes in nickel mining site by remote-sensing technique, and knowledge to increase the resource efficiency in recycling based on metallurgical thermodynamic approach.

2. Global supply chain analysis of nickel

This study clarified the worldwide nickel flow in the global supply chain by analysing the volume of international trade among the world's 231 countries and regions. For considerations of space, we omit a description on the methodology. (Please see the detailed descriptions of methodology in previous publications [2-3]) With respect to the volume of international trade, we extracted trade volumes for each commodity group in monetary or physical units for 231 countries and regions, using the BACI (Base pour l'Analyse du Commerce International, CEPII). The estimates were converted to the flow of nickel embedded in trade by multiplying the values by the nickel content rate of each of the goods available from various sources and the WIO-MFA model [4-5].



Figure 1 The 50 largest global flows of iron through international trade in 2005

The result of our analysis indicated that the worldwide follow of nickel though the trade in 2005 was 2.7×10^6 t-Ni, with the largest 10 flows accounting for 17% of the entire flow of nickel among 231 countries and regions, and largest 50 accounting for 43% (Figure 1). The percentage of the BRICS and the Next Eleven in the worldwide flow is worthy of special mention. The BRICS excluding China accounted for 5% in the world's resource imports. Adding the N-11, the percentage of 15 countries was no more than 11%. These results indicate the vital importance of Japan's and Europe's actions to control the nickel supply chain and its environmental impacts.

3. Land-use changes in nickel mining sites

The quantitative analysis on the relationship between the land-use changes and mineral production is quite few, and thus the effect of mining on land-use change, and further environmental impacts, remains to be examined. This paper performed a preliminary case study in New Caledonia, because it is a major nickel mining area, and is also known as one of the biodiversity hotspots, where exceptional concentrations of endemic species are suffering from extensive decreases in their habitats [6]. The laterite nickel deposits are relatively thin and usually located close to surface, therefore the depth of the pit will be shallow. We chose five mine sites at which Société Le Nickel operates, and compared the temporal changes in land use with statistics of nickel ore production published by SNL Metals & Mining. We used historical satellite images to reconstruct temporal changes in bare land areas due to mining activities from 1999 to 2012. Figure 2 shows the cumulative nickel production and land-use change in nickel mining site from 1995 to 2012. Our result shows four out of the five mine sites have similar tendency of land-use change per kg-Ni of nickel of mining, however the Tiebaghi mine site has quite large land-use change. From the satellite image for 2007 in the Tiebaghi mine, we observed a new facility on the western side of the mine. Then, in 2012, we also found out a new area was under development (stripped) at the northern side of the current pit. The area was not in operation stage and therefore not related to the production until 2012, while the area was not small compared with that of the pit.

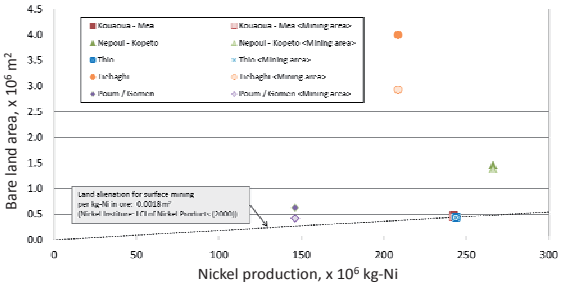


Figure 2: Cumulative nickel production and land-use change in nickel mining site (from 1995-2012)

Acknowledgments

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Sustainability of Rare Metal Supply Chains from Unconventional Resources

Glen Corder,*[1] Saleem Ali, [1] Artem Golev, [1] and Ben McLellan[2]

[1] *Centre for Social Responsibility in Mining, Sustainable Minerals Institute, University of Queensland, Australia*; [2] *Graduate School of Energy Science, Kyoto University, Japan*
*Corresponding author: g.corder@smi.uq.edu.au

1. Introduction

There has been heightened interest in rare earths in recent years driven by a variety of reasons, including concerns over the security of supply for modern high efficiency electronics and energy technologies. As a result, rare earths have been placed on the list of "critical" or "strategic" elements in countries such as the United States of America (USA), the European Union (EU), Japan and in the largest producer and holder of reserves, China [1].

This increasing demand for rare metals and subsequent price fluctuations as well as potential squeeze on supply of conventional resources has been prompting examination of unconventional resources such as recycling, urban mining and deep ocean resources.

2. Potential from Unconventional Resources

By utilizing an industrial ecology approach, extraction, recycling and re-use of rare earths metals from unconventional sources is possible and thereby both influencing their supply and implementing solutions that are a means of retaining materials in a circular economy. Industrial ecology, using nature as a metaphor, closely examines the opportunities to reuse and recycle different waste streams arising in industrial and consumer activities, as well as reorganizing the industrial systems to ensure resource efficiency and resilience [2]. Such examples of industrial ecology for rare earths are shown below.

The potential for the recovery of rare earths via recycling of low value waste streams such as bauxite residue, phosphogypsum, waste water, slag and mine tailings has recently been examined by workers; and in addition there is continuing activities in recycling of end-of-life batteries, fluorescent lamps and magnets [1]. Deep sea mining is a new potential high concentration source of rare earths with numerous sites being identified throughout parts of the Pacific [3]. Coal and coal ash are another potential unconventional resource for rare earths [4].

There are also environmental benefits from unconventional resources. Environmental impacts related to extraction, processing and final application of rare earths from mining are positive in terms of clean energy and negative in terms of waste. However, high environmental impacts of rare earth mining and processing (on a per kg basis), as indicated by life cycle assessment, coupled with supply constraints provide a sound incentive to investigate recycling and recovery of rare earths or minerals containing rare earths [5].

The resistance to social aspects of rare earths mining typically is related to concerns about environmental and health impacts making it more difficult to gain approvals of new mine sites in some countries, such as Australia and the USA. This is also another driver for sourcing rare earths from unconventional sources where the concerns of environmental impacts can be potentially minimized.

3. Applying Industrial Ecology

Although utilizing unconventional sources for rare earths can appear more attractive than conventional sources, there are, however, challenges for the implementation of industrial ecology solutions that are more than technological, especially when organizational boundaries are crossed. Having a thorough understanding of these challenges greatly helps in identifying the barriers and enablers to developing feasible industrial ecology strategies that can move a group of commodities, such as rare earth metals, closer to a circular economy paradigm and in doing so deliver enhanced sustainability benefits. Determining factors related to the industrial ecology barriers and enablers include: suitable economic returns for businesses along the circular value chain, fitting regulations that encourage an industrial ecology approach, technical feasibility for recovering value from waste materials and availability of information and data across businesses that have traditionally not necessarily worked together [6]. It is important to weigh up these factors when comparing with the production of rare earths from conventional mining.

4. Conclusions

The demand for rare earths will drive the interest in sourcing rare earths from unconventional resources. This extended abstract has illustrated some potential unconventional resources and associated challenges for extracting or recovering rare earths. However, each needs closer examination of their life cycle sustainability impacts, focusing on the technological constraints, social responsibility and environmental implications, to fully understand potential benefits and possible detriments. Without such knowledge, appropriate systems and policies cannot be developed.

Acknowledgments

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Refinement of a Simulation Model to Analyze the Formation of Urban Mines with Demonstrative Experiments

Hitoshi Komoto,*[1] Shinsuke Kondo,[1] and Keijiro Masui[1]

[1]*National Institute of Advanced Industrial Science and Technology, Japan*
*Corresponding author: h.komoto@aist.go.jp

1. Introduction

Used products accumulated at the end of life cycles are potentially used as alternative reserves of natural resources, and thus named urban mines [1]. To promote the development and utilization of urban mines in Japan, a law about the recycling of Small Waste Electrical and Electronic Equipment (SWEEE) was introduced in 2013 [2]. Related work has quantified the impact of the recycling processes of specific metals from urban mines in terms of the total material requirement (TMR) and compared the TMR from urban mines with that of from natural mines (e.g., [3]), which addresses the superiority of the recycling of specific metals (e.g., gold, silver, and coppers) from urban mines to the extraction of these metals from natural mines. However, these studies have excluded the investigation of the potential amount of these metals recovered with these processes from the scope of the study.

To estimate the amount of metals recovered from urban mines with the current state of the art of recycling processes, the authors have developed a simulation system to analyze the formation of urban mines [4]. The system deals with the geographical distribution of the users of products, local governments, and operators in the recycling processes in Japan, and their rational decisions about the execution of operations. This report introduces the simulation model and a type of empirical data recently collected by the Ministry of Environment [5] used to refine the simulation model.

2. Overview of the simulation procedure

Figure 1 shows the overview of the simulation procedure. The simulation uses the following information as inputs.

- Physical and material composition of products, which defines the recycling processes applied to the products and their inputs and outputs, and their prices.
- Population, location, and area of local governments, which define the distributed amount of used products.
- Location of operators in the recycling processes (e.g., mechanical separation and refinement).
- Fixed and variable costs of the recycling process, and transportation costs.

With these inputs, the simulation computes the execution of individual recycling process that generate the transportation and transformation of products, parts, and materials defined in their physical and material composition. Finally, the simulated results are visualized as material flows and the breakdown of profits and costs of the operators in the recycling processes. Figure 2 shows illustrative results of the simulation. The gray dots show the location of the local government. The red and blue spots indicate the accumulation of different types of metals of specific recycling processes.

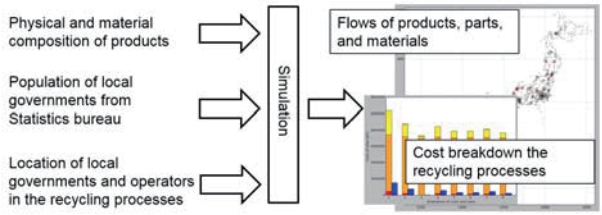


Figure 1. Overview of the simulation procedure

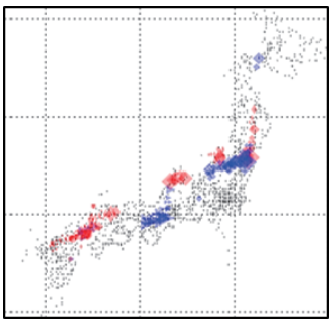


Figure 2. Illustrative results of the simulation

3. Demonstrative experiments

Ministry of Environment started to conduct demonstrative experiments about SWEEE collection with participation of more than 40 local governments (which have 3.8 million population in total) [5]. In spite of the limited period, they could collect over 20,000 units (over 42,000 kg) of SWEEE. In comparison, the target amount of SWEEE to be collected is 1kg per person per year, which is 20% of the amount of disposed SWEEE in 2011 [2]. Since the number of the experiments is still limited, the results are not enough to perform the analysis of the collection process from a statistical viewpoint. Similar experiments are planned in this year [5].

4. Future work

The input of the simulation model will be refined with the information obtained from the demonstrative experiments, which includes the deviation of the total amount of collected SWEEE regarding the regional characteristics (e.g., geographic and demographic population distribution), collection means (i.e., box, station, pick-up, and event-type collection), and seasonal characteristics, and the proportion of collected SWEEE in terms of product types. The information about the state of the art of recycling processes for SWEEE is also crucial to estimate the amount of metals and other resources recycled from SWEEE.

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Quality-Oriented End-of-Life Vehicle Scrap Recycling Aimed at Efficient Utilization of Steel Alloying Elements

Hajime Ohno,*[1] Kazuyo Matsubae,[1] Kenichi Nakajima,[2] Yasushi Kondo,[3] Shinichiro Nakamura,[3] and Tetsuya Nagasaka[1]

[1]*Tohoku University, Japan*; [2]*National Institute for Environmental Studies, Japan*; [3]*Waseda University, Japan*
*Corresponding author: fy11041@mail.kankyo.tohoku.ac.jp

1. Introduction

For the achievement of quality-oriented steel recycling, exogenous contamination should be avoided by the removal of contaminant before re-melting. Although alloying elements (AEs) should also be removed, they cannot be separated mechanically because they are alloyed with iron matrix. Therefore contents of AEs in recycled steel must be controlled within requirement and/or regulation during re-melting process to save not only the quality of steel but also precious AEs.

For this background, focusing on the recycling of AEs in End-of-Life vehicle derived scrap (ELV-dSS), this study evaluated alloying elements contents in an ELV-dSS by means of input-output (IO) based material flow analysis. Furthermore, efficient use of AEs oriented ELV-dSS recycling was optimized by integrating IO with linear programming (LP).

2. Methodology

This study considers an LP model to find out optimal technology choices to utilize ELV-dSS in crude steelmaking by electric arc furnace (EAF), which is the main process to recycle iron and steel scrap. Let there be n^g goods- and service-producing sectors (hereafter 'goods sector') except sectors of crude steel made by EAF, n^{cs} crude steel made by EAF sectors (hereafter 'EAF-CS sector'), and n^{ss} ELV-dSS sectors. The present LP model is concerned with identifying which types of EAF-CS should be made from which types of ELV-dSS. Formally, the problem is given as follows

$$\text{minimize} \quad \mathrm{R}_g\mathrm{x}_g + \mathrm{R}_{cs}\mathrm{x}_{cs} \tag{1}$$

$$\text{subject to} \quad \mathrm{x}_g = \mathrm{A}_{g,g}\mathrm{x}_g + \mathrm{A}_{g,cs}\mathrm{x}_{cs} + \mathrm{f}_g \tag{2}$$

$$\mathrm{H}_{cs}\mathrm{x}_{cs} = \mathrm{A}_{cs,g}\mathrm{x}_g + \mathrm{A}_{cs,cs}\mathrm{x}_{cs} + \mathrm{f}_{cs} \tag{3}$$

$$\mathrm{x}_{ss} = \mathrm{A}_{ss,cs}\mathrm{x}_{cs} + w_{ss} \tag{4}$$

$$\mathrm{x}_g \geq 0_{n^g}, \mathrm{x}_{cs} \geq 0_{m^{cs}}, \mathrm{x}_{ss} = 0 \tag{5}$$

where R_g and R_{CS} are $1 \times n^g$ and $1 \times m^{cs}$ $(n^g \leq m^{cs})$ vectors representing the objective function, x_g, x_{cs} and x_{ss} are output vectors of goods sector, EAF-CS sector and ELV-dSS, respectively, As are input coefficient matrices, and fs are final demand vectors. The vector w_{ss} indicates weights of each ELV-dSS in negative values. In this model, ELV-dSS is supplied exogenously and there is no process producing scrap in the IO system. Consequently, equation (4) is the constraint representing that all amounts of supplied ELV-dSS are used in EAF-CS making process. The (i,j)-component of $\mathrm{A}_{g,g}$ (or $\mathrm{A}_{g,cs}$) refers to the input of the ith goods par unit of production of the jth goods (or the jth EAF-CS sector, respectively). The (i,j)-component of $\mathrm{A}_{cs,g}$ refers to the input of the ith goods par unit of production of the jth goods. Because crude steels are not input to other crude steelmaking, $\mathrm{A}_{cs,cs}$ is basically zero in this model. The (i,j)-component of $\mathrm{A}_{ss,cs}$ refers to the input of the ith ELV-dSS par unit of in EAF-CS production. H_{cs} is $n^{cs} \times m^{cs}$ matrix of zeros and unities, and its (i,j)-component h_{ij} is defined as

$$h_{ij} = \begin{cases} 1 & \text{technology } j \text{ produces goods } i \\ 0 & \text{otherwise} \end{cases} \tag{6}$$

This matrix to calculate the total quantity of each crude steel produced by multiple technologies was employed, for example of the application of matrix H, see Kondo and Nakamura[1]. The objective function Rs consists of zeros and unities to see the changes in productions of AE virgin souces caused by utilization of ELV-dSS for simplicity in this paper.

3. Results and discussion

Focusing on the efficient recycling of AEs in the ELV-dSS, the matching of each part scrap and secondary steels were optimized by means of IO-based LP. Figure 1 (upper half) shows optimized matching of separated ELV-dSS with steel materials to efficiently recycle AEs in the ELV-dSS under the objective function aimed at minimizing total consumption of virgin sources of AEs. Relatively low AEs concentration of parts scrap such as body, steering, and breaks were mainly matched with ordinary steel. In contrast, parts scrap which have over 0.5% of AE concentration such as suspension, shaft, and exhaust tend to be used to produce alloy steels in the optimal matching. As a consequence of the optimized utilization, 88% of AEs contained in ELV-dSS were efficiently used as secondary AEs source in secondary steelmaking.

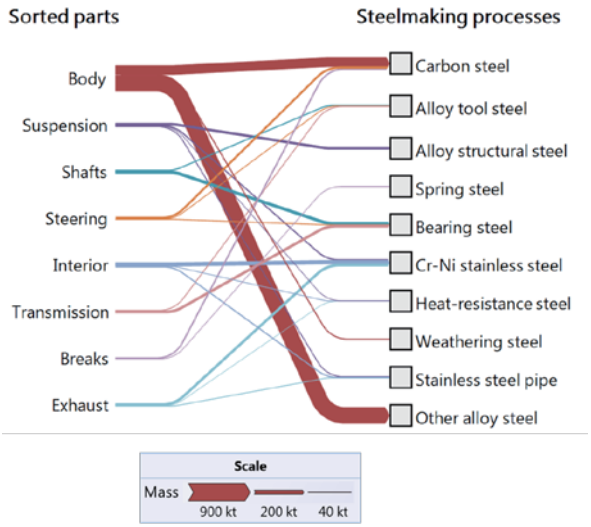


Figure 1. Optimized matching between sorted ELV-dSS and secondary steels

Acknowledgments

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Measuring supply risk footprints of critical metals for Japanese goods and services

Keisuke Nansai*[1], Kenichi Nakajima[1], Shigemi Kagawa[2], Yasushi Kondo[3] and Sangwon Suh[4]

[1]*National Institute for Environmental Studies, Japan,* [2]*Kyushu University, Japan,* [3]*Waseda University, Japan*, [4]*University of California Santa Barbara, USA;*
*Corresponding author: nansai.keisuke@nies.go.jp

1. Introduction

Exotic metals, which are those metal resources that are particularly essential to future energy technologies but to which access is limited to certain counties where they are mined, are recognized as critical metals [1-3]. Discussions are taking place [1-4] regarding their economic importance, as well as the risks from a resource security perspective. In light of the dependence of the Japanese economy on all import of such critical metals through international supply chains, it is increasingly becoming important to identify the amount of their supply security related to Japan. Against the background, this study proposed a new index to measure supply security of the metals for a nation using the concept of an environmental footprint. Especially, the mining risk and trade risk are considered as key factors that compose supply security. In this paper, we describe the methodology to identify the mining risk that a nation bears as mining risk footprint (MRF) of a nation. The case study of MRF calculation for Japan in 2005 was performed.

2. Methods and data

First, the international trade through which critical metals moved from countries of origin to consumption countries was examined using material flow analysis (MFA) based on a global system boundary [5]. The MFA encompasses 231 countries and regions and considered all trade commodities that would contain the metals. Our focused critical metals are neodymium (Nd), which is used for motors associated with wind power and EV, cobalt (Co), for electrodes in EV batteries and platinum (Pt) for catalysts in fuel cells.

Subsequently, a global link input-output model (GLIO) [6] that incorporates the MFA data obtained above was used to calculate the output of the metals in mining courtiers or the material footprint [7] which Japan caused directly and indirectly. The GLIO is designed to reduce the labour required for data compilation by employing a simple accounting framework that differs from that of conventional multiregional input-output models. The accounting framework of GLIO enables the definition of about 400 sectors of the Japanese products, the inclusion of 230 nations and regions except for Japan.

Then, we combined the metal output g_p^{JPD} (MF) induced by Japanese domestic final demand measured and the mining risk value η_p of mining country p, and quantified the mining risk footprint of the Japanese economy. The basic concept of an environmental footprint index is the allocation of an environmental burden such as carbon emission in a country to each country that induces the environmental burden on the basis of some allocation factor closely related to the generation of the environmental burden. In the same manner, we allocated η_p to a country that induces the mining in country p in proportion to the share of output induced by the country in the total output of country p. Specifically, when the annual total output of country p is g_p and the output induced by Japan is g_p^{JPD}, η_p (g_p^{JPD}/ g_p) of country p's mining risk is attributed to Japan. Then this mining risk was normalized by dividing by the global mining risk η, and MRF (%) of Japan was determined.

3. Results and discussion

MRFs of Japanese final consumption were measured as 10.3 % for neodymium, 5.0 % for cobalt, and 14 % for platinum, measured in % of global mining risk of each material. The MRFs of Japan were all dominated by export demand.

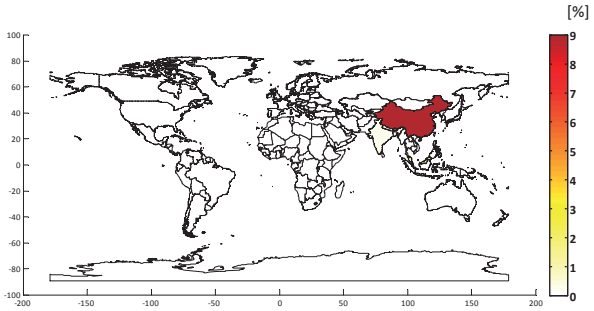


Figure 1: Global distribution of mining risk footprints of neodymium associated with Japanese total final demand in 2005

Acknowledgments

This research was supported in part by a Grant-in-Aid for research (No. 25281065) from the Ministry of Education, Culture, Sports, Science and Technology of Japan, and the Environment Research & Technology Development Fund (3K122024) of the Ministry of Environment, Japan.

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Material Flow of Cobalt in Taiwan

Lu-Yen Chen,*[1] Shun-Tian Huang,[1] and Yu-Wen Huang[1]

[1] *National United University, Taiwan*
*Corresponding author: lychen@nuu.edu.tw

1. Introduction

Cobalt is widely used in alloys for different industries worldwide. Scott F. Sibley(1998) reported the material flow of cobalt in the United States, about 32 percent of U.S. cobalt supply came from scrap in 1998. "The ratio of cobalt consumed from new scrap to that from old scrap was estimated to be 50:50. Of all the cobalt in old scrap available for recycling, an estimated 68 percent was either consumed in the United States or exported to be recycled."[1] It was reported in the website of National Institute for Materials Science that cobalt were used to produce some special iron, catalysts, and magnets in Japan. The possible recycle ratio was reported as 87%.[2]The import and export information of cobalt were reported by USGS(2005).[3] The price of cobalt made from electrolyzed in China as well as the global supply-and-demand of cobalt were also reported.[4] In addition to other metals used in transportation, the use of cobalt was also reported by UNEP(2010).[5] However, there are no cobalt reserves in Taiwan. In order to investigate the processes in which cobalt was used, and the amount of cobalt consumption in Taiwan, the material flow of cobalt had been carried out.

2. Materials and Methods

Figure 1 is the flow chart of this study. The study began from the investigation of cobalt-containing products in Taiwan. The scope of this study is the material flow of cobalt in Taiwan during 2011.

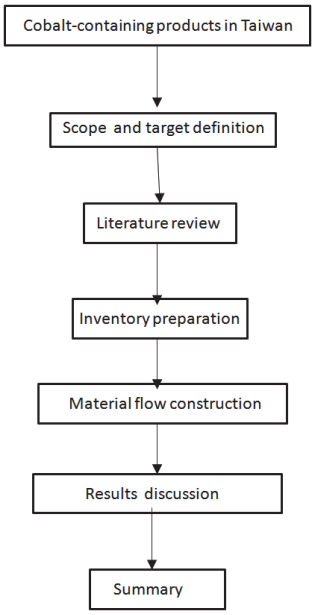


Figure 1. The methodology of this study

All the data used to construct the cobalt inventory were shown in Table 1.

Table 1. Data used to construct the cobalt inventory

Database	Content	Resolution
Customs Administration, Ministry of Finance[6]	Import/Export amount of products	Some lack of detail information
Information System of Stationary Sources of Air Pollutants[7]	Process description	Raw material and product amount
Taiwan Economic Data Center[8]	Amount of products	Only larger categories available

3. Material flow results

The material flow of cobalt can be shown as Figure 2.

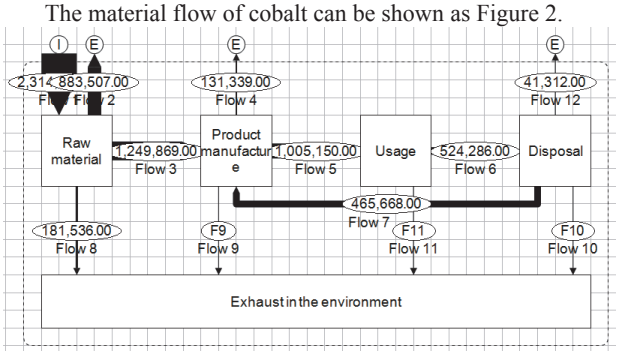


Figure 1. The logo of EcoBalance 2014

4. Summary

About 89.73% of the import of cobalt raw material is under further treatment. The usage of cobalt as catalyst was about 24.34%, that hint the recycle of waste catalyst should be helpful for creating new sources of cobalt.

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Sustainability Assessment of Deep Ocean Resources

Benjamin C McLellan,*[1,2]

[1]*Graduate School of Energy Science, Kyoto University, Japan*
[2]*Sustainable Minerals Institute, The University of Queensland, Australia*
*Corresponding author: b-mclellan@energy.kyoto-u.ac.jp

1. Introduction

Critical minerals have become of concern in recent years due to the increasing demand from use in new energy technologies and the limitations on supply due to price, capacity and political reasons. Deep ocean resources (DOR) – e.g. rich cobalt crusts, massive sulphide deposits and manganese nodule deposits – have been of increasing interest to provide supply security for strategic minerals for sustainable energy futures, but are currently inaccessible due to lack of appropriate technology or economically unfeasible to extract. This is despite many decades of investment and investigation. The actualisation of this mining activity would the start of a new mining revolution, and the social and environmental implications are as yet unclear. The life cycle sustainability assessment of critical minerals from DOR in comparison with conventional resources is therefore vital and urgent.

2. Background

The deep ocean seabed is a vast, largely unexplored and largely unknown area, which has been found to contain potentially valuable deposits of minerals. Particularly for resource-poor countries such as Japan, the available DOR maybe attractive as a method of improving resource security. Mining these on an industrial scale has only really been contemplated seriously since the 1960`s, but is coming closer to fruition with the Solwara I project in Papua New Guinea.

The main types of DOR are designated in Table 1. Cobalt-rich crusts are layers of precipitated material similar to manganese nodules, but formed in a continuous layer of typically 4-15cm for commercially considered deposits, on the flanks of seamounts, ridges and undersea volcanoes. Polymetallic sulphides are often associated with active hydrothermal vents, occurring as muds or hard consolidated deposits depending on their mixture with sediments, and some concern has been raised over the potential for mining of these deposits to impact on the unique ecosystems associated with hydrothermal vents (although only inactive vent deposits are currently being considered).

Table 1. Deep ocean resource classifications

Resource type	Description
Cobalt-rich crusts	Hard surface layered deposits containing Mn, Fe, Cu, Ni, Co, Zn (depth ~ 800 – 3000m)
Manganese nodules	"Potato-like" nodules on seabed containing Mn, Fe, Cu, Ni/Co, Zn (5-15 kg / m^2 seabed) (depth ~ 4000-6000m)
Seafloor massive sulfides	Surface layered deposits formed around hydrothermal vents, containing Mn, Fe, Cu, Ni, Co, Zn (depth ~ 700 – 2400m)

3. Discussion

The technological components of deep ocean mining are all individually feasible from a technical perspective, but as a whole the economic operation is yet to be proven. Depth, grade and form of the deposit are important characteristics influencing the potential environmental impacts associated with extraction and the economic viability. In comparison with above-ground resources, the reduction in blasting requirement, and minimal overburden (in many cases) can possibly reduce the mining impacts. However, the greater the depth, the higher the impact of the pumping processes to transport the ore to the surface. For a depth of 1500m, this results in estimated mining energy 2-3 times, and emissions of greenhouse gases 2-4 times that of land-based ores (based on estimations of existing studies [1, 2]). Increasing the depth significantly increases that impact. Importantly, there are limitations on the potential to mitigate such impacts by, for example, utilizing renewable energy – as the distance offshore is generally quite far, and the depth of the water makes floating installations difficult.

After extraction and transportation to land, the processing these deep ocean minerals is typically quite similar to land-based ores, hence the grade and specific mineral composition will be the key determining factors in the minerals-processing stages of the life cycle. Typically higher grade deposits are likely to reduce such impacts. The treatment and disposal of wastes from the process is a key area of concern.

Despite being able to give a quantitative estimate of many impacts on the environment, the impact on deep ocean biodiversity is controversial and unclear. Many deep ocean ecosystems are locally specific, and the extraction of minerals is likely to cause significant damage which in some cases will be irreversible. Environmental management plans are being developed, but it is uncertain what level of disturbance or loss of biodiversity can be classed as acceptable.

On the social pillar of sustainability, the identification of, and interaction with, stakeholders is an important aspect for consideration. In particular, mining in "The Area" beyond the boundaries of national exclusive economic zones is remote, uninhabited, and recognized as being the common heritage of humanity – requiring a very broad consultation that has yet to be undertaken. The ongoing social license to operate is uncertain in such context.

4. Conclusions

Some of the life cycle impacts of deep ocean resources will be highlighted in the poster presentation of this paper. Importantly, the lifecycle requirements for energy and the emissions of greenhouse gases will be compared with land-based minerals.

Acknowledgments

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Indicators for environmental impacts at mine sites: Case studies for large-scale underground mines

Shinsuke Murakami[1], Tsuyoshi Adachi[2], Yoshihiko Wada[3] and Satoshi Kojima[4]*

1 The University of Tokyo, Japan; 2 Akita University, Japan; 3 Doshisha University, Japan, 4 Institute for Global Environmental Strategies
**Corresponding author: smurakam@sys.t.u-tokyo.ac.jp*

1. Introduction

Discussion on decoupling resource use and its negative environmental impact from economic growth has attracted great attention recently. Unfortunately, we have not found out any absolute answer to how we achieve this goal. Accounting the environmental impacts in the resource extraction stage is one of our important jobs. However, in the LCA context, even the inventories for a specific type of resource may vary among sites. Therefore the impacts of course vary. Mining operation is always forced to be adapted the situation of the mine. Recently, decreasing grade and increasing depth of the operation are two huge concerns for the industry. These issues require the mines to change their methodology sometime and eventually environmental impacts will change.

In this paper, we analyze one specific case study with three different approaches; TMR (Total Material Requirement), CO_2 emission and EF (Ecological Footprint.) These three are not necessarily the environmental impact indicators, however, somehow widely applied and common. In this extended abstract, we will organize the characteristics and methodologies and lead the pros and cons for all three approaches. Results of our case study will be introduced in the oral presentation.

2. TMR (Total Material Requirement)

TMR is originally designed as the indicator in the EW-MFA (economy wide Material Flow Analysis,) which accounts all the material flows caused by the economy's activity including hidden flows. [1] The hidden flows include stripping, wastes or tailings for resources. Some researchers realize this characteristic may be useful for first order estimation of the environmental impacts of mining, because it can reveal the real size of activities. Bringezu et al. provided the rationale to understand TMR as an environmental impact indicator. [2] In this context, methodologically, TMR is quite close to the ecological rucksack. All we have to do is to account all the material flow caused by the production of our concerned resources. In the case of metals, we often set the material production as the system boundary and to see how much of flows caused for the production of 1 unit of the material. EW-MFA is originally a static snapshot analysis. However, the caused flows significantly change in the stage of the mining operation. Some flows may be generated even after the mine closure. [3] Therefore biggest issue is the correct accounting for this indicator for now.

3. CO_2 emission

We already have various inventory databases for this indicator. However, it is not necessarily sufficient, because the operation is always changing due to the situation of the mining sites. From our case study, the electricity use and fuels for transportation cause most of the CO2 emissions from mining activities. Difficulty exists once again in the consideration of dynamic nature of mining operation. Annual CO_2 emission can be relatively easily accounted but, it may change as operation proceeds. For example, if the pit becomes deeper, simply the transportation distance of the mined ore will become longer. Also, it drastically changes if mining method is changed.

3. EF (Ecological Footprint)

It can be defined as follows; the corresponding area of productive land and aquatic ecosystems required to produce the resources used, and to assimilate the wastes produced, by a defined population at a specified material standard of living, wherever on Earth that land may be located. [4] This indicator works well to see the overall sustainability. However, this indicator also has some shortcomings to capture the delayed impact from our activity. For now, most of EF analysis depends on the NFA (National Footprint Account) data, which is on a single year basis. If an impact caused by our current activity will occur in next year, the impact will not be accounted. Once again, the dynamic nature of mining activities seems difficult to be analyzed with this methodology.

4. Conclusion

As mentioned, all three approaches show the difficulty to appropriately account for the impacts throughout the lifecycle of the mine. Environmental impacts vary among sites, but also among the stages. (Figure 1.) However, considering our ultimate purpose is to assess the sustainability, our interests surely exist in the dynamic analysis. In the oral presentation, we will discuss these points with the case study. A case study for underground mining reveals another concern for accounts. Recently, the number of large-scale underground mines is increasing. But the land use change is hardly accountable and TMR often decreases comparing to large-scale open pit mining. Obviously we need some method to compare the impacts of underground and surface mining appropriately.

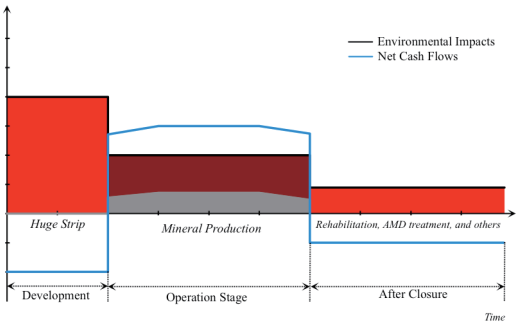


Figure 1. Example of the difference of impacts in stages

Acknowledgments

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Repercussion Effects of Final Consumption on Production and Environmental Loads Using a China-Japan Waste Input-output Table

Makiko Tsukui,*[1] and Chen Lin[2]

[1]*Tokyo International University, Japan*; [2]*Shandong University, China*
*Corresponding author: makiko@tiu.ac.jp

1. Introduction

The economic relationship between China and Japan is one of the most important bilateral relationships in East Asia. China has mainly exported goods and services to supplement final demand in Japan, while Japan has mainly exported goods that are required as intermediate inputs for industries in China. Consumption in Japan directly and indirectly induces both economic benefits (e.g., production, employment) and environmental loads (e.g., CO_2 emissions, waste generation) in China. The issue of production activities in China inducing large amounts of GHG emissions for exports has been extensively examined in empirical investigations [1-3]. However, the amount of waste generated in China by industrial sectors that produce products to satisfy the demand that is induced by consumption in Japan has not yet been clarified. We therefore investigated the direct and indirect effects of consumption in Japan on the Chinese economy and on environmental loads, particularly in the area of waste generation. To this end, we compiled a China-Japan waste input-output table for 2007 (CJWIOT 2007) and examined the differences in the types and amounts of waste generated by the industrial sectors of China and Japan.

2. Model and data

The model described in this study is essentially based on the MRWIO model of Kagawa et al. [4], which itself is an expansion of the conventional MRIO model of Isard [5] and the WIO model of Nakamura and Kondo [6].

Table 1. The basic structure of the CJWIOT 2007

			Outputs: Japan		Outputs: China		Japan: Final demands	Japan: Exports to ROW	China: Final demands	China: Exports to ROW	Production value or amount of emission
			1 … n_x		1 … n_x						
Inputs	Japan	1 … n_x	Z_I^{11}		Z_I^{12}		F^{11}	E_I^{11}	F^{12}	E_I^{12}	X_I^1
	China	1 … n_x	Z_I^{21}		Z_I^{22}		F^{21}	E_I^{21}	F^{22}	E_I^{22}	X_I^2
	ROW	1 … n_x	Z_I^{31}		Z_I^{32}		F^{31}	E_I^{31}	F^{32}	E_I^{32}	X_I^3
Waste generation	Japan	1 … n_w	W_I^{11}		W_I^{12}		F_w^{11}	E_w^{11}	F_w^{12}	E_w^{12}	W^1
	China	1 … n_w	W_I^{21}		W_I^{22}		F_w^{21}	E_w^{21}	F_w^{22}	E_w^{22}	W^2
Value added			V_I^1		V_I^2						
Production value or amount of treatment			X_I^1		X_I^2		ROW: Rest of the world				

The Japanese and Chinese parts of the CJWIOT 2007 each have 30 industrial sectors, but the number of waste categories differs between the two countries. The Japanese part has 49 municipal solid waste (MSW) categories and 19 industrial waste categories. The Chinese part has 29 MSW categories but only four industrial sectors: “smelting waste”, “fly ash”, “slag” and “other industrial waste”. To compile this table, we used the “Japan-China international input-output table 2007” (METI, Japan), “Japanese input-output table 2005” (MIC, Japan), “Industrial waste generation and treatment survey 2007” (Ministry of the Environment, Japan), “Chinese input-output table 2007”, “China statistical yearbook on environment 2008”, “China classification garbage statistics”, “China statistical yearbook for 2008”. We applied the model of Habara et al.[7] to estimate MSW generation and waste treatment.

3. Repercussion Effects of Final Consumption in China and Japan

Figure 1 shows the results of the repercussion effects of final consumption in China and Japan. The 74 billion dollars-worth of final consumption imported into Japan from China induced considerable production value in China, which is accompanied by large environmental loads.

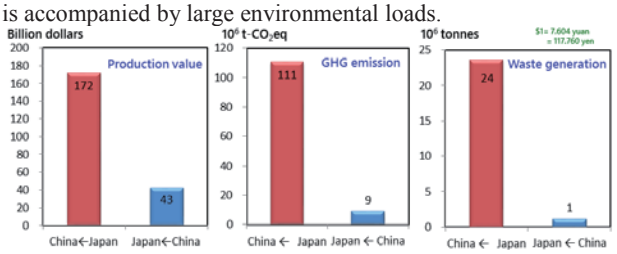


Figure 1. Repercussion effect of final consumption in Japan

6. Conclusion

The repercussion effects of final consumption in Japan on China are considerably larger than the repercussion effects of China on Japan, both economically and environmentally. Large imports of textile products by Japan from China induced production value, not only within the textile industry, but also in the chemical and agricultural industries. The repercussion effects associated with the importation of textile products by Japan from China induced large amounts of GHG emissions and waste generation. It is considered important to improve the energy efficiency in the extraction of “petroleum and coal products” and in “electricity and heat supply” sectors in China. In order to reduce waste generation in China, it will be necessary to improve the efficiency of the mining and heat supply industries in China.

Acknowledgments

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The Implementation of Financial Incentive on Single-Use Takeout Cup Source Reduction and Recycling in Taiwan

Wei-Kai Yang,*[1] Ying Hsuan Lin[1] and Chih-Ku Chen[1]
[1]*Sustainable Environmental Technology and Management, Taiwan*
*Corresponding author: greg5210@sustainable.com.tw

1. Introduction

Taiwan Environmental Protection Administration (TEPA) enacted "Enforcement of Source Reduction and Recycling Incentives for Single-Use Take-Out Cup" ordinance to restrict designated vendor (includes convenient store, fast-food store, coffee shop and non-alcoholic beverage shop) to recycle the single-use cup or to encourage consumer Bring Your Own Mug (BYOM)[1]. Consumers should be feedback with at least one New Taiwan Dollar (NTD) if they return the single-use cup to the vendor. For exemption, vendor should offer an alternative plan called "source reduction program" to provide a favorable price when consumers bring their own reusable mug.

A total of 17,926 stores of 419 brands offer discount to BYOM consumers and 70 stores of 6 brands offer used single-use cup recycling incentive after the ordinance was enforced. Statistics of overall designated vendor shows that 4.6% [2] single-use cup consumption is replaced by BYOM in 2012. An average of 69 million single use cups reduction per year was estimated as a result of the ordinance. The correlation between BYOM and various incentives is analyzed. It was found that consumers purchasing at coffee shop show highest potential to BYOM.

2. Case study

To further understand the correlation between consumers purchasing habits and the ordinance implementation outcomes, qualitative and quantitative marketing research analysis was conducted [3].

Public poll was used for qualitative investigation to understand consumers' environmental opinion. Field survey method was used for quantitative investigation. The scenarios for this investigation include: Scenario 1 (S1), consumers with single-use cup; Scenario 2 (S2), BYOM consumers; and Scenario 3 (S3), consumers sit-in with reusable cup.

For qualitative investigation, public poll was carried out by phone interview. The subjects were general public of 20 years old and above with a sampling size of 1,073 people throughout the country, the confidence level was 95%±3%, completed by May 2013. The results of the investigation showed that 55% of the consumers would purchase take-out beverages, and 15% were willing to BYOM, among which, coffee purchasers formed the major group, see the results in Figure 1.

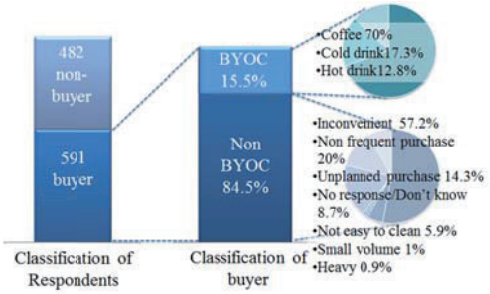


Figure 1. Analysis of questionnaire result

For the quantitative investigation, data were collected from the convenient chain stores, beverage chain stores and coffee chain stores in nearby areas of train stations, school areas, and well known commercial shopping districts of the five major cities in Taiwan to understand the practice of the consumers. Samples of 4,602 consumption purchases from September to October in 2013 were taken according to the three scenarios. Table 2 shows the results. The investigation found that only coffee shops provide sit-in and most vendors provide consumers beverages using reusable cups. Therefore, this data analysis does not include difference analysis of S3, consumers sit-in with reusable cup. Data analysis was conducted only for take-away consumer behavior, and includes the ratio of BYOM (R). Equations included the number of consumers of S1 and S2, as follows.

$$R = (S2 \div (S1 + S2)) \times 100\% \quad (1)$$

Table 2. Classification of consumer by study object

	Coffee shop	Convenient store	Beverage store
S1	1,439	585	2,363
S2	32	21	41
S3	121	0	0
R	2.2%	3.5%	1.7%

Table 3. Classification of consumer by incentive type

	2NTD off	3NTD off	5NTD off	10NTD off
S1	2,208	791	286	1,102
S2	2	24	40	28
S3	0	22	48	51
R	0.1%	2.9%	12.3%	2.5%

3. Results

Consumers making purchases at coffee shops and convenient stores are more likely to bring their own cups (2.2%-3.5%). Consumers making purchases at beverage stores are less willing to bring their own cups at 1.7% BYOM ratio. The common feature between coffee shops and convenient stores is that both sell coffee. Cross analysis with the public poll results shows that 70% of the consumers who bring their own mugs are mainly for coffee purchases.

In addition, the amount of the incentive does not show significant correlation to BYOM. When vendors come up with innovative practices, such as in the case of the NTD $5 discount, vendors offer reusable PE plastic bottles along with discount. Thus, this greatly increases the willingness of the consumers to cooperate.

4. Conclusions

Innovative low-carbon business service that enhances consumers linkage and consumption reward system is arising after the ordinance was implemented and these operations will decouple traditional over production-consumption model gradually that increases both the resource utilization efficiency and living environmental quality.

Acknowledgments

This study was supported by the Promoting General Waste Source Reduction Related Work Project 2013 (EPA-102-H101/H103-02-221) that is granted by Taiwan Environmental Protection Administration. The authors also like to thank Ms. Chin-Wei Tang for her supports in the work.

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Environmental impacts assessment of plastic waste in Thailand

Unchalee Suwanmanee,[1] Thanawadee Leejarkpai,[2] Wanwilai Kraipech Evans,[1]
Shinatiphkorn Pongpinyopap,[3] and Thumrongrut Mungcharoen, *[3]

[1]*Department of Chemical Engineering, Faculty of Engineering, Srinakharinwirot University, Nakhon-nayok 26120 Thailand*
[2]*National Metal and Materials Technology Center, National Science and Technology Development Agency, Pathumthani 12120 Thailand,*
[3]*Department of Chemical Engineering, Faculty of Engineering, Kasetsart University, Bangkok 10900 Thailand,*
*Corresponding author: fengtrm@ku.ac.th

1. Introduction

Currently, the annual Municipal Solid Waste (MSW) generation in Thailand was 14 million tons. About 15.88% of total MSW was accounted as 2.22 million tons of plastics waste which need to be disposed each year. The MSW in Thailand has been steadily increasing which bring a crisis in many area of country because of lack of potential site for the sanitary landfill. Nowadays, Thailand has a total of 127 waste disposal sites. Many landfill sites are now facing with the overload capacities and will have a shorter life time than expected. In this study was analyzed and evaluated two environmental impacts, global warming potential (GWP) and land use capacity of bio-based boxes, PLA derived from sugarcane (PLA′) and PLA derived from corn (PLA″), and petroleum-based box, PS derived from natural gas and crude oil. Two waste management scenarios were considered, namely the combination of 25% composting cooperation with 75% landfill (scenario 1), the combination of 50% composting cooperation with 50% landfill (scenario 2).

2.1 Goal and scope of the study

The scope of the study was shown in Figure 1. The functional unit was set as 1% of total plastics waste in Thailand or 2.22×10^4 tons in each year.

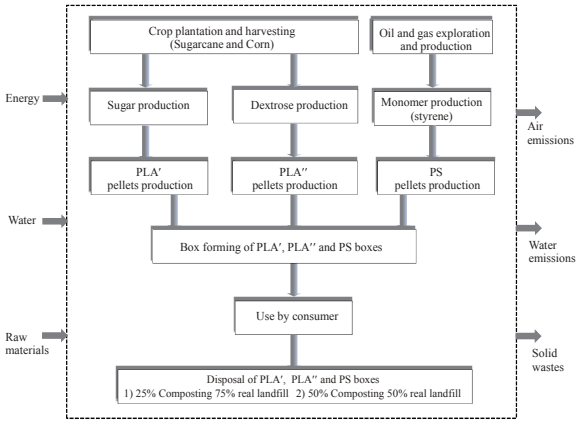


Figure 1. System boundary of PLA′, PLA″ and PS boxes.

3. Results and Discussion

3.1 Life Cycle Impact Assessment or LCIA

It was found that the PLA″ in scenario 1 contributed the highest GWP impact of 3.45×10^4 tons CO_2 equivalent per year as shown in Figure 2. In scenario 1, PLA″ revealed higher the total GWP impact than PLA ′ and PS by 2.5 and 2.8 times respectively. This was because of the high amount of GWP impact of PLA″ during resin production of 3.37×10^4 tons CO_2 equivalent per year or 97% of total GWP impact. It can be observed that the increasing of 50% composting rate (50C/50L) give significantly different value of the total GWP impact of 25C/75L. The significant and benefit effect on the total GWP impact values were obtained by the increasing of composting rate. The total GWP impacts of PLA′ and PLA″ in scenario 2 were significantly decreased by 60.8% and 23.8% of the total GWP impact of PLA′ and PLA″ in scenario 1 respectively. It clearly seen that the impact value during resin production exhibited the most important contribution as 57-97% of the total GWP impact of PLA′ and PLA″ boxes. Figure 3 showed that the land use impact from both scenario 1 and 2 were very highest impact for PS boxes about 2.073×10^6 m^3 per year. This is because of PS is not degraded under real landfill and composting conditions.

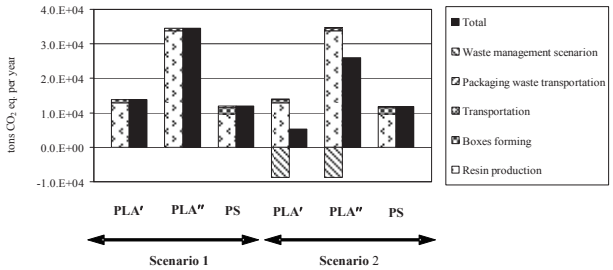


Figure 1. The GWP impact of PLA′, PLA″ and PS boxes.

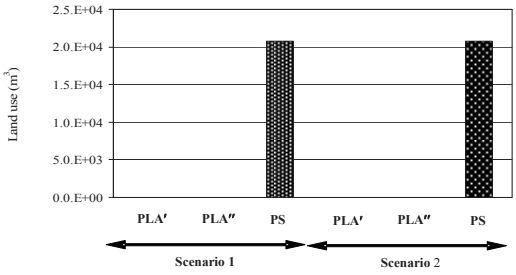


Figure 2. Land use capacity (m^3) of PLA′, PLA″ and PS boxes.

4. Conclusion

It was found that the PLA″ in scenario 1 contributed the highest GWP impact of 3.45×10^4 tons CO_2 equivalent per year. The significant and benefit effect on the total GWP impact values of PLA′ and PLA′were obtained by the increasing of composting rate. PS in both scenario 1 and 2 showed the highest land use capacity of 2.073×10^6 m^3 per year.

Acknowledgments

This work has been supported by Faculty of Engineering, Srinakharinwirot University and Kasetsart University, Thai Research Fund (TRG5780114) and National Science and Technology Development Agency (NSTDA) Fund.

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Assessing Environmental Impact of Fiber Reinforced Plastic Table Top Product Mixed With Non-Metallic Fraction from Printed Circuit Board Waste

Sawanya Jareemit,[1] Suphaphat Kwonpongsagoon,*[1] and Premrudee Kanchanapiya[2]

[1]*Department of Sanitary Engineering, Faculty of Public Health, Mahidol University, Thailand*;
[2]*National Metal and Material Technology Center, National Science and Technology Development Agency, Thailand*
*Corresponding author: suphaphat@hotmail.com.

1. Introduction

Non-Metallic Fraction (NMF) is non-valuable waste from the copper recovery process of Printed Circuit Board Waste (PCBW). According to waste management options, we tried to study the potential of NMF recycling from PCBW as a substitution material in a Fiber Reinforced Plastic (FRP) furniture product. Normally, the FRP furniture products in Thailand consist of 3 main layers [1]. For top and bottom layers, they are laminated structure of polyester resin and glass fiber made by a hand lay-up technique. In the middle layer, a plywood or particle board is used to increase the thickness of product. According to our study, it is possible to use NMF from PCBW recovery process replaced plywood in a traditional FRP product. Since the NMF is a powder therefore it was mixed with polyester resin and other additives (styrene monomer and methyl ethyl ketone peroxide as hardener) and casting in mold. Focusing on the hand lay-up process of FRP laminate and the mixing and casting processes of NMF, there are many chemicals that used in the production process. Moreover the process depends on labor intensity. So these may cause the human toxicity such as skin irritation, allergic reaction, and burn [2], as well as a chemical contamination to the surrounding that would effect to the environmental toxicity. Therefore the objective of this paper is to investigate the environmental aspects of a new FRP product (FRP product mixed with NMF) by applying Life Cycle Assessment (LCA) methodology. This study is the part of a whole research project with the National Metal and Materials Technology Center, carried out in co-operation with the SMEs companies in Thailand.

2. Methodology

According to the ISO 14040 and 14044 [3-4], Life Cycle Assessment (LCA) methodology is used in this study to evaluate the environmental impact from a gate-to-gate of the new FRP product. The functional unit of this LCA study is 1x1 m^2 of a table top product. The data used in life cycle inventory was primarily collected from F.R.P. Industry Co., Ltd. and databases provided in SimaPro software Version 7.3. The World ReCiPe Midpoint impact assessment method was applied to estimate the environmental impacts of this product [5].

3. Results and Discussion

The LCA results of the new FRP using the World ReCiPe Midpoint impact assessment method result in six damage categories. These consist of human toxicity, marine ecotoxicity, climate change, fossil depletion, ionising radiation and metal depletion (see Figure 1). It shows that the highest environmental impacts of the new FRP product are human toxicity and marine ecotoxicity, accounting for 480.2 kg 1,4-DB eq and 372.1 kg 1,4-DB eq, respectively. These two environmental impact categories are the most concern as the production process of this new FRP product is a chemical-based process and labor intensity, as mentioned above. In order to study the environmental impact related to raw material use of the new FRP production process, all raw materials were assessed and divided into 4 groups: 1) polyester resin, 2) styrene monomer, 3) glass fiber, and 4) others including electricity and water consumption, acetone and hardener. The comparison of environmental impacts between these raw materials is shown in Figure 2. About 80-90% of each environmental impact category results from polyester resin which is used as a raw material in the FRP process, when compared to other raw materials, like styrene, glass fiber, and others.

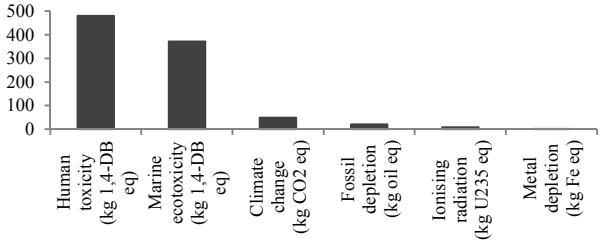


Figure 1. Environmental Impact of a new FRP product by World ReCiPe Midpoint impact assessment method

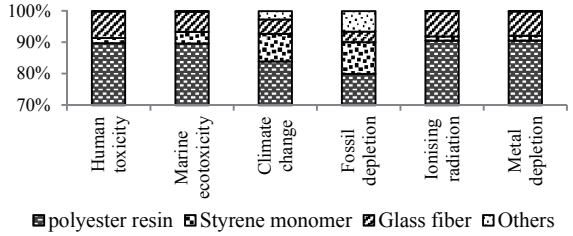


Figure 2. Environmental Impact related to raw materials

4. Conclusion

In conclusion, the highest environmental impacts of a 1 x 1 m^2 FRP table top product mixed with NMF from PCBW recovery process are human toxicity and marine ecotoxicity. It was also found that polyester resin is the most potential raw material contributing to all environmental impacts.

Acknowledgments

The authors would like to thank NSTDA University Industry Research Collaboration (NUI-RC) for research funding, and Chatumit Recycle Company and F.R.P. Industry Co., Ltd for their data support in this study.

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WEEE management in Lombardia region (Italy): an LCA-based evaluation

Laura Biganzoli[1], Alida Falbo[1], Federica Forte[1], Lucia Rigamonti*[1] and Mario Grosso[1]

[1]*Politecnico di Milano, Italy*
*Corresponding author: lucia.rigamonti@polimi.it

1. Introduction

Waste electrical and electronic equipment (WEEE) is one of the fastest growing waste streams in Europe. It is strategic not only because of the presence of hazardous substances, which require a great attention during treatment and disposal operations, but also for its high content of recyclable materials [1]. With regard to this aspect, Life Cycle Assessment (LCA) is a fundamental tool to assess the environmental benefits and burdens associated with WEEE management; however, most of the works available in the open literature focus on a specific WEEE product [2, 3] and only few of them extend the evaluation to the whole WEEE collection and recovery systems on a given geographical area [4].

2. Material and methods

This research investigates the WEEE management system in Lombardia Region (Italy). The focus is on two WEEE categories: TV and monitor, and small household appliances (which includes the IT and telecommunication equipment, the consumer equipment, the electrical and electronic tools, toys, leisure and sports equipment).

The aim of the research is to quantify the environmental benefits/burdens associated with the treatment and the recovery of these two WEEE categories. The LCA methodology is applied to evaluate the current management in Lombardia Region and identify possible improvements.

The functional unit is defined as 1 kg of collected WEEE. The system boundaries include the collection, the pre-processing and the treatment of the waste, the disposal/treatment of the residues and the recycling of the recovered materials, accounting for the benefits of the consequent substitution of primary raw materials and energy.

The WEEE flows from the collection platforms to the first treatment plants were assessed by means of the official regional database. The most important treatment plants were identified and visited, in order to gather primary data about the process layout, the energy and material consumption, and the material flows in output. As an example, the main outputs of the first treatment of small household appliance are reported in Figure 1. Primary data were also collected about the destination of the WEEE components separated after the first treatment and their subsequent recovery processes. This means that the inventory is mostly based on primary data, reflecting the real management system implemented in the region under study. When primary data were not available, data from literature were used.

The model was implemented in the SimaPro software. For each process, a new dataset was designed, including the substituted avoided materials, with the same approach adopted in previous studies [5, 6].

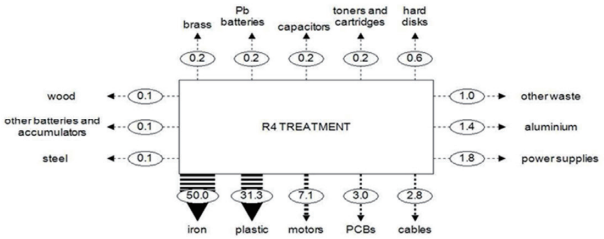


Figure 1. Small household appliances treatment outputs (wt.%)

3. Conclusions

The detailed material flow analysis performed has allowed the identification and quantification of the materials recovered by the treatment of TV and monitor and small household appliances. The subsequent LCA has quantified the impacts associated with this treatment and the benefits associated with the recovery of material and energy. Recommendations were advanced to improve the environmental performances of the system currently implemented in Lombardia Region.

Acknowledgments

The authors wish to thank all plant operators who have supplied primary data for the LCA.

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Investigation of Effects of Waste Recycling from Food Supply Chain Using Hybrid Analysis

Tamon Maruyama,* Jun Nakatani, and Yuichi Moriguchi

The University of Tokyo, Japan
*Corresponding author: maruyama@env.t.u-tokyo.ac.jp

1. Introduction

Food recycling law and containers and packaging recycling law in Japan have some problem, so there is room for improvement on these laws.

So our research objective is to evaluate effects of whole existing industries by recycling of food wastes and containers and packaging wastes attendant on foods, and then compare scenarios with current recycling system.

2. Method

It is effective to use bottom up approach for analyzing individual recycling technology or wastes treatment system, while using Input-Output analysis is valid for evaluating effects of whole existing industries by recycling of food wastes and containers and packaging wastes attendant on foods.

So we used Integrated Hybrid Analysis which is the method for calculating environmental load discharged from whole supply chain without overs and shorts by making up information which is not written in process data for bottom up approach from Input-Output table.

3. Connection between process data and IO table

Suh and Huppes [1] formulized the method to calculate environmental load by using Integrated Hybrid Analysis.

$$M_{IH} = B_{IH}{A_{IH}}^{-1}k_{IH} = \begin{bmatrix}\tilde{B} & 0\\ 0 & B\end{bmatrix}\begin{bmatrix}\tilde{A} & Y\\ X & I-A\end{bmatrix}^{-1}\begin{bmatrix}\tilde{k}\\ 0\end{bmatrix} \quad (1)$$

$\tilde{B}, B$ are environmental matric for process data and IO table, $\tilde{A}, A$ are technology matrix, I is identity matrix, $\tilde{k}$ is an arbitrary vector, X is upstream cut-off flows from IO table to process data, Y is downstream cut-off flows from process data to IO table.

Specifically, A_{IH} is written in matrix form as follows.

Table 1. A_{IH} in matrix form

	Sector A	Sector B	Sector 1	Sector 2	Sector 3
Sector A					
Sector B					
Sector 1					
Sector 2					
Sector 3					

$\tilde{A}$: Process data; Y: Transaction value of sector A, B and sector 1-3; X: Input of material obtained from process data; $I-A$: IO table

In Table 1, Sector A and B are sectors of process data, and Sector 1, 2, and 3 are sectors of IO table.

4. Case study

Using Integrated Hybrid Analysis, we calculated CO_2 emission when we bought one lunch and one canned aluminum drink and took out lunch and drink by using plastic bag. And then, we analyzed change of CO_2 emission when lunch box or aluminum can or plastic bag was recycled.

We can analyze about reusing, recycling, waste from household, separating action of consumer, imported material by Integrated Hybrid Analysis.

When we took note of canned aluminum drink, flow of canned aluminum drink was written as figure 1.

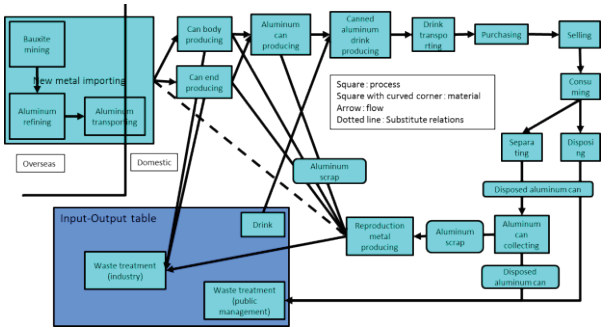


Figure 1. Flow of canned aluminum drink

Then we are going to show the matrix which is made by transforming process data of canned aluminum drink into matrix form. That matrix corresponds $\tilde{A}$ in formula (1).

Table 2. Matrix form of canned aluminum drink

	New metal importing	Can body producing	Can end producing	Aluminum can producing	Canned aluminum drink producing	Drink transporting	Purchasing	Selling	Consuming	Separating	Disposing	Aluminum can collecting	Reproduction metal producing
Imported new metal(kg)	1	−1.0403	−0.99088	0	0	0	0	0	0	0	0	0	−0.96339
Can body(kg)	0	1	0	−0.938	0	0	0	0	0	0	0	1	0
Can end(kg)	0	0	1	−0.234	0	0	0	0	0	0	0	1	0
Aluminum can(kg)	0	0	0	1	−0.015	0	0	0	0	0	0	1	0
Canned aluminum drink(can)	0	0	0	0	1	−1	0	0	0	0	0	0	0
Drink transporting service(can)	0	0	0	0	0	1	−1	0	0				
Purchase(time)	0	0	0	0	0	0	1	−1	0				
Buying(time)	0	0	0	0	0	0	0	1	−1				
Consume(time)	0	0	0	0	0	0	0	0	1				
Separation(time)	0	0	0	0	0	0	0	0	−0.5				
Disposal(time)	0	0	0	0	0	0	0	0	−0.5	0	1		0
Aluminum can separating service(kg)	0	0	0	0	0	0	0	0	0	−0.015	0	1	0
Aluminum scrap treatment service(kg)	0	−0.06197	−0.04886	−0.1755	0	0	0	0	0	0	0	−0.5	1

Supply from IO table except for can; Target process for analyzing; Recycling process; Substitute new metal; This element shows recycling waste from household. Wastes not recycled treated by waste treatment service in IO table.; Ratio of consumer who did separation action; Goods and services produced subsidiary →Input to other process; Goods and services are produced by treating inputs

Value of elements shows the amount of flow of material.

Red elements show input of goods and services, blue, light blue, and yellow elements show production of goods and services, and green elements show recycling. And we can change value of yellow elements by scenario.

We made same type of matrix of lunch and plastic bag, and connected them. Then we can get matrix $\tilde{A}$, so we can calculate CO_2 emission discharged from whole supply chain by formula (1).

In the result, electricity and transportation sector in the IO sector, and new metal importing sector in the process data sector have large CO_2 emission. When recycling is done, CO_2 emission from IO sector seldom changed, however CO_2 emission from new metal import sector largely decreased.

4. Future plan

We are going to collect process data using inventory database and data about environmental load by statistic, and evaluate effects of reduction of environmental load by recycling food wastes and containers and packaging waste. And then, we are going to make recycling scenarios not only for containers and packaging wastes but also for food wastes

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Climate Co-Benefit from Improving Food Waste Management: A Case of Small Communities in Thailand

Amornchai Challcharoenwattana,[*1,*2] Chanathip Pharino,[2,3]

[1]*International Postgraduate Programs in Environmental Management, Graduate School, Chulalongkorn University, Thailand*

[2]*Center of Excellence on Hazardous Substance Management (HSM), Chulalongkorn University, Thailand*

[3]*Department of Environmental Engineering, Faculty of Engineering, Chulalongkorn University, Thailand*

*Corresponding author: amornchai.c@student.chula.ac.th

1. Introduction

Higher levels of urbanization are often accompanied with higher activities on MSW generating but lesser percentage of food waste in the waste stream[1]. Interestingly, percentage of food waste in Thailand's MSW stream seemed to be increased in the same direction with the level of urbanization. This condition does not agree with the global trend as Thailand's percentage of food waste in all town sizes remained at similar level[2]. This trend posts significant concerns as decomposition of food waste in landfills under anaerobic condition can produce greenhouse gas emission up to 0.945 tons CO_2 eq of 1 tons landfilled food waste. Therefore, GHG emission from food waste, under doing-nothing condition, will worsen climate change problem but can also help to shed GHG contribution if the food waste is managed in appropriate manner. Hence, scenario developments and analyses for food waste management are needed in order to extend the concept of climate co-benefit to strengthen supports for waste minimization especially when 74.76% of all Thai population has resided in small towns.

2. Methodology

Four food waste management scenarios were developed based on the following conditions: completely landfilled of food waste (*s1*), 30% of food waste was fermented to produce biogas at home and 70% of those were collected and then landfilled (s*2*), and 30% of food waste was composted on-site or at community center and 70% of those were collected and then landfilled (*s3*), and the dehydration of food waste by 20% by sun-drying and then collected to be landfilled (*s4*). The functional unit for this study was defined as 1.740 tons/day of the mean daily food waste generation from 1,020 small municipalities in Thailand with registered population of 5,000-10,000. For the transportation part, the waste collection system was based on a standard 6-wheel garbage collection truck with the carrying capacity of 5 metric tons. Daily MSW collection route within the city was defined at 20 km and the distance between the city's perimeters to landfill is 5 km. Emission factors from Thailand Greenhouse Gas Management Organization were primary employed before emission factors from other sources were employed.

3. Result

For GHG emissions from the decomposition of food waste and the waste collection, the baseline scenario (*s1)* contribute the highest GHG emission of 1.238 and 2.078 tons of CO_{2eq} per day respectively. In term of the ability to reduce GHGs, employing household biogas system (*s2*) was able to reduce 43.62% from (*s1*) while composting system (*s3)* was able to reduce 41.83% from (*s1)*. 20% Removal of moisture content (*s4*) can help to reduce 28.74% of GHGs from (*s1)* due to the lesser fuel consumption compared to (*s1*).

4. Conclusion

Overall, GHG reduction in *(s2)* and *(s3)* were found at the similar level. Therefore, both options can be selected to based-on the need of soil amendment (*s3)* or energy (*s2*) of the community. Removal of moisture by residents prior to waste collection (*s4*) may be more appropriated if the demand for energy/soil amendment is not met.

Acknowledgments

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Material Flow Cost Accounting - MFCA: Simple Approach, Untapped Opportunities, Upcoming Tasks

Bernd Wagner*[1]

[1]*University of Augsburg, Germany*
*Corresponding author: wagner@wzu.uni-augsburg.de

1. Simple approach and communication of the MFCA idea

Since its conceptual birth in the early 1990s and its global appearance as ISO standard 14051 in 2011 [1] MFCA has come a long way. MFCA's basic idea, which is easy to understand and to communicate, has experienced global dissemination. This idea behind MFCA is to show material flows in physical as well as in monetary values. Using this simple approach MFCA integrates economic and environmental thinking. Its goal is to insure long-term corporate sustainability by increasing material or resource efficiency, decreasing the environmental burden and at the same time saving cost. While much of the corporate world today still sees a clear distinction between two separate views, the economic or business view on the one hand and the sustainability or environmental perception on the other, MFCA is based on the idea that for long-term corporate survival both sides have to be considered in their mutual interdependence. To this end it uses simple instruments such as material flow charts and aggregated material flow data matrices showing their cost dimension of materials used (business view) as well as their physical properties (production, engineering, environmental view) as two sides of the same coin. MFCA uses readily available data from Accounting, LCA or other, compacting this data to indicators for managerial planning and steering purposes.

With its international diffusion MFCA has grown in breadth, e.g. by including social aspects of sustainability, it has focused in-depth e.g. on waste management issues, and it has been linked to other concepts such as Supply Chain Management or LCA. But with these developments new questions arise: Does MFCA, as it is generally practiced today, meet the concept's original expectations and opportunities? Where is there room for further development and improvement**?** Which upcoming tasks can be identified in order to target potential opportunities of MFCA?

Despite widespread awareness of the MFCA, there is still, extensive room for broader application and adoption and not just in the so far predominantly targeted area of resource saving. Main reasons why companies have not more fully implemented MFCA is their fear that data collection will be too costly, and established accounting procedures will be disrupted. [2].

2. Opportunities of MFCA

Looking at reported MFCA applications and case studies one can get the impression that MFCA so far mainly is used to increase resource efficiency through waste reduction and thus save costs [3]. This seems to be the low hanging fruit of MFCA application. But there are a number of opportunities that companies are currently missing, such as:

- a stronger integration of sustainability aspects (environmental, social) into corporate decision making from strategies and policies to operation management
- facilitating the integration of available tools: e.g. Managerial Accounting, ERP, LCA, SNA [4], and profit from synergies
- making use of material flow charts and data, supporting a holistic view, as a communication tool between functional corporate departments (e.g. waste management and R&D) or between partners along the supply chain.
- strengthening strategic resource planning and risk assessment, e.g. through integrating criticality assessment, into MFCA [5]

3. Upcoming tasks and developments

A great number of next steps or measures are available to be taken in order to reach these opportunities. Some selected examples from practical experiences are provided:

- We show a Quick Results Assessment Tool that allows in a two day workshop to estimate possible resource saving potentials and to spot deficits of existing material efficiency information regarding product material, waste, and energy.
- Most MFCA applications focus on waste reduction. But increased resource efficiency can also be achieved by reducing product materials, even auxiliary materials, not going to waste. In order to uncover these hidden treasures MFCA must delve deeper into ERP and controlling systems, allowing exact Input-Output-Mass-Balances, for the company as a whole, for quantity centers, products, selected materials etc. MFCA can help companies focus on the critical and the strategically essential resources within the vast varieties of materials and parts.
- Despite the fact that MFCA originated from environmental management, many present applications have been reduced in scope to pure cost saving exercises. Yet companies will increasingly be under strategic pressure to deal with topics like GHG effects, Carbon and Water Footprint, effects on eco-systems and biodiversity, on health and social issues. MFCA has significant untapped potential to bridge the gap between financial (cost) and sustainability considerations and to highlight the mutual interdependencies.
- A frequently neglected strength of MFCA is its use as an interdepartmental communication tool. While many optimization processes focus on departmental tasks, corporate MFCA flow charts and the corresponding data show "the big picture", and one that is cross functional from input to output.

In addition to the listed examples above other opportunities on hand will be identified.

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Extending Raw Material Input Evaluation in the MFCA Framework through Implementation of Criticality Assessments

Christoph Helbig,*[1] Christoph Kolotzek,[1] Andrea Thorenz,[1] and Axel Tuma[1]

[1]*Resource Lab, University of Augsburg, Germany*
*Corresponding author: christoph.helbig@wiwi.uni-augsburg.de

1. Introduction

Material efficiency is a main focus of Material Flow Cost Accounting (MFCA), which provides a well-established, standardized method for evaluation within a company. Evolving from a mass-based Material Flow Analysis (MFA) for any process within the company or the complete company, it allows for the identification of cost-saving efficiency improvements by linking mass flows to costs. This material flow data is essential for efficiency considerations and can be the starting point for resource-based improvements.

2. Integrating Supply Chain Impacts into Material Flow Cost Accounting Framework

Current research extends the MFCA approach to the supply chain, collecting data even outside the company system, looking for further improvements [1]. Due to data issues as well as the increasing complexity, this can be very expensive. However, this supply chain approach is essential for systemic improvements concerning sustainable resource use.

Figure 1 displays the advantages of data exchange between MFCA and 'Criticality Assessments'. While MFCA is useful for analyzing intra-organizational processes in search for cost optimization and waste reduction potential, criticality assessments are best for estimating upstream raw material risks. Synergies emerge from considering both evaluation methods.

- Input & output products - Auxiliaries & wastes - Mass & value flows	Data requirements	- Production & resource data - Supply & demand trend - Corporate input flow data
MFCA	Material flow data → ← Supply chain proxy data	Criticality Assessment
- Cost optimization - Waste flow reduction - Ecological impacts	Knowledge gained	- Supply risk evaluation - Upstream ecological implications - Social alert signals
- Effective for intraorganizational processes	Special strengths	- Effective for upstream risk assessment

Figure 1: Relations between MFCA and Criticality Assessments

3. Criticality Assessment as Raw Material Input Evaluation

Scarcity of metal and mineral resources in combination with company guidelines for the security of sustainable supply for companies is a main focus in a well evaluated project of the Resource Lab of the University of Augsburg. The result of our project is a criticality assessment with evaluated indicators that can be used by companies for sustainability evaluation of the upstream supply chain, which is essentially determined by input flows quantified in the MFCA.

These criticality assessments emerge from a raw material conception involving geological, technical, political, economic and ecologic considerations [2, 3]. Indicators identified in our work touch the dimensions supply risk, ecological implications and social circumstances. In the dimension supply risk, risks emerging from the market concentration, the political situation as well as supply reduction and demand increase estimations are evaluated, emerging from existing supply risk evaluations [4]. The ecological dimension includes indicators about the impacts on human health as well as ecosystem quality. In the social dimension indicators like the control of corruption are considered.

These risks are valuable information for a rapid proxy evaluation in supply chain material flow cost accounting. The quantifiable indicators are evaluated by a multi-step process, starting with the selection of relevant resources (available from MFCA data collection [5]), continuing with the raw material based assessment, giving information about the interpretation within the MFCA framework, leading to decision support for mitigation efforts. Input flow evaluation is exemplified on case studies for companies (e.g. electronics industry).

4. Conclusion

This presented evaluation method gives companies the opportunity to use the data collected in standardized MFCA in order to reduce the resource-based criticality of its input flows, i.e. by reducing its supply risk or the upstream environmental and social implications. The methods presented can be extended in future research on product and waste outputs, to get a more complete view on the supply chain implications connected to the MFCA-based efficiency improvements.

Acknowledgments

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Cost Accounting Instruments as Components in a Material Flow Analysis Tool-Chain

Andreas Moeller*[1] and Martina Prox[2]

[1]*Leuphana University Lueneburg, Germany*; [2]*ifu Hamburg GmbH, Germany*
*Corresponding author: moeller@uni.leuphana.de

1. Introduction

In the field of life cycle assessment (LCA) [1] and material flow analysis (MFA) [2] several cost accounting instruments are discussed: at least life cycle costing (LCC) [3], conventional cost accounting (based on an analysis of material and energy flows) and material flow cost accounting (MFCA) [4]. It is more and more important to provide an integrated approach to the economic impacts of activities within the frameworks of MFA and LCA.

2. Purposes of Cost Accounting Instruments

The concepts of instruments and the computational structures behind are not alternative approaches to the same problem. The purposes of LCC, conventional cost accounting and MFCA are different:

(1) Conventional cost accounting is focused on the negative economic impacts (costs) and positive outcomes (revenue) of management decisions [5, 6, 7]. Compared with LCA, the accounting entities (or controlling areas) are different: business units, production plants, single production processes and not entire product life cycles. As a consequence, the challenges and calculation approaches [8, 9] are similar: application of matrix methods, allocation problems, fixed costs etc. The integration of LCA, LCC and conventional material and energy-based cost accounting is quite simple as all instruments use (life cycle) inventories as a starting point and data source [2].

(2) Life cycle costing brings together different companies (business units) and their perspectives. LCC analyses the value added, the business units realize – and not the difference of revenues and costs. The accounting entities in conventional cost accounting become the nodes in life cycle costing: conventional cost accounting is embedded into LCC. As a result, conventional cost accounting, related to accounting entities, and LCC can be implemented as components of a single calculation procedure [10].

(3) The purpose of MFCA is to quantify improvement potentials. Starting point of MFCA is that unit processes can be improved by reducing the waste streams. By reducing the waste streams (material loss), not only the costs of waste treatment can be reduced but also the input of raw materials and intermediate goods [4]. Life cycle approaches are applied to represent the means/end relationships between the final products and required raw materials and emissions. MFCA provides two complementary performance indicators: the product costs and the costs of material loss. It is obvious to use such an approach in carbon footprinting or LCA in general. By doing so, LCA can quantify the reduction of environmental impacts connected of possible improvements.

1. Computational Structure of MFCA

Unfortunately, the computational structures of MFCA are more complex. Whereas conventional cost accounting and LCC can be realized as instruments within a life cycle assessment tool-chain, MFCA requires preparatory material flow analysis steps which deal with non-linear process specifications and recycle streams [11, 12] (e.g. based on an sequential modular or equation-based approach). In principle, MFCA consists of two calculation steps: for default scenarios and improved scenario, in which material loss is avoided. When wasteful processes and in particular their material loss are involved in recycling loops, the reduction of material can have an impact on the steady states of the loops. For instance, the reduction of material loss may result in reduced recycle streams so that the production coefficients of the mixer process, which mixes the recycle streams and virgin raw materials, must be updated.

It is necessary that the tool-chain integrates MFA and LCA. The MFA component allows calculating all absolute material and energy flows, the flow properties, components and stocks for a given sequence of time periods. The data can be used to perform LCAs and cost accountings as evaluation steps. In case of MFCA, the tool-chain has to be applied twice, and the difference of the two scenarios quantifies the improvement potential. Again, an integration of the instrument is possible so that an integrated calculation procedure can determine the data for all cost accounting instruments based on only one material and energy flow model.

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New Challenge to develop Sustainable Value Chain Management by MFCA Information

Michiyasu NAKAJIMA,*[1] and Asako KIMURA[2]

[1]*Kansai University, Japan*; [2]*Kansai University, Japan*
*Corresponding author: nakajima@kansai-u.ac.jp

1. Introduction: Purpose of the Research

Material Flow Cost Accounting (MFCA) is one of the most useful tools on Environmental Management Accounting (EMA) in practice. MFCA makes new visibility in a process on material efficiency, concretely with material loss. When a company introduces MFCA into own process and find out some material losses, the company tries to reduce simultaneously material losses and manufacturing costs. As a result, the company improves material inefficiency in own process. The reduction of material loss is evaluated as both of economic performance and environmental one. Companies use MFCA as EMA in own process, for example, production line.

The visibility of MFCA expands usually to supply chain between buyer and supplier. Some material losses are generated by transaction with supplier or customer. So MFCA users try to improve own material losses with supplier or/and customer. We have researched MFCA to be developed as a tool of value chain management. MFCA methodology has improved material in-efficiency in process that covers between buyer and supplier. We have analyzed the relationship in Japanese listed companies and Malaysian listed companies by Questionnaire Research. And we have conducted MFCA project between buyer and suppliers in Japan to make collaboration on improvement of material inefficiency in supply chain. We found new future subjects and successful possibilities to establish Sustainability Value Chain in practice.

In Sustainability Value Chain, MFCA will be integrated with LCA. We have researched to establish a new MFCA method to integrate MFCA information with LCI data in some Asian countries. And this method will be expanded to MFCA analysis in global supply chain with LCI. This method intends to improve or reduce CO_2 emission from material inefficiency in process.

This research shows the possibilities to develop MFCA as a new EMA tool of sustainability value chain.

2. Results of Case Study between Buyer-Suppliers

The case study had been started to improve material in-efficiency in production process by a buyer (Assembler X) and suppliers (Supplier A, B, C and D), based on MFCA information. All of 5 companies produce own products through plastic injection molding process. From viewpoint of MFCA, all companies generate the same material losses cased by molding. To improve these material losses needs a collaboration between buyer (X) and suppliers (A, B, C, and D), and some revolutionary technologies or production way. A project to achieve it was established in Dec. 2011(closed in Oct. 2013), and then, periodically the project meetings were held at the factories of 5 member companies.

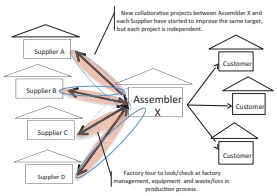


Figure 1. Result (1)

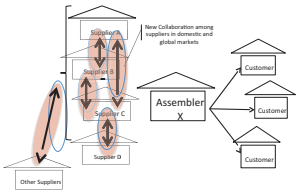


Figure 2. Result (2)

The Figure 1 shows a result of case study. The member companies made factory tour to look/check at factory management, equipment and wastes/losses in production process at the factories of them. As the result, the collaborative relationship between buyer and each supplier became closer, and new technical collaborations were occurred independently.

On the other hand, new collaborations between suppliers, without X, were occurred on other business of suppliers, as shown Figure 2. Usually the supplier tried to make more appropriate product mix with other suppliers to accept an order from other customers.

3. Conclusions

The project was intended to reduce material losses by revolutionary technologies or production way, based on collaboration between buyer and suppliers. But this kind of collaboration couldn't be occurred in this case study, because each supplier had original philosophy of production and production way. And each supplier exercised caution to other suppliers.

MFCA can show bigger potentials of material loss between buyer and supplier (in supply chain), from accumulated case examples of MFCA. To reduce material losses in supply chain needs to share MFCA information in supply chain, and to establish collaboration between buyer and suppliers, based on extended MFCA information in Figure 3.

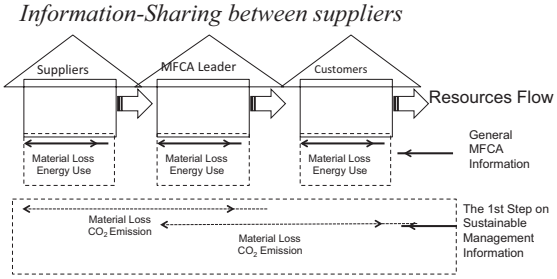


Figure 3. Sustainable Value Chain Management based on the Extended MFCA Information

Acknowledgments

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Integrating LCA Into a Design Innovation Method

Jeremy Faludi*[1]

[1]*University of California Berkeley, USA*
*Corresponding author: faludi@berkeley.edu

1. Introduction

Companies still primarily use life-cycle assessment (LCA) for measurement after a product has been designed, or after idea generation—this relegates LCA to the role of gatekeeper, which designers and engineers consider a burden on their creativity and productivity [1]. Since most experts argue that 80% of a product's environmental impacts are set during the early design phase [2, 3], many have tried to move LCA into early-stage design. Past efforts have primarily focused on making LCA easier [4, 5], improving the cost-benefit ratio by decreasing the perceived cost. The method described here focuses instead on increasing perceived benefit, by using LCA to help design teams work more effectively. It also aims, as some previous tools have [6], to both lower cost and raise benefit by smoothing communication between LCA experts and designers.

2. The Design Method

A design method was developed for the Autodesk Sustainability Workshop [7]. It moves LCA into the early stages of design, using LCA to set initial design specifications which designers use to create new solutions, not just disqualify solutions created with other methods.

The Whole Systems + Life Cycle design method (WSLC) is a four-step process. Step 1: designers / engineers / business managers visually map the whole system of the product or service—all major components, sub-systems, life-cycle stages, inputs and outputs, customer usage and context, and the connections / flows between these nodes. (See Figure 1.) Step 2: boundaries for LCA are drawn on the map and LCA is performed on the system inside the boundaries. This LCA sets the top-priority sustainability problem(s) to solve, for which the team sets goal(s) and concrete metrics alongside the project's top business goals and metrics. Step 3: the team brainstorms on their top-priority sustainability goal, using the visual system map to facilitate the brainstorm. The map helps designers be more thorough and more radical in their ideation. Step 4: estimated LCAs are used to judge the brainstorm results, fulfilling their traditional gatekeeping role. While imprecise, such estimates are still far wiser guidance than untrained guesswork, since the designers, engineers, and business executives making design decisions are not environmental scientists but are experts in their product area.

3. Anecdotal Trials

This method has been used at UC Berkeley, California College of the Arts, Minneapolis College of Art and Design, Emily Carr University, and elsewhere, with student groups redesigning real products for real companies such as Motorola, Steelcase, Hamilton Beach, HP, Thermarest, Oboz, Panasonic, and several others.

Design students have shown great improvement in their understanding of how to choose functional units and boundaries, as well as their ability to interpret LCA results—even students who were previously trained in LCA. Choosing functional units spurred and refined discussion of what user needs each product fulfills, helping designers focus their ideation. Using LCA to set priorities focused the brainstorms. Moreover, company partners have praised the method as providing not just sustainability but also innovation. One representative said, "Your process was as valuable as the actual concepts it produced."

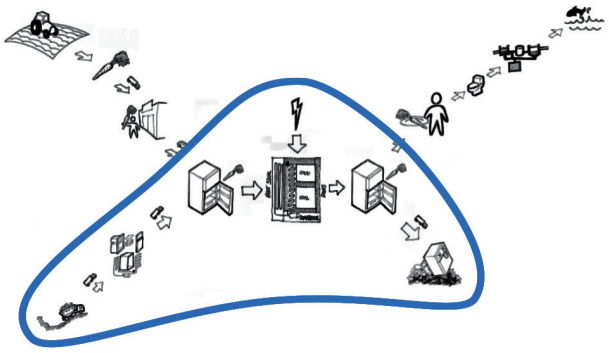


Figure 1. Example system map showing LCA boundaries.

3. Conclusion

This design method attempts to integrate LCA better into the early-stage design process, using it to focus design team ideation and thus actually improve innovation, not merely act as gatekeeper that is perceived as a burden. Anecdotal evidence suggests it fulfills these goals. Further studies should test other ways that LCA may be used to benefit design team effectiveness, and compare design methods.

Acknowledgments

Thanks to Adam Menter and Dawn Danby of Autodesk for their support in the development of the method.

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Product and Organisation Environmental Footprint – Challenges in theory and practice

Annekatrin Lehmann,*[1], Vanessa Bach[1], Matthias Finkbeiner[1]

[1]*Technische Universität Berlin, Germany,*
*Corresponding author: annekatrin.lehmann@tu-berlin.de

1. Introduction

ISO 14044:2006 is a standardised method to assess a range of potential environmental impacts of products and services [1]. It is transparent, worldwide used and accepted throughout policy and in the market and can amongst others be applied for environmental labeling of products, e.g. as basis for type III label. In 2013 the European Commission published the Product and Organisation Environmental Footprint (PEF/OEF) methodology – a life cycle based multi-criteria measure of the environmental performance of products, services and organisations [2] developed as part of the 2020 European strategy "A resource efficient Europe". It aims at harmonising existing methods, while decreasing the flexibility provided by the ISO standards regarding methodological choices. Currently, a three year pilot phase is running, aiming at testing the methodology and developing product category and organisation sector rules (PEFCR/OEFSR). The first PEFCR/OEFSR drafts of the pilots from the first wave (start: Nov 2013) were publicly consulted in May/June; first drafts from the 2nd wave pilots (start: June 2014) are expected to be available also this year.

2. Analysis of the PEF/OEF method and identification of challenges

The idea of a harmonised, life cycle based method enabling comparisons of products/organisations within the same product category/sector is principally good. However, it is accompanied by various risks and challenges and controversially discussed by organizations, associations, science etc. In order to identify the challenges, a thorough analysis comparing ISO 14044 and PEF/OEF methodology was conducted. Moreover, the ongoing pilot phase is followed and the first PEFCR drafts were evaluated – again aiming at highlighting challenges. Based on these analyses recommendations for adaptations of the PEF/OEF methodology and pilot phase were formulated.

3. Results

It was found, that the PEF/OEF methodology shows various differences to ISO 14044 – it is e.g. communication driven – and that some methodological aspects of the PEF/OEF methodology are even contradictory to ISO 14044, e.g.:

- allowing for weighting of LCA results to single scores or
- providing predefined impact categories and a fixed EoL formula.

These differences and contradictions may cause confusion and proliferation rather than harmonisation. Moreover, many aspects seem to be hardly applicable in practice, e.g.:

- exclusion of cut-off criteria,
- use of certain predefined impact assessment methods – some, for which only insufficient inventory data exists (PM10, land use)

Also, it is unclear which measures might be appropriate to communicate the results, how the intended benchmarks and environmental performance classes will be defined and if the PEFCRs/OEFSRs will be indeed a suitable basis for comparisons and comparative assertions of products/organisations [3].

Besides this, following main criteria need to be considered for the success of the PEF/OEF methodology: consistency of pilots, clear goal formulation and measurable added value compared to existing systems for environmental analysis and declaration. However, with regard to first results of the pilot phase, namely the definition of the scope in the particular PEFCR drafts, none of these criteria seem to be fully met.

Some general challenges and inconsistencies between key features of the PEFCR drafts are summarized in Table 1.

Table 1. General challenges/inconsistencies between key features of the first PEFCR drafts

Key features	Inconsistencies and resulting risks
Product category; CPA/ NACE code	Some product categories are very broad, others very narrow. For both, it is unclear, if comparability is indeed supported
Functional unit	Some are not suitable for functionally equivalent comparability; an added value to current practice is not provided
Representative product/ Bill of materials	Some do not fulfill the functional units chosen; are defined based on different approaches; aim/ application is unclear
System boundaries	life cycle phases are treated inconsistently; capital goods are partly missing (contradicts the ban of cut-off)

4. Discussion and Outlook

The idea of the PEF/OEF methodology – harmonization and comparability – is good and supported and the comprehensive and intensive work on the pilot projects is acknowledged and appreciated. However, several challenges exist and needs to be considered in the ongoing pilot phase and the upcoming adaptations of the PEF/OEF methodology, e.g.:

- clear definition of the goal of each pilot project and the use of PEFCRs/OEFSRs in policy/ market
- ensuring consistency between the pilots
- discussing about communication, specification of the process on defining benchmarks/environmental performance classes and consideration of existing schemes for environmental analysis and declaration
- reconsidering some methodological requirements, e.g. predefined impact categories, ban of cut-offs etc.

We think that following these recommendations could help to position PEF/OEF as useful instruments facilitating the use of LCA and providing a basis for sound political decisions.

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20 years of LCA development, have we understood the user needs?

Mark Goedkoop[1]

[1]*PRé Consultants, The Netherlands; Goedkoop@pre-sustainability.com*

Introduction
LCA methodology is used by thousands of companies, and has proven to be a relatively robust tool for understanding the impacts of products. Most major multinational companies nowadays have something like an LCA department, a team of usually a handful specialists that perform LCA's mostly to support internal decisions. Yet one may wonder why it is still a relatively small community that performs LCA, and why LCA has not become more main-stream in business processes.
This paper reports from a number of workshops we have organized in various countries in 2012 and again in 2014 with representatives of corporate LCA teams. We listened to their concerns and bottlenecks, challenges and successes.

Process
For this research, we worked together with a number of business partners of our organisation in Europe. We asked them to invite their corporate clients, to come together for an open discussion on how they see the future of LCA, what their challenges are and how they cope with them. Of course we also asked them what kind of features and tools would help them most. We clearly explained that we like to organise this as a listening session; a clear goal was to create an atmosphere in which these corporate clients could learn from each other and share common issues. The meetings were organised early 2012 with 7 partners.

Before the 2012 meeting the PRé organiser phoned all participants in advance (about 50) to ask them what their business objectives are and what they expected, in order to be well prepared. Although we wanted the participants to talk and explain their issues many also wanted to hear the vision of PRé and the partner, so we inserted that subject as last part of the agenda, in order to keep the discussion free and open. In the 2014 version of the meetings these phone calls were no longer necessary, as many came back.

The overarching message
Many Corporate LCA experts are telling us they have difficulty to communicate their findings to the internal stakeholders. One of the problems is that the results are not well understood by their colleagues in marketing, research and product development; it is as if they speak a different language. LCA results do not really connect to what they want to know. This means many are seeking for ways to drastically simplify results or translate them into guidelines.
Getting the results out and understood is a problem, getting data in is another big problem; often other departments are not really motivated to supply data. Getting access to data held by the purchasing department can also be difficult.

The general picture that emerges, is that the LCA department finds it difficult to connect and to be relevant, while at the same time companies have committed themselves to improve the sustainability of products in a rational way. This seems to imply there is a disconnect between the ambitions of the companies, and what the LCA experts can offer; do they speak different language, or why are they not able to connect; this is an intriguing question.

More detailed findings
From all the comments and discussions we got some really interesting additional insights

1. Participants were very happy with the workshop format, as they told us they had learned so much from each other, and they saw comfort in the thought that the issues they are facing are often very similar to the issues, other face in their company. Some said: "this is great, finally a meeting where I can talk and do not have to listen to the opinion of consultants"
2. Although we expected there would be much attention on software features, most told us that this was not their problem; they are generally happy with what they have; so features are not the bottleneck. They do however see a need to better manage their data, which refers to keeping track of all the questionnaires they are sending out and getting access to data held in other systems, such as ERP.
3. Data was an important discussion point. There is always a need for more data, especially data representative for their sector. On the other hand there was a clear understanding that this need will always exist. In the 2014 sessions the new ecoinvent version 3 with its new modelling approaches was also a topic for some members.

Alternative approaches to LCA
We also tried to discuss the merits of what people see as "alternatives" for LCA, like Circular Economy, Natural Capital and the Sustainability Consortium approach; which problems do they solve and which new problems do they create, or are they just new names for LCA? Interestingly not many had studied these new approaches and were sometimes only vaguely aware of them. We were surprised as these " alternatives" do often appeal to management, marketing and designers; at least in our experience. So we also have the impression that many LCA experts should do more to understand these alternatives, and especially why other departments find them more appealing. If connection with the other department is a bottleneck, both sides should do their best to try to understand each other. So is the LCA department too much focussed inward, and not really exploring what is happening outside the LCA community? Have LCA experts a genuine interest in alternative approaches?

Conclusions
The project has resulted in very valuable insights, both for the organisers and for the participants. In the new roundtables in 2014, people acknowledged this and proudly told what they had been doing with the insights and told about how they improved the connection and the relevance of the LCA team in the organisation. We will use the findings to develop software that overcomes the communication bottlenecks, both in collecting and sharing the data and findings. We are already piloting this with a number of participants, to learn more.
As a message to the LCA community and the researchers: the bottleneck is not in the lack of sophisticated tools and methodologies. Companies need LCA departments that are better connected with other departments, and shows genuine interest in alternative approaches. The solution is not to make better LCA's but get a better understanding of what marketing, design, research and purchasing departments need.

The significance of land use effects on groundwater resource availability in Japan

Masaharu Motoshita*[1,2], Stephan Pfister[3], Brad Ridoutt[4], Yuya Ono[5], Kiyotaka Tahara[1] and Atsushi Inaba[6]

[1]*Natioanal Institute of Advanced Industrial Science and Technology, Japan*; [2]*Technische Universitaet Berlin, Germany*; [3]*Swiss Federal Institute of Technology Zurich, Switzerland*; [4]*The Commonwealth Scientific and Industrial Research Organization, Australia*; [5]*Tokyo City University, Japan*; [6]*Kogakuin University, Japan*
*Corresponding author: m-motoshita@aist.go.jp

1. Introduction

Water footprinting is expected to play a very important role as a tool for managing environmental impacts related to water use through life cycle of products, services and organizations. In the discussion of drafting the international standard of water footprinting (ISO14046 [1]), all the relevant factors to the change of freshwater availability are required to be considered, like not only physical scarcity of freshwater but emission of pollutants and land use (may affect the freshwater availability of downstream users). Thus, the significance of land use effects on groundwater resource availability in Japan was assessed and verified in terms of water footprinting considering both effects of physical and qualitative changes.

2. Method

Simple water flow model was applied on mesh scale (1km*1km) to estimate the change of rain water infiltration due to the land occupation by the artificial land cover. The balance of water in each mesh was calculated by estimating the amount of evapotranspiration and infiltration to underground based on climatic data and physical characters of land surface covers. The target land use types were classified into five (forest, uncultivated land, paddy field, arable land, urban area) according to the definition of statistical data of land use. The loss of infiltration rate in different types of land use was assumed to be the shortage of ground water availability. The effects of land use by goods and services production on water availability were also assessed based on Input-Output analysis [2] with comparing those of water consumption [3] and water degradation (pollutant emissions) [4].

3. Results and discussions

As a result of calculating water balance, the average volume of water recharge loss to groundwater was calculated as 0.97 [$m^3/m^2/yr$] for the case of land occupation as urban area. It was accounted as around 58% of the average annual amount of precipitation in Japan, which implied that the large part of potential water input to groundwater by rain might be lost by artificial land occupation. However, the effects of land use on the availability of groundwater were different from region to region and the differences could be counted up to 70 times at maximum.

In the aspect of direct effects of goods and services production (without considering retroactive effects in supply chain), the effect of land use accounted for around 9% of total loss of water availability (Figure 1). On the other hand, the effects of land use were different among goods and services in comparison with water consumption and pollutant emissions. In particular, the impacts of land use was assessed as more significant in case of considering impacts (water stress) of water availability loss because the water stress (rate of demand to resource amount) of groundwater is relatively higher than that of surface water. By including the effects of whole supply chain, the significance of land use on water footprinting seemed to be almost same as water degradation. The results of this analysis indicated that the effects of land use on water footprinting of products, services and organizations could not be disregarded.

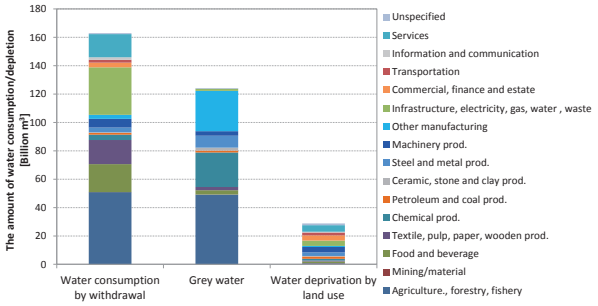


Figure 1 Water availability loss due to three factors (withdrawal, pollution, land use) for whole activities in Japan

4. Summary

The amount of the availability loss of freshwater due to artificial land use was relatively smaller than those due to water withdrawal and pollution. However, the dominant factor (withdrawal, pollution, land use) were dependent on the characteristics of industrial sectors and some of the sectors showed high significance of land use in terms of the availability loss of freshwater. In addition, regional differences could be found in the effects and the availability of each resource (surface and groundwater) of freshwater was also different among regions. In this context, the loss of groundwater availability may have significant meanings in some sectors and some regions. In this analysis, only inventory analysis related to land use was focused on and more precise analysis including impact assessment will be expected.

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Human health impact models from water use: comparing to better harmonize

Anne-Marie Boulay,*[1] Masaharu Motoshita,[2] Stephan Pfister[3], Cecile Bulle[1], Manuele Margni[1]

[1]*CIRAIG, Ecole Polytechnique of Montreal, Canada*; [2] *National Institute of Advanced Industrial Science and Technology, Japan;* [3] *Institute of Environmental Engineering, ETH Zurich, Switzerland*
*Corresponding author: anne-marie.boulay@polymtl.ca

1. Introduction

In the past decade, several methods have emerged to quantify human health impacts of water use [1–4]. Since these models cover the same impact pathways, this paper aims to (i) identify the key relevant modeling choices that explain the main differences between characterization models leading to the same impact indicators; (ii) quantify the significance of the differences between methods, including the assessment of model uncertainty and (iii) discuss the main methodological choices and provide recommendations to guide method development and harmonization efforts.

2. Method

A general framework describing the impact pathway leading to human health impact is presented and the modeling choices for each of the modeling steps are analyzed for difference in results (using mean relative difference) and model response consistency (through rank correlation coefficient). Uncertainty data associated with the choice of model is provided for the results of each of the model, and an average value is provided as a tool for sensitivity analyses.

3. Results

The results determined the modeling choices that significantly influence the indicators and should be further improved and harmonized (see Tab.1). The inclusion or exclusion of (1) quality when assessing water deprivation, (2) impacts from domestic user deprivation, and (3) trade effects, significantly influence human health impacts. The differences among the models are substantial, as can be seen in Fig.2.

Tab.1: Table of results describing the importance of specific modeling choices in human health impact models (the longer the red bar the lower the correlation, the longer the blue bar, the higher the difference)

Modeling Choice	Consistency*	Difference**
Highercomplexity: water quality specification at endpoint		
100% consumption good quality water	46%	0.79
100% consumption poor quality water	59%	1.24
100% degradation good quality water into very poor quality	43%	0.83
Inclusion or exclusion of user deprived		
Aquaculture	100%	0.0004
Domestic	84%	0.69
Source of data for user distribution		
Watergap - Aquastat	93%	0.30
Watergap - Vorosmarthy	87%	0.59
Vorosmarthy - Aquastat	89%	0.60
Socio-economic		
Trade effect		
E-Motoshita_agri / E-Motoshita_agri (no TE)	76%	1.32

* the longer the red bar the lower the correlation
**the longer the blue bar, the higher the difference

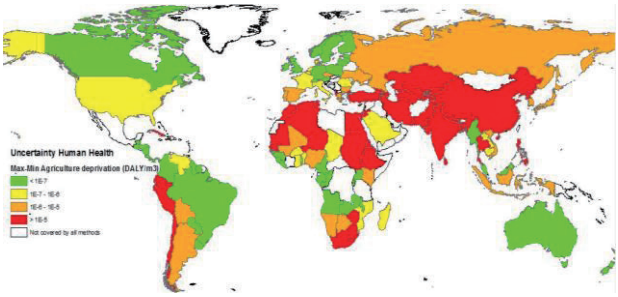


Figure 2: Maximal difference found between human health impacts from agricultural deprivation using different models (Boulay, Pfister and Motoshita).

6. Conclusion

This paper provides useful insights to better understand human health impact models for water use and identifies the key relevant modeling choices and differences, making it possible to quantify model uncertainty and the significance of these choices in a specific regional context. Deconstructing the existing models into a common framework and highlighting the differences and similarities has helped to determine building blocks to support the development of a consensual method. Such model will soon become essential to ensure consistent application of the forthcoming ISO 14046 international standard on Water Footprinting.

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Functional mapping for sustainable consumption: an example through drinking water consumption.

Sébastien M.R. Dente,* Seiji Hashimoto

Ritsumeikan University, Japan
*Corresponding author: 13v00202@gst.ritsumeik.ac.jp

1. Introduction

Environmental system analysis uses decomposition technics in order to distinguish between relevant parameters of an environmental impact. The purpose is to find lever of actions for solving environmental issues. One of the most famous decomposition technics is the I=PAT equation which allows the decomposition of environmental impacts into population, affluence and technology factors [1, 2]. These factors are nevertheless not treated equally as environmental policies have so far mainly focused on the management of technological factors (carbon, energy efficiency) leaving the affluence factor to be mainly represented through the GDP economic indicator.

2. Functional mapping

The present presentation aims at filling this gap by providing a clear linkage between affluence and technological features, notably applicable at the micro-economic level. This way, a more sounded lifecycle perspective of products could be driven. This new methodology considers affluence as a set of functions defined at the final consumer level which determines his/her welfare. Therefore welfare is understood as a functional system specific to the final consumer. Then, a functional mapping is established transforming the welfare functions into technical functions manageable by producers [3].

3. Application to drinking water consumption

This new methodology is illustrated through the study case of household drinking water consumption based on the comparison of the systems presented in Figure 1 . The customer's function considered is the quality of water which should be adapted to each particular use. This way, in systems 2 and 3, the water quality and associated treatments is differentiated in "drinking-cooking use" (around 8% of Household consumption [4]) and "other use" (92%). The environmental gains that could be expected from this new design of water supply system is then made explicit in comparison to the usual conventional treatment systems in which water uses are not differentiated (system 1). The potential for the application of these new water supply systems in developed and developing countries is then discussed together with the usefulness of process-based LCA in the design of functional oriented systems.

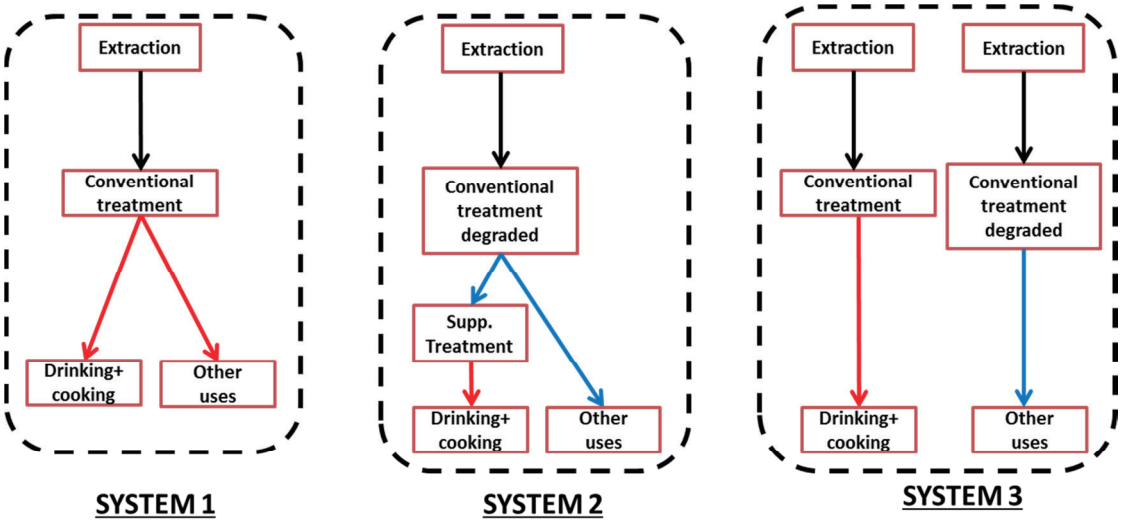


Figure 1. Comparison of use-differentiated (system 2 and 3) and non-differentiated (system 1) water supply systems

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Economic Water Productivity of Polylactic Acid (PLA) Production Chain in Thailand

Shinatiphkorn Pongpinyopap,[1] Unchalee Suwanmanee,[2] and Thumrongrut Mungcharoen*[1]

[1]*Center for Petroleum Petrochemicals and Advanced Materials, Center for Advanced Studies in Industrial Technology, Department of Chemical Engineering, Kasetsart University, Bangkok 10900, Thailand*;
[2]*Department of Chemical Engineering, Srinakharinwirot University, Nakhon-nayok 26120 Thailand*
*Corresponding author: fengtrm@ku.ac.th

1. Introduction

Thailand will establish PLA factory in order to reduce PLA import and add value to agricultural commodities. Cassava, corn and sugarcane have a high potential to use as feedstock for PLA production [1]. Although it is an attractive in term of reduce GHG emission but it is an unattractive in term of increase water consumption. Moreover, a few studies are interested in the value per unit of water used in agriculture (economic water productivity) more than the physical water productivity [2]. This study aims to evaluate and analysis the economic water productivity (baht/m^3) associated with PLA production chain using cassava, corn and sugarcane as the feedstock in Thailand based on the Water Footprint Network (WFN) approach [3]. The functional unit is 1 ton of PLA granulate at the factory gate in Thailand. The system boundary is drawn to include water consumption of all steps from crops cultivation and harvesting, transport to intermediate production factory, intermediate processing process, transport to PLA factory and the polymerization process to produce PLA granulate.

2. Methodology

The economic water productivity (EWP) is the net financial returns for a unit of water used. The EWP (baht/m^3) was estimated as the ratio of the PLA price to the blue water footprint. The blue water footprint was the volume of surface and groundwater consumed as a result of the production of a good or service. In the PLA production chain, there are two types of blue water consumption which relevant to each stage of PLA production chain; 1) Water consumed during the processing step (i.e. the consumptive water used over the period of crops cultivation, the consumptive water used for cooling system) and 2) Water consumed to produce raw material for the processing step. The crop water requirement (CWR) was calculated by multiplying the reference crop evapotranspiration (ET_o) by the crop coefficient (K_c). The reference crop evapotranspiration (ET_o) was calculated by multiplying the pan evaporation coefficient (K_p) by the pan evaporation (E_p). All data sources for calculation were taken from local data. Integration of Daily Soil Water Balance method with Geographic Information System (GIS) was used to distinguish between green (effective rainfall) and blue (irrigation requirement) water component. The amount of water use to produce raw material in each stage of PLA production chain were obtained from Ecoinvent [4] and converted to water consumption with the consumption factors [5].

3. Results and Discussion

Table 1 shows the economic water productivity of PLA production chain. The results indicated that the cassava-based PLA production chain had the highest economic water productivity followed by the corn-based and the sugarcane-based. The advantage of cassava-based compared with the other crops was its potentially low evapotranspiration and could grow without irrigation water. Thus, the PLA production chain, that using cassava as the feedstock was attractive crop in water perspective. The strategies for increasing the EWP could be done by increasing crop yield or re-allocating water from low to higher valued uses.

Table 1. Economic water productivity of PLA production chain

Crops	Economic water productivity (baht/m^3)
Cassava	57,803
Corn	45,662
Sugarcane	680

4. Conclusions

In this study, we evaluate and analysis the economic water productivity of PLA production chain using cassava, corn and sugarcane as the feedstock in Thailand. The results show that the cassava-based PLA production chain had the highest economic water productivity. It can be concluded that the cassava was attractive crop for using as the feedstock in PLA production chain in water perspective. Moreover, this study provide information for operational planning and management of PLA production chain for maximizing net financial returns from limited land and water resources.

Acknowledgments

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Environmental Life Cycle Emissions for Vegetable oil Microemulsion-based Biofuels

Noulkamol Arpornponga[1], Virin Kittithammavong[1], David A. Sabatini[2], Sutha Khaodhiar[1], Ampira Charoensaeng[1]

[1]*Chulalongkorn University, Thailand,* [2]*The University of Oklahoma, USA.*
*Corresponding author: ampira.c@chula.ac.th

1. Introduction

To date, a variety of biofuel productions have been technologically developed to reduce greenhouse emissions (GHGs). A microemulsion biofuel (ME) as an emerging technology for bio-based diesel production presets environmental advantages in terms of replacing thermochemical conversion of transesterification process and avoiding byproduct and wastewater. The microemulsion fuel is a thermodynamically stable mixture of at least two-immiscible liquid fuel blends, which the polar ethanol phase dispersed in non-polar oil phase, stabilized by surfactant. Several vegetable oil feedstock and surfactant/cosurfactant systems have been employed to achieve comparable fuel properties to those of the no. 2 diesel standard [1,2]. In order to promote the ME technology, GHG emissions and environmental implications need to be addressed. This study reveals the GHG emissions and impacts through Life Cycle Analysis (LCA) approach for the ME production from palm oil/diesel and ethanol blends as an alternative fuel for sustainable future.

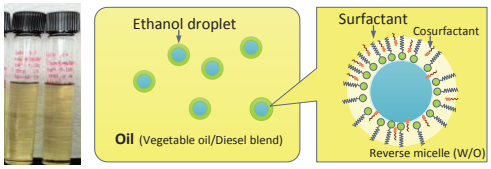


Figure 1 Microemulsion fuel and reverse micelle structure

2. Methodology and system boundary

In this study, the microemulsion biofuels (so called ME50) formulated by the mixture of palm oil/diesel (50:50 v/v%) blend (58 vol.%) with ethanol (20 vol.%), and stabilized by methyl oleate/1-octanol (22vol.%) as surfactant and cosurfactant, respectively [1]. The system boundary of the ME50 production covered from palm oil cultivation to liquid fuel (cradle to gate). The production of the ME50 was separated into three main stages; palm oil cultivation, palm oil, extraction and refinery and microemulsion process. The GHG emissions were calculated based on the standard for carbon footprint of product (ISO14067) as described by CO_{2eq}. The environmental impacts were evaluated through LCA approach by the SimaPro (v. 7.1).

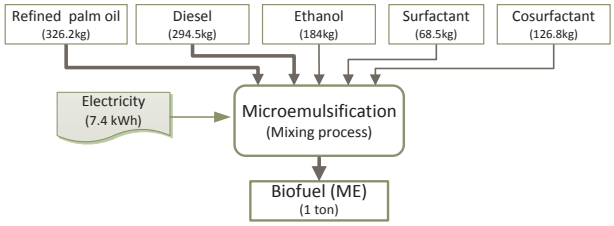


Figure 2 Production of microemulsion biofuel (ME50)

3. Results

3.1 The GHG emission of microemulsion biofuel

The GHG emissions from the ME production stage were estimated to be 1,140 kg CO_{2eq} per ton of ME50. The significant GHG emissions during the ME50 production influenced from its raw material preparation, accounting for 99% of all GHG emissions. Whereas GHG emissions generated from production stage were relatively low, due to the fact that only electrical mixing the main process consumes small amount of electricity to produce the biofuel. Among all of the materials preparation, the production of palm oil indicates a large contribution about 315 kg CO_2/ton (27.6 percent), due to fertilizer loading during cultivation, and energy uses and wastewater discharges during the oil extraction.

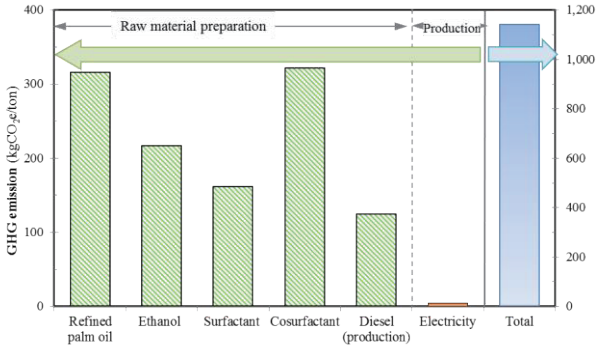


Figure 3 GHG emissions of ME50 production and each raw material acquisition

3.2 Environmental impact assessment of ME50 production

The ME50 production contributes significantly to environmental impact categories including, global warming, acidification, eutrophication, human toxicity, aquatic and terrestrial ecotoxicity, land use, water depletion. The emissions of each impact category were compared to those of the biodiesel B50 (biodisel: diesel 50:50 v/v%) and pure biodiesel (the data is not shown). Based on the inventory data, the ME50 presents a benefit regarding with less impact to water environment due to no water supply being required for purifying biodiesel. Moreover, the ME50 production also indicates remarkably positive impacts due to less toxic impacts contributing to aquatic and terrestrial environments as well as human health.

4. Conclusion

The production of microemulsion biofuel from palm oil causes 1,140 kg CO_{2eq} per ton. Based on GHG emission calculation and LCA analysis, the raw material selection and formulation to achieve a stable single-phase microemulsion fuel are the key parameters to optimize its emissions. Thus, the microemulsion biofuel could be considered as eco-friendly sound technology for future biofuel production.

Acknowledgments

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Life Cycle Assessment of Biofuels and the Issue of Indirect Land Use Change

Liselotte Schebek*[1], Yalda Cikovani[1]

[1]*Technische Universität Darmstadt, Institute IWAR, Chair of Material Flow Management and Resource Economy, Franziska-Braun-Straße 7, D-64287 Darmstadt, Germany*
*Corresponding author: l.schebek@iwar.tu-darmstadt.de

1. Introduction

Today, biofuels play a major role in climate policies worldwide. In 2008, however, the well-known study by Searchinger et. al. postulated that biofuels might on the contrary enhance climate change, due to the effect of indirect land use change on the carbon balance which had not been taken into account so far. Since then, the assessment of indirect land use change is an ongoing but highly challenging issue for LCA. Controversial views exist how to tackle this problem methodologically. It is even questioned whether it should be included in LCA at all because of the large variety of results studies revealed. As part of a current research project on biofuel policy we investigated the state of the art for assessment of land use change in connection with LCA, focusing on the interlinkage between LCA and models for Land Use Change (LUC).

2. Methodology

We carried out a comprehensive literature review, from which we identified types of LUC and of models applied for assessment of LUC from biofuels. By comparing characteristics of these types to typical research cases of LCA, we derived a mapping to support the choice of adequate approaches for incorporation of LUC.

3. Land Use Change and Land Use Change Models

LUC is the conversion of one type of land to another [1]. In connection to a certain driver, e.g. the demand for biofuels, LUC is discerned in direct and indirect LUC: DLUC means, that land is changed from any previous use to biofuel feedstock production. ILUC denoted LUC that is induced by the production of feedstock for biofuels because the former feedstock now has to be produced elsewhere. As to LUC models, economic and deterministic (or allocation) models are discerned, e.g. [1]. Economic models market equilibrium models, covering CGE and PE models. Deterministic models base on allocating LUC to certain biofuels by fixed assumptions, mostly derived from historical data. Above these, in recent years also spatially explicit simulation models have been used which are based on the general concept of land-use systems [2][3]. For all models it has to be noted, that they deliver LUC as a result, where DLUC and ILUC are identified from interpretation of results.

4. Interlinkage between LCA and LUC modelling

In LCA methodology, assessment of ILUC is conceived to be part of Consequentional LCA (CLCA). CLCA aims to cover changes in the economy, where ideally economic models are the corresponding tool. However, as LUC models are complex and need a high degree of expertise, our review showed that in fact assessment of ILUC is no integral part of LCA: on one hand, those approaches focusing on ILUC assessment stand on their own and do not necessarily follow the methodological outlines of CLCA. On the other hand, most publications on biofuels based on LCA ISO 14040 do not incorporate ILUC assessment, and if, only by adopting results from ILUC studies performed independently. If LCA and ILUC assessment are independent, however, there is no attention to the question which model fits to goal and scope of the respective LCA.

Consequently, combining LCA and assessment of ILUC comes down to a conceptual interlinkage between LCA and the respective LUC model. This interlinkage has to be based on goal and scope and has to bridge the basic difference generally inherent to CLCA approaches that LCA looks from the individual product or technology respectively, while LUC models look for the macroeconomic level.

Possible cases for studies on biofuels cover the range from regional case studies to the assessment of biofuel policies. Here, different levels are encountered as to the incorporation of global economy and trade as well as to the regionalization of land use change and carbon flow assessment. Based on these considerations, we propose a matching between goal and scope and the ILUC modelling, based on three criteria (Table 1).

Table 1 Criteria for mapping of LUC Model to application case

	Biofuel demand	**Importance of international trade**	**Spatial information on soil/above-ground C**
Economic models	high	high	low
Deterministic models	low	low	low
Land Use models	medium to low	low [a]	high

[a] (if high: coupling to economic models)

5. Conclusions

It has to be emphasized that as to LUC assessment a trade-off exists between a most comprehensive inclusion of global market effects, where economic models are best state of science and an easy to use and transparent assessment where deterministic approaches are advantageous. The discussion presented above therefore is in line with a general argumentation introduced in the discussion on ALCA versus CLCA, saying that CLCA should be performed as far as uncertainties and intransperancy of consequential modelling do not outweigh the insights gained from it [4]. On this basis our matching approach presented above should support the appropriate treatment of ILUC by combining LCA and LUC modelling.

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Evaluation of uncertainty in for- and background systems: A case study of municipal wastewater treatment plant

Hiroko Yoshida*, Charlotte Scheutz, and Thomas H. Christensen

Technical University of Denmark
*Corresponding author:hyos@env.dtu.dk

1. Introduction

The quality of a Life Cycle Assessment (LCA) depends on the availability of input data for constructing a Life Cycle Inventory (LCI). Nonetheless, collecting a site-specific input dataset could be prohibitively time- and resource-consuming. As a consequence, LCA practitioners rely heavily on existing emission and operational data for target systems. For instance, LCA of 400 wastewater treatment plants (WWTPs) in Denmark was conducted based on the information compiled under existing regulation [1], yet this approach could result in the underestimation of environmental impacts from the foreground systems and overlook the uncertainty due to the variation in daily operation [2]. The other source of uncertainty is the uncertainties embedded in the background systems. Since the previous studies [1, 2] shows that more than half of the environmental impacts for WWTPs, the evaluation of uncertainties ought to be extended to the background systems. For this purpose, LCA of a municipal wastewater treatment plant in the Danish capital region was used as a case study

2. Approach

The functional unit of the assessment involved the treatment of average daily inflows of wastewater at the Avedøre WWTP. The assessment was conducted in the four levels to illustrate the source of uncertainties in the background systems. The baseline scenario only includes the foreground system and the uncertainties embedded in each emission data (L3). Then, the system expanded to include the background system and here the source of variation of energy and chemical demand by the WWTPs were regarded as the source of uncertainty (L3+). The uncertainties of external process were evaluated in two steps; first the quality and representativeness of each external process LCI data was evaluated following the pedigree matrix developed by [3] (L3+DQ). Finally, the uncertainty embedded in the Ecoinvent process was included in the assessment (L3+DQ+DB). EASETECH model was used to conduct the assessment including uncertainty analysis and the LCI data for the background systems were taken from Ecoinvent database. Detail description of study site and technical modeling approach was provided in [2]. The uncertainty was evaluated by using Monte Carlo simulation with 100,000 simulation runs .Nine impact categories (global warming (GW); acidification (AC); terrestrial eutrophication (TE); marine eutrophication (ME); photochemical ozone formation (POF); ecotoxicity (ET); human toxicity- cancer (HTc); human toxicity, non-cancer (HTnc); particulate matter (PM)) and the ILCD recommended characterization method and normalizing factors were adopted [4].

3. Result and Discussion

The outcome of the assessment is presented in the Figure 1. With exception of marine eutrophication in which majority of impact comes from the foreground systems, the inclusion of background system has more than doubled the median impact potential. The uncertainty factor for data quality and representativeness ranged from 1.2 to 12% of mean value and the inclusion of uncertainties in the Ecoinvent database introduced two to three folded the uncertainty range though the median impact potential remain unchanged. Based on the results, it is recommended to extend the uncertainty analysis not only to the data quality assessment but also to include the uncertainty embedded in the LCI dataset, especially for the toxicity categories.

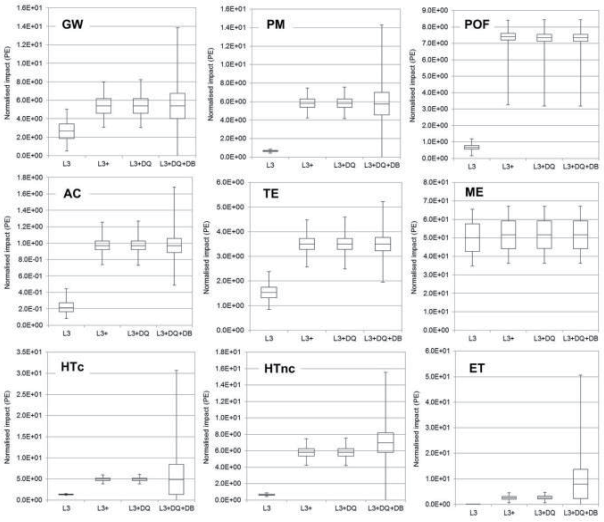


Figure1. Normalized impacts obtained for data collection schemes L3, L3+, L3+DQ, and L3+DQ+DB.

Acknowledgement
The authors thank Dr. Julie Clavreul for assisting EASETECH modeling and Dr. Thomas Guildal for providing operational data of WWTPs.

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Basin-scale Multi-objective Optimization of Water and Wastewater Systems Considering Global and Regional Impacts

Seiya MAKI[*1], Jun NAKATANI[*1], Kiyo KURISU[*2] and Keisuke HANAKI[*1]

*1 Department of Urban Engineering, The University of Tokyo, Japan
*2 Research Center for Advanced Science and Technology, The University of Tokyo, Japan

*Corresponding author: maki@env.t.u-tokyo.ac.jp-

1. Introduction

Water use systems include stakeholders who have various preferences. Hence, their planning requires a comprehensive assessment of various evaluation axes including environmental, economic and social aspects. However, it is considered that desirable systems are different depending on stakeholder preferences when tradeoffs exist among evaluation axes.

The objective of this study is to obtain the Pareto optimal, necessary and sufficient alternatives of a water use system in consideration of diverse stakeholder preferences for evaluation axes. The study area of this study is Arakawa basin, Japan. We applied multiple-objective optimization using a mixed integer linear programming (MILP), with an objective functions that is composed of global warming, water pollution substance and so on, and with design variables including components of water purification plants, wastewater treatment and reclamation plants and pipe networks.

2. Methods

An optimization problem indicates a mathematical method that makes a search for a solution that maximizes or minimizes its objective function under constraints. In general, a weighted multi-objective optimization model is expressed by Equation (1).

$$\begin{aligned} &\min \quad z(x) = \sum_{i=1}^{n} w_i \cdot f_i(x) \\ &sub.to \quad g(x) \leqq 0 \quad x \geqq 0 \quad \sum_{i=1}^{n} w_i = 1 \quad w_i \geqq 0 \end{aligned} \tag{1}$$

where, $f_i(x)$ is ith objective function, x is design variables. $g(x)$ is a constraint functions, and w_i is a weighting coefficient of the ith objective function.

The evaluation axes relevant to desirable water use system include fundamental performances and regional impacts, such as the business cost, the amount of water pollution substances, surface water and groundwater intakes. As global impacts that the water use system imposes on outside the region, life cycle impacts on global warming, acidification and eutrophication, life cycle fossil resource, mineral resource and water resource consumptions are evaluated using LCA. In addition, the quantities of good-tasting clean water and surplus reclaimed water are considered for evaluation of amenity.

We applied components of water use systems such as the amount of groundwater intakes in water purification plants, purification methods (flocculation-sedimentation or ozonation processes), wastewater treatment methods (conventional activated-sludge or A_2O processes), sizes and lengths of water and sewage pipes between cities, water-supply pipes in each city, as design variables. Wastewater reclamation methods (ozonation or RO processes) and sizes and lengths of reclaimed water pipes between cities were also taken into account as design variables.

As constraints of optimization problem, we considered the minimum requirements of water use system as follows:

1. The amount of water demand in each city should be fulfilled.
2. All wastewater generated in each city should be treated.
3. Reclaimed water should satisfy the required level of water quality according to application (e.g., water for flushing toilets, general service water).

By applying various sets of weighting coefficients to the optimization problem of Equation (1), alternatives reflecting various preferences can be obtained. In this research, we input 10,000 sets of random numbers as weighting coefficients. Sum of weighting coefficients in each set was equal to 1.

3. Results and Discussion

As a result of optimization for 10,000 sets of random numbers, we obtained 68 Pareto optimal solutions, which could be alternatives of the water use systems. Those solutions were classified into five groups using k-means clustering.

Figure 1 illustrates distributions of the optimal solutions. The upper figure presents their relationship between global warming and water pollution substances, and the lower figure presents that between global warming and surplus reclaimed water. There is a tradeoff between global warming and water pollution substance, or surplus reclaimed water. As shown in the lower figure, an increase in the amount of reclaimed water increases the impact on global warming. Alternatives with the positive amount of surplus reclaimed water were derived only when the weighting coefficients of surplus reclaimed water were significantly large.

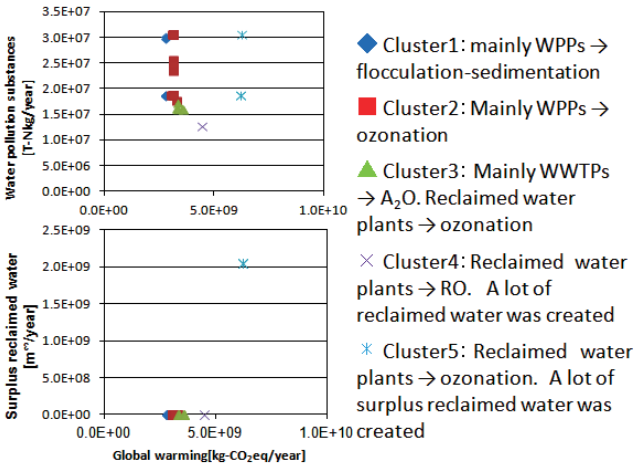


Figure 1. Distribution of Pareto optimal solutions and their clusters

4. Conclusion

Each Pareto optimal solution can be regarded as the best feasible alternative corresponding to a particular stakeholder preference. Owing to the feature of MLIP, we could obtain a relatively small number of Pareto optimal solutions from a large number of weighting coefficient sets. In addition, we could classify those Pareto optimal solutions into a small number of groups using cluster analysis.

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Life Cycle based Sustainability Solutions: How successful companies turn sustainability solutions into company benefit and business value.

Martin Baitz,*[1] Masahiro Osumi[2], Hatori Yukiyoshi[2] and Harald Florin[1]

[1]*PE International AG, Germany*; [2]*PE Asia Corporation, Japan*
*Corresponding author: m.baitz@pe-international.com

1. Introduction

Sustainability is core to a company's ability to prosper in a competitive and changing global business environment. Companies which can successfully anticipate and manage economic, environmental and social opportunities and risks will emerge as leaders. A focus on quality, innovation and productivity is likely to create a competitive advantage and long-term stakeholder value.

Life Cycle Solutions established in industry as important pillar in the sustainability domain, as it helps to prevent spreadsheet sustainability approaches, greenwashing, single metric evaluation and unacceptable inaccuracy or arbitrary.

Life Cycle Solutions are supporting trends like "innovation and clean tech", strategic energy management, sustainable supply chains and "next generation strategies". Successful sustainability implementation is not "doing what you have to do", but succeeding in doing innovation with sustainability.

2. Landscape of stakeholder

Life Cycle based approaches is practiced and communicated differently amongst stakeholders.

Academia focuses on public and influenceable data, model theory and system behavior and uses Life Cycle Assessments.

Politics focuses on reproducibility and method regulation, has stimulation interest and uses Life Cycle Thinking [1].

Industry focuses on company and supply chain data, product stewardship, decision support and integration in daily operation and uses Life Cycle Management.

If these 3 interests and 3 different mindsets are understood, companies can focus on value creation in the life cycle of their products, if their solution respects political initiatives and facilitates practice-proven scientific improvements.

3. Standards as basis, networks as connection

International standards e.g. [2], [3], [4] support the setup of consistent supply chains across nations and markets. Standards must be met and be applicable in IT tools and databases to enable scalability. International networks e.g. [5] support interoperability and data access if common format and nomenclature rules are defined and applied.

4. Materiality, practicability, quality, transparency

The four core pillars of successful sustainability solution implementation in industry are materiality (which data do I have and which data is relevant?), practicability (where do I get the data from and which tool and databases do exist to support my goal?), quality (which are relevant quality indicators for my goal achievement?) and transparency (are processes clearly documented, is change monitored and are routines auditable?).

5. Tools, databases and user responsibilities

The need for technology to support sustainability is obvious. Initial motivation of companies may vary, however successful companies act now or already did. The industry has a prominent role to play in sustainability; either through design, sustainable practices in the development process or in response to regulations and customer demands. It doesn't matter how to start sustainable business, but it does matters which tools and data solutions are chosen; ideally those fits the company and cover multiple purposes such as compliance & reporting, product development & innovation, sales & marketing, performance communication and attracting shareholders.

6. The business value of sustainability

Successful companies create value through sustainability in 4 discrete ways:

- in sales over increasing market share or new market entry by quantifying of benefits B2B or B2C or by promoting Innovation and new products based on solid facts.
- through cost reduction due to increase of value chain and operational efficiency as well as over employee productivity.
- risk mitigation like operational risk management or regulatory management supports business continuity.
- the brand value is increased due to reputation as well as employee attraction and retention.

7. Screen, Scope, Scale

To generate value on sustainability in a company a platform combining IT technology (like software and data exchange systems), content (like adequate databases) and a positive user experience is key. The positive user experience is most efficiently implemented by an adequate and balanced share technology and service support.

In sequence, companies want to determine more quickly what the social, environmental and economic tradeoffs of their products are (screening)? How they can provide more value by combining multiple data sources (scoping)? And how the companies may integrate sustainability management with existing management systems, such as ERP, PLM, CAD or supply chain management (scale)?

8. Example(s)

We will present different ways of different companies to create their optimal value with sustainability.

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Guidance to assess avoided emissions of GHGs

Atsushi Inaba[1] and Masaharu Motoshita*[2,3]

[1]*Kogakuin University, Japan,* [2]*Natioanal Institute of Advanced Industrial Science and Technology, Japan*; [3]*Technische Universitaet Berlin, Germany*
*Corresponding author: m-motoshita@aist.go.jp

1. Introduction

It will be advantageous for LCA practitioners to assert the contribution of their new products to the avoidance of environmental impacts compared to the current/past situations. In fact, some methods for estimating the contribution of products to reduce greenhouse gas emissions (GHGs) have been developed and proposed by several industrial associations from the viewpoints of specific sectors (e.g. chemical, electrical and electronics) [1] [2]. Some local governments also encourage industries to quantify and assess the contribution by publishing guidelines [3] [4].

On the other hand, there is still no consensus on the methodology to assess the effectiveness of so-called green products in terms of reducing environmental impacts. A study group was established in the Institute of Life Cycle Assessment, Japan to discuss about the crucial issues and build up the guidance for practitioners to assess avoided GHGs emissions of their products based on scientific knowledge of experts.

2. Critical points raised in the group

At the first step, current existing practices and methodologies for assessing the effects of products on the avoidance of GHGs emissions were reviewed and several points for discussion were extracted and argued by proceeding the drafting of the guidance. Regarding the calculation and assessment of avoided emissions by introducing new technologies and products, several points are carefully mentioned in the draft of the guidance from the viewpoints of experts. Some crucial points are raised and mentioned in the draft of the guidance as follows.

2.1. Definition of the term "Avoided emissions"

As a fundamental issue, the definition of "*Avoided emissions*" is absolutely one of the most significant points. As a result of discussion, "*Avoided emissions" has defined as "the quantified amount of reduced GHGs emissions through life cycle of the final products compared to the base-line situation with the consideration of the contribution of the target*". The definitions of "*the target*", "*final product(s)*" and "*base-line*" should be clarified as explained in the following section.

2.2. Definition of the target, final product(s) and base-line

"*The target*" is defined as the target technologies, materials, parts and products that practitioners aim to assess the contribution to GHGs reduction. This should not be necessarily the "*final product(s)*" that will directly contribute to the reduction of emissions. In that sense, not only an automobile as such but also tires could be the target if tires actually contribute to reduce emissions through the life cycle of an automobile.

"*Base-line*" is also one of the key issues in the assessment of avoided emissions. For preventing from misleading and malicious assertions, "*base-line*" shall be defined and explained in clear and appropriate ways. In the draft of the guidance, "*base-line*" is defined as the final product(s) that would be used when the target is not on the markets. Obviously, the functional unit shall be the same as the case with the target and the spatial information shall be considered for the calculation of avoided emissions. In the setting of "*base-line*", sufficient attentions shall be paid to a case of comparative assertion with regard to ISO14044.

2.3. Calculation procedures of avoided emissions

The amount of avoided emissions should be assessed by multiplying the following three items; (1) the amount of net reduction of emissions of the final product(s) with the target compared to base-line, (2) the total amount of the target products on the market, (3) the rate of contribution of the target to the total reduction by the final product(s) in accordance with ISO14040 and ISO14044.

2.4. Simplified approach for the calculation

In the case that the final product(s) with the target and base-line have absolutely same processes on some stages of life cycle, simplified approach can be applied by skipping the calculation of emissions on the same stages of life cycle. It would be profitable for practitioners to save their efforts. On the other hand, the rate of the contribution amount on limited life stages by simplified approach shall not be used for declaring to the public to prevent from misleading.

2.5. Contribution rate of the target

The reduction of emissions may be achieved by many of stakeholders on the supply chain of the final product(s). The contribution rate of the target will be desirable to be determined. There are several sorts of options to allocate the reduction amount to the target (e.g. technical aspects, consensus among stakeholders, value add-base, and decisions by practitioners). In any cases, the contribution rate should be clearly stated with the supporting evidences.

3. Summary

This guidance is expected to support practitioners to perform the assessment and assert the effectiveness in an appropriate way for avoiding confusion and mislead due to the disclosure of results in different methodologies. Further steps to finalize the guidance will be proceeded to achieve this scope.

Acknowledgments

We greatly thank all of the contributors in the discussion group, and especially acknowledge Ms. Maki Ogura and Mr. Shoichiro Tsuruta for great efforts in drafting the guidance. [Note] The definition of the words in English have not been approved by the study group of the guidance for avoided GHGs emissions in the Institute of Life Cycle Assessment, Japan.

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Life Cycle Inventory Analysis for Environmental Footprints – Case Study on Skin Care and Cosmetic Products

Hsin-Jui Wu and Yuh-Ming Lee*

National Taipei University, Taiwan
*Corresponding author: yml@mail.ntpu.edu.tw

1. Introduction

Because of global climate, the amounts of GHG emissions become very important. Moreover, after Kyoto Protocol in 1997, the term "carbon footprint" is promoted globally. Until now, the green mark and normal become very complex which make consumers confuse and decreased the credence.

European Union(EU) has a 3 years trial program, it's according to Product Environment Footprint Guide. From 2013 to 2016 .It has a unified standardization include scope definition, reduction of carbon dioxide, which can count environment data and set up unitary label with one standardization to resolve the firm verifies many times from state to state and load double fee for the same verification item. [1]

2. Methodology

Along with the concept - life cycle analysis, this study is based on inventory product environmental footprint especially product carbon footprint.
According to British Standards Institute, Specification for the assessment of the life cycle greenhouse gas emissions of goods and services, PAS2050 and ISO / DIS 14067, Taiwan Environmental Protection Administration announcement "Carbon Footprint of Products and Services Guidelines" in 2008.

3. Study Targets

Information of green products, such as green shampoo or body wash. We are seeking for a benchmark company, which have been coordinating with government's policy, revealing information that benefits the environment, conducting a streamlined self-audit regarding corporate social responsibility issues. For example, the specific product with PAS_2060 carbon neutral.

Carbon Labeling	Taiwan	UK.
	CO2 Carbon Footprint Taiwan EPA	working with the Carbon Trust 100g CO2

4. Results and Discussions

We anticipate that, according to this 3-year trial program of Product Environmental Footprint Guide [2], Program Industry will use their successful experiences to make policy consensus. One of the goals of environment footprint is to clarify information on green product market. It can help consumers to know and recognize environment information easier and consumers can compare different products using one standard. For firm, besides cutting the multi-verification cost, there is also a better public image via transparency of information.

Shampoo(400ml)	Boots Botanics		O'right Green Tea	
	Proportion	emissions (gCO2e)	Proportion	emissions (gCO2e)
Materials	4.7%	55.645	18.68%	147.5
Production	0.30%	3.55	2.96%	23.39
Distribution	2.00%	23.68	2.10%	16.59
Use	93.00%	1101.12	50.12%	395.77
Disposal	0.00%	0	26.14%	206.43
Total	100%	1184.00	100%	789.68

This table compare two products[3] [4], along with Life-cycle analysis counts carbon emissions by each emission. For all stages of a product-and-service cycle which from material extraction through materials processing, manufacture, distribution, use and disposal or recycling.

5. Summary and Conclusion

Since 2009, Taiwan government has been promoting carbon label. There is still a limited usage for cosmetics industry, mostly dish washing cleansers. If the corporations would implement this concept to various types of the cosmetics products, exposing the environment information of products, then consumers would know carbon emissions in each stage of cosmetic products, and furthermore industry can cut down costs and improve profits by analysis every stage's emissions. Through this process, the value of green products should be enhanced.

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Estimation of the Workload of Calculating GHG Emissions of Scope 3

Hideki Sasaki,* Sachiko Motoike, and Hiroshi Onishi

Panasonic Corporation, Japan
*Corresponding author: sasaki.hideki001@jp.panasonic.com

1. Introduction

With stronger demands for disclosure of environment-related information, disclosure of GHG emissions in accordance with the Scope 3 Standard [1] is increasingly expanding [2]. On the other hand, there is an issue that calculation of emissions requires significant workloads.

Based on our review of calculated emissions and necessary workloads, this is to propose ways to reduce workloads required for emissions calculation.

2. Approaches to reducing workloads

1) Given the relation between calculated emissions and necessary workloads, we explored excluding categories of less significance from the scope of calculation.

2) We considered using alternative activity data for categories with large amounts of emissions and thereby subject to calculation.

3. Exclusion of categories of less significance

3-1. Estimation of workloads

Table 1 shows the estimated workload for each category.

Workloads necessary for garnering energy consumption data of manufacturing sites are assumed as 4 man-hours per month, based on information obtained from persons in charge at said sites.

The total amount of workloads of all categories subject to calculation of emissions was estimated to be 744,748 man-hours. Categories 1 and 5 accounted for about 95% of the total.

Table 1. Category-specific workload

Scope/Category			Work subject to estimation; Method of estimation or assumption	Workload (man-hour)	
Scopes 1 & 2			Identify and report energy use per site; Information obtained from person in charge	13,248	1.8%
Scope 3	1	Purchased Goods and Services	Implement survey per supplier (Of re-estimation for Panasonic, costs paid by Panasonic); Assumed as the same as Scopes 1 & 2	659,520	88.6%
	2	Capital Goods	Identify and report the types of capital goods and amount of money per business division; Information obtained from person in charge	86	0.0%
	3	Fuel- and Energy-Related Activities Not Included in Scope 1 or Scope 2	(Use the same data as Scopes 1 & 2)	-	-
	4	Upstream Transportation and Distribution	Product weight and transportation distance; Assumed as five times the workload after introduction of system, based on information obtained from person in charge	14,800	2.0%
	5	Waste Generated in Operations	Measure, identify, and report the weight of waste per site; Information obtained from person in charge	46,368	6.2%
	6	Business Travel	Identify and report transportation-specific distance and amount of money for business travels per site; Information obtained from person in charge	528	0.1%
	7	Employee Commuting	Identify and report transportation-specific distance and amount of money for employee commuting per site; Information obtained from person in charge	528	0.1%
	8	Upstream Leased Assets	Identify and report energy use per site; Information obtained from person in charge	3,648	0.5%
	9	Downstream Transportation and Distribution	Survey sales companies per country; Assumed as the same amount of workload required for supplier surveys	690	0.1%
	11	Use of Sold Products	Identify and report the lifetime power consumption per product; Information obtained from person in charge	2,666	0.4%
	12	End-of-Life Treatment of Sold Products	Identify and report the weight per product; Assumed as the same as Category 11	2,666	0.4%
Scopes 1, 2, and 3 total				744,748	100.0%

Category 10 cannot be identified by Panasonic and therefore is not calculated. Categories 13-15 are inapplicable to Panasonic activities and are also not calculated.

3-2. Relation between emissions and workloads

Emissions for all categories amounted to approximately 168,060,000 tons. The top three categories with the most emissions, namely Category 11, Category 1, and Scopes 1 & 2, accounted for about 93% of the total.

Figure 1 indicates category-specific relations between emissions and workloads for specific categories. Emissions for Categories 8 and 5 were low at around 0.03% of the total. While exclusion from the scope of calculation had nearly no impact on emissions, workloads decreased by 80%, demonstrating that excluding these categories from calculation was effective in reducing workloads.

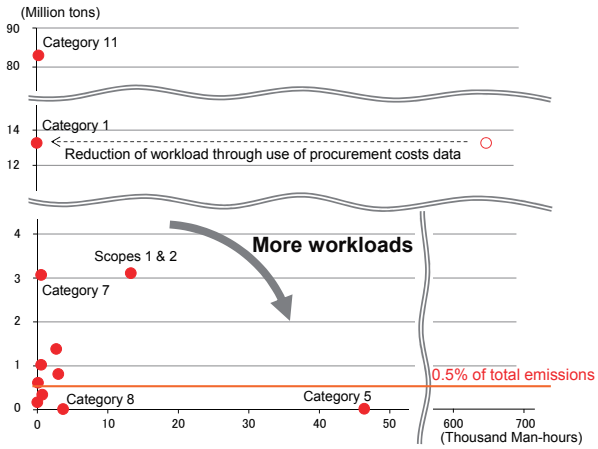


Figure 1. Relation between emissions and workloads

4. Use of alternative activity data

Workload required for calculating Category 1 through supplier surveys was estimated to be about 660,000 man-hours. To reduce this workload, corporate procurement costs data and input-output basic unit were used.

As a result, the workload necessary for calculation was about 4-5 man-hours, showing that employing procurement data in lieu of supplier surveys reduced workloads.

5. Proposals

1) Based on calculation of all items throughout Scopes 1-3, exclude from future calculation the categories whose emissions are small but workloads are heavy.

2) When the workload required for supplier surveys is extremely heavy in calculating Category 1, use procurement costs data and input-output basic unit.

6. Summary

From the relation between GHG emissions and necessary workloads, we explored reducing workloads required for calculating emissions. We conclude that workloads can be reduced by: excluding categories of less significance from the scope of calculation, or using procurement costs data in lieu of supplier surveys for calculation of Category 1.

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Application of Life Cycle Assessment and Economic Rationality: A Cost Survey

Tomohiro Tasaki*[1], Koichi Shobatake[2], Kenichi Nakajima1[1], Carl Dalhammar[3]

[1]*National Institute for Environmental Studies, Japan*; [2]*TCO2 Co. Ltd., Japan*; [3]*Lund University, Sweden*
*Corresponding author: tasaki.tomohiro@nies.go.jp

1. Introduction

Life cycle assessment (LCA) and similar tools based on life cycle thinking have been used as a basis for many global standards, product policy, and corporate decisions for a green industry. Carbon Footprints and Type III labels are examples of such practical applications. While LCA has become a very important tool, it has not reached widespread application. LCA has been developed with many discussions over its precision, comparability, verification and validity. Such a pursuit toward objectivity and robustness of results may hinder its widespread use due to the high costs involved. Simplified assessment [1, 2] is an alternative approach, used to increase the practical usefulness. Moreover, emergence of social LCA [3] and LCSA (Life Cycle Sustainability Assessment) [4] expands impact categories to be assessed and makes it harder to conduct such LCAs. Is a limited number of applications with a detailed or advanced assessment preferable to a large number of applications with a simpler assessment? How do stakeholders, especially decision makers in industries, value such different ways of application of LCA and similar tools? One of the metrics to determine what is preferable is cost: economic rationality. However, information on the actual cost and workload associated to conducting LCAs and creating PCRs (Product Category Rule) and EPDs (Environmental Product Declarations) has been very limited.

In this study, we conducted a survey on the average rough price and workload to create PCRs and EPDs of different program operators with a purpose of examining what would be a rational, practical application of LCA for the whole society.

2. Methods

First, we surveyed websites of 35 program operators in the world, and obtained information about cost for the assessment. We determined cost items (tasks) to be investigated (see Table 1). Then, questionnaires asking costs and man-hour of the tasks of a program were sent to the program operators by email. This was carried out in April and May, 2014, and we received 15 effective responses (Europe 6; North America 5; Asia 4). For cases when a program operator wanted to account for more than one representative case, we asked the proportion of the occurrence of each case in addition. The costs surveyed were converted from local currencies to USD, and adjusted with the country's PPP (purchasing power parity).

3. Results and discussion

The results of the cost survey are shown in Table 1. The median of the overall cost (PCR and EPD) was $19k (The average was $29k). Among the individual costs, the cost for LCA and EPD preparation (hereinafter referred to as “cost of LCA”) accounted for $15k and the largest. The median of the man-hours for 1) PCR and EPD, and 2) LCA and EPD preparation were 26 and 15, respectively. Deviations of the distributions of man-hours were smaller than those of cost. The total costs were smaller than the sum of their subitems, which implies that program operators make effort to reduce costs by avoiding duplicating tasks, etc. (e.g. for PCR and EPD, the total was $19k and the sum of subitems was $33.)

There are a variety of individual products from simple ones to complex ones, and the cost of LCA varies depending on products. Iteration of LCA of similar products would reduce the cost of LCA. Moreover, a PCR can be reused by other individual products belonging to the same commodity. Hence, the cost of assessing an individual product is somewhere between the cost of LCA & EPD preparation and the cost of the sum of all the cost items (i.e. from $15k to $33k). Next, neglecting these diverse situations, we discuss what the cost of tens of thousand dollars implies for the use of LCA.

Table 1. Results of cost survey to program operators

	Task	Quatiles			n
		Lower	Median	Upper	
PCR	Scoping	485	1,693	3,375	6
	Research & drafting	2,114	5,928	17,563	8
	Review	1,013	5,072	8,587	7
	Total	2,738	15,000	25,625	9
EPD	LCA & EPD preparation	8,365	15,250	22,745	12
	Verification	2,108	2,447	3,413	12
	Registration	663	1,312	2,629	9
	Initial fees other than registration	528	750	947	6
	Running fee	587	973	1,531	10
	Total	10,309	12,826	30,001	15
Total		12,509	18,761	41,238	15

* Totals are not the sum of the subitems.

Measures should be taken if benefits are larger than costs. When considering product sale and implementation of an environmental measure, this can be written as:
Sales profit + Environmental benefit by implementing a measure > Cost of LCA + Cost of implementing a measure.
However, the environmental benefit is usually externalized in a normal economic state, and therefore excluded for the economic calculation, so
Sales profit > Cost of LCA + Cost of implementing a measure > Cost of LCA;
that is, cost of LCA must be smaller than profit of sales unless private companies gain a profit from the environmental benefit. Assuming that profit is about 10% of sales, annual sale of $100k, equivalent to 10^7 yen, would be required. From Japanese point-of sales data obtained in 2008 or 2009, 49% of TVs were sold more than this figure while only 14% of clothes detergents and 21% coffees were done so. This suggests that only expensive or major products can afford to apply conventional, detailed LCA.

If we would like to expand items of assessment, like LCSA, we need to devise alternative approach of assessment. We also should examine what kinds of products are suitable to apply conventional LCA methodology from a viewpoint of economic rationality, and specify such products concretely.

Acknowledgments

Several anonymous program operators kindly participated in this survey. We sincerely express our appreciation to their cooperation.

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SCOPE3 of Kogakuin University

Atsushi INABA[1]*, Kou MIYATA[1], Koji TANAKA[2]

[1]*Kogakuin University,Japan*; [2]*es.feed, Japan*
*Corresponding author: a-inaba@cc.kogakuin.ac.jp

1. Introduction

Recently the Scope3 GHGs emissions have been paid attention by large companies in the world and also in Japan, which guidance published in November 2011 by WRI/WBCSD (They called it as Scope3 Standard). The Ministry of Environment and the Ministry of Economy, Trade and Industry of the Government of Japan followed this activity and published the guidance in March 2012 to show how it should be conducted exactly in Japanese companies [1]. The guidance of WRI/WBCSD listed 15 categories related to the activities of the targeted organization, in which the organization shall calculate the whole GHG emissions related to their activities including the organizations underlining in their value chain. In this paper, the calculation result of Scope3 CO_2 emission of Kogakuin University was reported. It might be the first case study of Scope3 by University in Japan.

2. Calculation

The calculation of the Scope3 CO_2 emission was conducted mainly using the expenditure data of Kogakuin University in fiscal 2012, and the energy and water consumption data collected for ISO-14001 was used complementarily.

Around 110 thousand items of the expenditure were classified into 465 categories, and then they were multiplied by the CO_2 emission factor of each items provided by the Milca[2] and the 3EID[3] database for LCA..

3. Results and Discussion

3.1. Expenditure of Kogakuin University

The total amount of the expenditure of Kogakuin University in fiscal 2012 was 11.3billion yen. The expenditures such as salary of employee were excluded because they are not related to the CO_2 emissions. And also, the leased assets, which are shown as category 8 and 13 in the guidance of Scope3, were excluded because the calculation method has not be established yet. As the result, we calculated Scope1, Scope2 and Scope3 for the expenditures of 47.5 billion yen, which was 53.0% of the total expenditure, which included the expenditure for education and research, administration, maintenance of facilities, commuters tickets, business travel and so on.

3.2. Ratio of each Scope on Expenditure and CO_2

The CO_2 emission of Kogakuin University was totally 1.61E+04t. The amounts of Scope1, Scope2 and Scope3 were 1.19E+02t, 7.13E+03t and 8.81E+03t respectively. Fig.1 shows the ratio of each scope on the expenditure and on the CO_2 emission. The scope3 had 92.9% on the expenditure, but only 54.8% on the CO2 emission.

The ratios of the CO_2 emission of each category of Scope3 to the total CO_2 emission of Scope3 are shown in Table 1. The CO_2 emissions of Scope3 in Kogakuin University could be divided into 7 categories among 15 categories listed in the guidance. The largest amount (68%) of the Scope3 CO_2 emission was caused by category 1, the goods and services purchased by Kogakuin University. The second was the category 2 like purchasing machine and vehicle. The business travels and commuters tickets were almost the same, which had the third position.

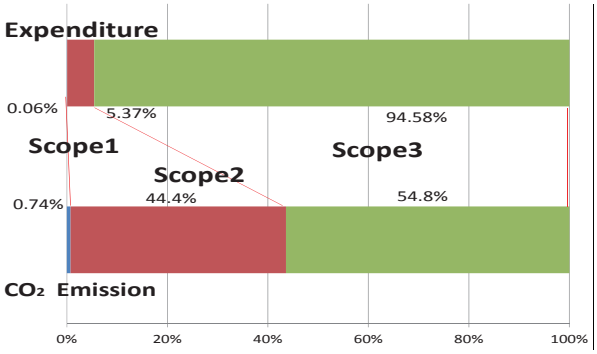


Fig.1 Ratio of Scope1,2 and 3 on Expenditure and CO_2 emission

Table1 CO_2 emission of Kogakuin University

Total	16,631t	
Scope1	119t (0.74 %)	
Scope2	7,135t (44.4 %)	
Scope3	9,377t (54.8 %)	
Category 1	68%	Stationery, PC, printer, book, paper, experimental goods, maintenance of facilities ...
2	13%	machine, vehicle...
5	5%	waste treatment, recylce ..
6	6%	business travel ..
7	5%	commuters ...
8	2%	rental
9	1%	mail

4. Conclusions

The Scope3 CO_2 emission had 54.8% of the total CO_2 emission of Kogakuin University. The measures to reduce Scope1 and 2 CO_2 emissions were executed so far, but the measures to reduce Scope3 CO_2 emission shall be executed in the future. It includes the measures to buy the eco-products more, to reduce the amount of waste and so on.

This study has a limitation using the data provided by Kogakuin University. It does not include the life of the students such as commute from home to University, having a lunch, buying PC, etc. The system boundary of the Scope3 CO_2 emission for University shall be re-considered.

Acknowledgments

This study was conducted by "Grants-in-Aid Scientific Research".

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Life cycle co-benefit of industrial and regional symbiosis: Environmental input-output analysis on typical resource dependent city in China (P008)

Liang Dong,*[1,2] Tsuyoshi Fujita,[1] Minoru Fujii,[1] Satoshi Ohnishi,[1] Takuya Togawa,[1] Huijuan Dong,[1]

[1]*Center for Social and Environmental System Research, National Institute for Environmental Studies, Japan*; [2]*Graduate school of Environmental studies, Nagoya University, Japan*

*Corresponding author: dong.liang@nies.go.jp

1. Introduction

Resource dependent cities, in which natural resource mining and material process industries (e.g. iron/steel, cement, ferrous and non-ferrous metallurgy industry) are dominated, is big issue for China's sustainable urban development (emissions, bulky solid waste…). NDRC launched "Resource dependent cities project" (2013->2020) to address this issue.

Industrial symbiosis (IS) provides smart solution to resource dependent city. It emphasizes unrelated industries exchange materials, energy and/or by-products in a mutually beneficial way (Chertow, 2000, 2007). Through IS, it could optimize the flows in the network.

This study conducts a scenario analysis on co-benefit, in typical resource dependent city in China. Focusing on: (1) Co-benefit: evaluating how IS can facilitate energy saving, CO2 and air pollutants reduction in the life cycles, using I-O model. (2) Investigate CO_2 emissions particularly. (3)Address policy implications for China's sustainable urban development.

2. Methodology and Case study

This paper applied hybrid physical input and monetary output model (HPIMO) to assess how industrial symbiosis could affect the energy consumption and waste reduction for each sector (Table 1). For specific IS process, it is analyzed with process LCA. We calculated the life cycle CO_2 emission change from the change of raw material consumption, energy consume in production, waste emissions/disposal and transportation in up-stream and down-stream under the scenarios.

Table 1. Structure of HPIMO model

Monetary Input		Intermediate Monetary Output Sector 1 …. n	Final demand	Total output	Pollutants emissions
			Y	*X*	*P*
Intermediate monetary input	1	*M*	Y_1	X_1	P_{11}
	…		…	…	…
	n		Y_n	X_n	P_{1n}
Added value	V				
Total monetary output	X				
Physical energy input		Physical input distribution			
Energy resource	1 … m	*E*			

Select one typical resource dependent city in southern China, named Liuzhou. Based on an analysis on the industry and current IS in Liuzhou, design BAU/4 IS scenarios in year 2015 (Figure 1): (1) S0-Business as usual; (2)S1-Waste plastics recycling(red line); (3) S2-Scrap tires recycling(blue line); (4) S3-Flying ash recycling (green line); (5) S4-Biomass utilization (yellow line).

3. Results and discussion

The results show that IS could contribute to waste reduction and further generate co-benefits of energy saving, CO_2 mitigation and air pollutants reduction (Figure 2). Dramatic life cycle emissions could be reduced by IS.

Results also indicate that different IS efforts may bring different benefits. While waste plastics recycling and biomass utilization could generate more co-benefits, flying ash reuse could only reduce the total amount of solid wastes, but increase energy consumption and related air pollutants. Hence, smart design on IS patterns by considering the local realities is critical.

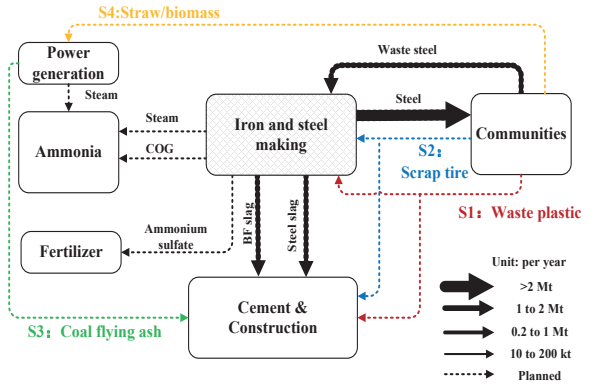
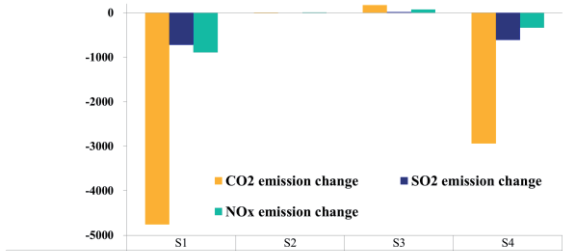


Figure 1 Current (solid line) and planned (dotted line) IS network and quantified material flow in Liuzhou, China



	S1	S2	S3	S4
CO2 emission change	-4758.99	-9.46	170.25	-2937.47
SO2 emission change	-722.54	-4.06	19.19	-607.80
NOx emission change	-889.70	2.48	73.80	-336.03

Figure 2 CO_2 and Air pollutants reduction in total life cycles

4. Conclusion and policy implication

IS is one effective and efficient approach to reduce both virgin material consumption and waste emissions. Particularly, IS could not only contribute to solid waste reduction, but also to the CO_2 reduction and SO_2, NO_X reduction.

Acknowledgments

This research is financially supported by the Environment Research and Technology Development Fund (2-1404) of the Ministry of the Environment, Japan.

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Projection of demand and supply change of first generation biomass

Yuri Hirako,*[1] Kenji Koido[1] and Kiyoshi Dowaki[1]

[1]*Tokyo University of Science, Japan*;
*7413612@ed.tus.ac.jp

1. Introduction

Recently, the large amount of greenhouse gases (GHGs) emissions due to the fossil fuel use has caused the serious problem all over the world. For the abatement countermeasure, the promotion of renewable energy, especially, bio-fuel would be promising. However, in the case that the biomass material is consumed as feedstock of bio-fuel, it is said that the serious competition between food and feed would be faced. For instance, in US, the agricultural products which are harvested are mainly maize. The agricultural product would be available for food and/or feed, too.

On the other hand, a couple of researches on food consumption are being executed. But, according to the recent results, it implies that the serious food competition would not always occur, if its consumption rate and sustainable supply chain are considered.

In this paper, on the supplies and demands of barley, maize, sugarcane, rice paddy and wheat from 2020 to 2030, we estimated the potential on whether the food balances of these agricultural products would fall into critical situations in the following countries: Australia, Brazil, Canada, India, Indonesia, Japan and US. We showed the extremely significant evidences based on the pass analysis and/or the system dynamics model.

2. Materials and methods

According to FAO data, the large amounts of barley, maize, rice paddy, sugar cane and wheat in our target countries are harvested, and they are consumed for diet, feeding for livestock. Or they would be biomass material for fuel production. Especially, using the feedstock, bioethanol production has already been established. Every country that doesn't include Japan are major agricultural producers and their all governments have had their own bioenergy policy [1].

Table1. Each country's bio-fuel policy

Countries	Bio-fuel policy
Brazil	Flex cars or E25
India	E20 by 2017
Japan	0.5 million KL by 2017
U.S.	136 million KL by 2022

In this paper, we focused on total $LCCO_2$ mitigation policy, especially, in Japan. Because EU countries who are very far from Japan would not bring the good effect.

So far, we executed the total biomass material balances in each agricultural product [2]. This time, we investigate the dynamic effect of these products. That is, we think that the crops yield, GDP, the population and food balances etc. would be influenced. Thus, at the second step, we estimated the products composition of every year in every target country and the feed consumption per protein [t-crop/ t-protein].

The future prospects of demand and supply on the first generation biomass material were calculated based on the path analysis, which is one application technique of multiple linear regression analysis.

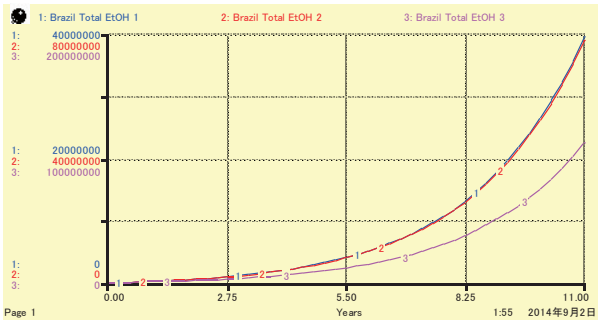
The system dynamics which can deal with internal feedback loops and time delays is an approach to understand the behavior of complex systems over time.

3. Results

Table 2 shows the results of path analysis First generation biomass consumption forecast in 7 areas. The sign of ○ represents "non-competitive" and that of × represents "competitive". According to the result of path analysis, although there would be competitive status in almost countries, it implies that 3 countries and 4 corps would not cause the serious problem. For instance, the amounts of sugar cane and wheat in Brazil would be available for bioethanol production of 4,753 KL/yr and 352 KL/yr as of 2020 (See Figure 1). Those of barley and maize in Japan would be 3,353 KL/yr and 7,596 KL/yr as of 2020.

Table 2. First generation biomass consumption forecast

	Barley	Maize	Rice Paddy	Sugar Cane	Wheat
Australia	×	×	×	×	×
Brazil	×	×	×	○	○
Canada	×	×	×	×	×
India	○	×	×	×	×
Indonesia	×	×	×	×	×
Japan	○	○	×	×	×
U.S.	○	×	×	×	×



Note: low variant (blue line) shows 40,000KL/yr, and high variant (pink line) shows 200,000KL/yr.
Figure 1. Brazil case from 2020 to 2030

4. Discussion

In this study, there should be uncertainties to some extent in the future projection. Also, we have to pay attention to their trends which are food security and energy security, simultaneously. Considering these issues, we try to propose the food and bio energy policy.

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Decision supporting tool for sustainable dairy cow system

Chun-Youl Baek*[1], Kiyotaka Tahara[1], Kun-Mo Lee[2], and Kyu-Hyun Park[3]

[1] *AIST, Japan,* [2]*Ajou University, Korea,* [3]*Kangwon National University, Korea*
*Corresponding author: c.baek@aist.go.jp

1. Introduction

One of the major objectives of this research was to develop a tool that allows the control of environmental aspect and economic aspect from a dairy cow system by considering variables such as feed composition, growth phase, enteric fermentation, and manure management. Of these, feed composition is the most influential and controllable variable. Therefore, any abatement measure applied for the reduction of environmental load and growth of economic profit from a dairy cow system must include the control of the feed composition. Thus, it requires that a tool for control of parameter such as feedstuffs with lower environmental load, high economic profit on similar nutriment should be used.

2. Materials and Method

Decision supporting tool (D.S. tool) was proposed for sustainable dairy cow system based on a GHG emission for environmental aspect and Life cycle cost (LCC) for economic aspect from each life cycle stage of dairy cow system. For this tool, the parameter and system boundary of dairy cow system was identified in shown fig.1. The GHG emission qualification was used a method based on a life cycle assessment (LCA) approach incorporating the IPCC's GHG emission calculation equations. The annualized net revenue of feed company and farm was used for LCC by integration feed company-oriented LCC and farm-oriented LCC in order to control variable parameter.

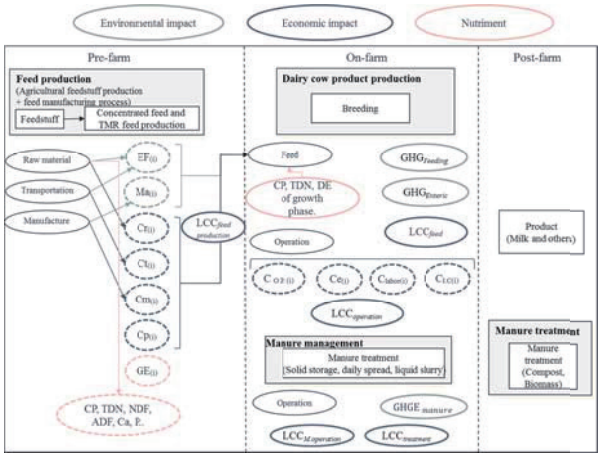


Figure 1 System boundary and 3 aspects for D.S. tool

We considered two assumptions related to the data collection and processing parameter: i) data collection and processing in each life cycle stage, which includes the growth phase of the livestock and the type of feed in a given growth phase, follows the national feeding standard for dairy cow in order to meet the requirement of nutriment, and ii) pre-farm and on-farm were limited to one feed company and one farm.

The GHG emissions for environmental aspect was calculated by a method [1] and LCC of dairy cow system for economic aspect was described in this paper as below and the functional unit (f.u.) of a dairy cow system and the reference flow chosen were 1kg of raw milk FPMC. The key equation (feed production and breeding) for LCC calculation is below.

Pre-farm

$$LCC_{feed\ production(j,k)} = \{\sum(Cr_{(i)} + Ct_{(i)} + Cm_{(i)})\} \times MF_{(i,j,k)}$$

$$LCC_{feed\ production} = \frac{\sum_{j=1}^{3}(Number\ of\ heads_{(k)} \times feeding_{(j,k)} \times LCC_{feed\ production(j,k)})}{FPCM_{annual}}$$

$$LCC_{feed\ production_{(profit)}} = LCC_{feeding} - LCC_{feed\ production}$$

where, $LCC_{feed\ production(j,k)}$, LCC of j[th] feed production due to the feeding in the k[th] growth phase, won/f.u.; $Cr_{(i)}$, raw material cost of i[th] feedstuff, won/kg; $Ct_{(i)}$, transport cost of i[th] feedstuff, won/kg; $Cm_{(i)}$, manufacture cost of i[th] feedstuff, won/kg; $MF_{(i,j,k)}$, ratio in mass fraction of the i[th] feedstuff to the j[th] feed in the k[th] growth phase; $LCC_{feed\ production}$, LCC of feed production due to the feeding on farm, won/f.u. (feed company-oriented LCC); $LCC_{feed\ production_{(profit)}}$, profit of feed company due to the feeding on farm, won/f.u.

On-farm

$$LCC_{feeding} = \frac{\sum_{j=1}^{3}(Number\ of\ heads_{(k)} \times feeding_{(j,k)} \times LCC_{feed(j,k)})}{FPCM_{annual}}$$

$$LCC_{(\text{operation,general})} = \frac{\sum(labor\ cost + maintenance\ cost_{(i)} + facility\ cost_{(i)})}{FPCM_{annual}}$$

$$LCC_{(\text{farm,total (profit)})} = LCC_{(\text{income})} - \left(LCC_{(\text{operation,general})} + LCC_{(\text{operation,energy})} + LCC_{feeding}\right)$$

where, $LCC_{feeding}$, LCC due to the feeding in the k[th] growth phase (farm-oriented LCC), won/f.u.; $LCC_{(\text{operation,general})}$, LCC of operation, won/f.u; $LCC_{(\text{income})}$, income due to the selling raw milk (FPMC), won/f.u.

4. Result and discussion

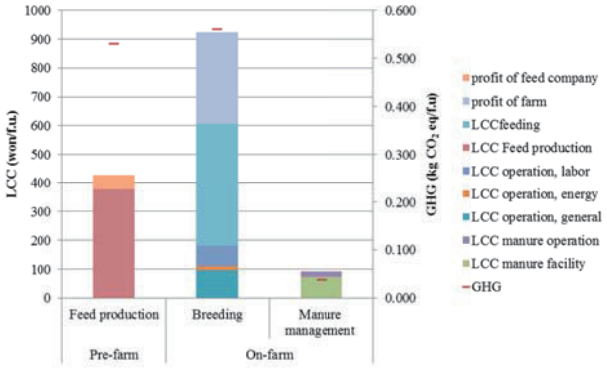


Figure 2 Result of LCC and GHG

D.S tool was proposed in order to control the environmental aspect and economic aspect of dairy cow system by considering the operating variables of the system such as feed composition, growth phase, enteric fermentation, and manure management. The proposed tool allows straightforward identification of the key activities and parameters and can support the policymaking for sustainable dairy cow system.

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Domestic Consumption and Household Stock of Storage Media in Japan

Junya Yano,*[1] Misuzu Asari[1], and Shin-ichi Sakai[1]

[1]*Environment Preservation Research Center, Kyoto University, Japan*
*Corresponding author: yano@eprc.kyoto-u.ac.jp

1. Introduction

Some studies have focused on the disposal of consumer-grade media reproduction devices, such as DVD (digital versatile disc) recorders, audio players, digital cameras, and so on [1, 2]. However, few studies have focused on waste management of the storage media itself. The purpose of this study was to research the current domestic consumption and stock of household storage media in Japan.

2. Materials and methods

Domestic storage media consumption was estimated using statistical data reported by such agencies as METI [3] and RIAJ [4]. This data included domestic production, import, export, and domestic sales, all between 1988 and 2011. These estimations included storage media used in both households and businesses because the distribution rate was unidentified.

To estimate household stock and disposal potential, an internet-based survey was conducted in January 2013. Three thousand people over the age of 15 were sampled and separated into six age groups. Questions included input, stock, and output numbers of each storage medium in the respondents' household. Each storage medium was distinguished by two groups based on intended use, "for personal use" and "for sharing with family." The reported number of storage media shared with family was divided by 2.14, the average number of people per household in Japan, to estimate the total number of storage media per person. Then, stock number of storage media was estimated by using by Eq. (1). In addition, the number of disposal potential was also questioned.

$$S_j = \sum N_i \times P_{i,j} \times U_{i,j} \qquad (1)$$

S_j : Stock number of storage media j

N_i : Population of age group i

$P_{i,j}$: Percent of people in age group i who own one or more storage media j

$U_{i,j}$: Unit stock per person of age group i who owns one or more storage media j

2. Results and discussion

Estimated results of domestic storage media consumption by weight between 1988 and 2011 is shown in Figure 1. In 2011, consumption by weight decreased to around 100 Kt. The most storage media consumed was around 140 Kt in 1998. These data are attributable to the changes in media types over the years, trending towards smaller, more compact forms. Consumption increased by 73% from 1.1 billion units in 1988 to 1.8 billion units in 2011. The data capacity of the media consumed in 2011 was 58 EB (10^{18} bytes), which is 37 times greater than that of 1988.

Estimated household stock and disposal potential as of 2011 is shown in Table 1. The accumulated total number of sales before 2011 was estimated to be 34 billion. Of that, approximately 60%, 21 billion was stocked in households. This number was roughly 11 times the annual number of sales in 2011, 1.8 billion. Disposal potential was estimated to be 4.5 billion, accounting for 13% of the accumulated total number of sales. Of the total sales of magnetic tape, roughly 37－40% were stocked.

There were some uncertainties for the newer storage media, such as BD, which, due to their relative recentness on the market, have low recognition with the public. It should also be noted that the amount stocked changes from year to year.

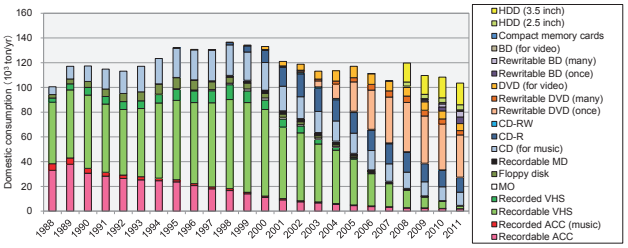


Figure 1. Domestic consumption of storage media type between 1988–2011 by weight

Table 1. Household stock and disposal potential of storage media in 2011 by millions of units sold

	Accumulating total sales	Stock in households	Disposal potential	Stock in household/Accumulating total sales	Disposal potential /Accumulating total sales
	(Million)	(Million)	(Million)	–	–
	A	B	C	B/A	C/A
Video tape	5,391	2,137	1,194	39.6%	22.1%
Audio tape	5,733	2,091	826	36.5%	14.4%
CD-R	4,595	2,842	656	61.9%	14.3%
Other CDs	8,148	5,998	745	73.6%	9.1%
DVD-R	6,893	3,843	655	55.7%	9.5%
Other DVDs	2,348	2,094	278	89.2%	11.9%
Recording BD	584	584	48	100.0%	8.2%
Other BDs	69	216	13	312.6%	19.4%
USB flash memory	NA	252	33	NA	NA
Compact memory cards	420	383	39	91.3%	9.3%
External HDD	NA	98	11	NA	NA
Total	**34,181**	**20,539**	**4,498**	**60.1%**	**13.2%**

NA: no statistical data

3. Conclusion

This study clarified the transition from domestic consumption to household stock and the disposal potential for storage media. Some storage media contain valuable substances such as cobalt in magnetic tape and silver in digital optical disks. In the future study, evaluating the resource potential of each storage medium is needed in considering proper waste management.

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Eco-Efficiency Assessment of ICT Product Systems
An Example of Set-Top Box

Jun-Yi Chiang and Yuh-Ming Lee*

National Taipei University, Taiwan
*Corresponding author: yml@mail.ntpu.edu.tw

1. Introduction

Eco-efficiency has been established as a crucial concept for corporate environmental management. However this concept has been discussed in the environmental management discourse for more than a decade (Schaltegger and Burritt 2000, 49ff). On the institutional level, the World Business Council of Sustainable Development (WBCSD) has strongly promoted ecoefficiency as a concept for businesses to pursue.

"ways of reducing their impact on the environment while continuing to grow and develop" (WBCSD 2000; cf. Verfaillie and Bidwell 2000;DeSimone et al. 1997). [1]

Organization for Economic Cooperation and Development (OECD) has developed and promulgated international policies which aimed at preventing and reducing waste generation and managing the residues in an environmentally sound manner. [2]

2. Methodology：Life cycle assessment and Eco-Efficiency Evaluation

Life Cycle Assessment is a process to evaluate the environmental burdens associated with a product, process, or activity by identifying and quantifying energy and materials used and wastes released to the environment; to assess the impact of those energy and materials used and releases to the environment; and to identify and evaluate opportunities to affect environmental improvements. The assessment includes the entire life cycle of the product, process or activity, encompassing, extracting and processing raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling, and final disposal.

There are four linked components of LCA: [3]

• Goal definition and scoping: identifying the LCA's purpose and the expected products of the study, and determining the boundaries (what is and is not included in the study) and assumptions based upon the goal definition.

• Life-cycle inventory: quantifying the energy and raw material inputs and environmental releases associated with each stage of production.

• Impact analysis: assessing the impacts on human health and the environment associated with energy and raw material inputs and environmental releases quantified by the inventory.

• Improvement analysis: evaluating opportunities to reduce energy, material inputs, or environmental impacts at each stage of the product life-cycle.

Eco-efficiency embraces other business concepts, such as "pollution prevention", "cleaner production" and "waste minimization". It shares characteristics with "design for the environment" and features a "life-cycle" perspective. In addition, it is a logical extension of the "Total Quality Management" concept. Where eco-efficiency differs from and goes beyond other managerial instruments is in its strong focus on creating value by making the challenge of sustainability a business opportunity. And this is what eco-efficiency is all about: combining the goals of business excellence and environmental excellence and creating the link through which corporate behavior can support sustainable development.[4]

$$\text{Eco} - \text{efficiency} = \frac{\text{Product or service value}}{\text{Environment influence}}$$

3. Study Target : Set-Top Box – An ICT Product

The emergence of internet and communication technology has led to the development of ICT industry. ICT plays an important role of unifying communications and telecommunications industries. The ICT industry includes electronic components manufacturing, computer Electronic and optical products, telecommunications and information industry. Set-top box is one of the important industries under the category of ICT. A set-top box (STB) or set-top unit (STU) is an information appliance device that generally contains a TV-tuner input and displays output connects to a television set and an external source of signal, turning the source signal into content in a form that can then be displayed on the television screen or other display device.

4. Inventory and Indicators

This study conducts a Life Cycle Inventory analysis of product and computes the Environmental Footprints of a set-top box by evaluating the input and output of the raw materials provided by supply chain, the production process, the emission of pollutants, the waste disposal, and so on.

They are recommending five generally applicable indicators for measuring environmental influence:[5]

- Energy consumption
- Materials consumption
- Water consumption
- Greenhouse gas emissions
- Ozone depleting substance emissions

5. Conclusion

This article presents a procedure for calculating eco-efficiency on the operational level. The proposed procedure for calculating operational eco-efficiency combines environmental assessment and valuation. Relying on the tools of life-cycle assessment (LCA) and environmental impact assessment (EIA), The proposed definition incorporates direct and indirect (external) environmental costs and benefits. point to the challenges of implementing this tool in a scientifically accurate and practically cost-efficient way.

Eco-efficiency reports inform about economic performance in addition to the environmental performance while sustainability reporting encompasses social, economic and environmental aspects. In the search for an eco-efficient corporate investment policy.

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A visualization system for carbon footprint of products on mobile devices

Zhao Peijiang*[1], Gun Suzuki[1], Koji Nagano[1] and Kazuhiko Sato[1]

[1]*Muroran Institute of Technology, Japan*
*Corresponding author: 14096014@mmm.muroran-it.ac.jp

1. Introduction

Carbon Footprint of Products (CFP) is a term used to describe the amount of greenhouse gas (GHG) emissions created in all processes from raw material production to disposal or recycling [1]. The CFP can not only show the quantity of GHG emissions, but also the data for the CFP can indicate details of production. Manufacturers can know how much they create GHG in each process based on the CFP. Therefore the CFP can help the manufacturers to cut down GHG emissions. It is necessary to collect data on raw material and all processes of production when we calculate the CFP. The data on the production are important in product security, especially for food. Consumers buy products whose security are proven. The CFP can also help consumers to create their secure and low carbon life.

This report describes our new system on mobile devices that inform the CFP to consumers. Our system is designed so that consumers can be familiar with the CFP.

2. Outline of the system

Our system consists of a data visualization system, a database. The data visualization system is built on Android OS. The Android OS is a popular mobile device OS. Consumers can use this visualization system on their Android mobile devices to see the CFP. The CFP database and the data management system are located in a network server. The CFP database is the data source for the CFP data visualization system.

3. CFP data visualization system

The visualization system combines convenience of use and visibility of the CFP. Figure.1 shows a configuration diagram of the CFP data visualization system. There are 4 parts in our system: starting part, CFP searching part, CFP data display part and CFP data note part. For the convenience of use, this visualization system is built on the mobile devices. Therefore, consumers can use this system to see the CFP data at anytime and anywhere. The visualization system helps consumers to understand the environmental impact of products and consumer's life.

Starting part is a launch point of the CFP data visualization system. When the system starts, the visualization system is connected to a computer server in order to check whether CFP data are updated. The computer server is a network server where all of the CFP data are stored.

CFP searching part consists of 2 functions, barcode decode function and CFP data search function. We find product data by reading its product barcode in the visualization system. Due to its uniqueness, the barcode is used as a key word on the searching part. For convenient use, a Smartphone camera is used to read the barcode. Consumers can get the CFP data only by taking a photo of the barcode. In this function, we use the Zxing [2], an open source, to decode the barcode. The product data are searched by using the SQL select code in the CFP data search function. If the product data is found in the database, this function starts the CFP data display part, else it will return to the starting part.

CFP data display part is used to exhibit a detail of the CFP data for a product. For the visibility of CFP, the CFP is shown

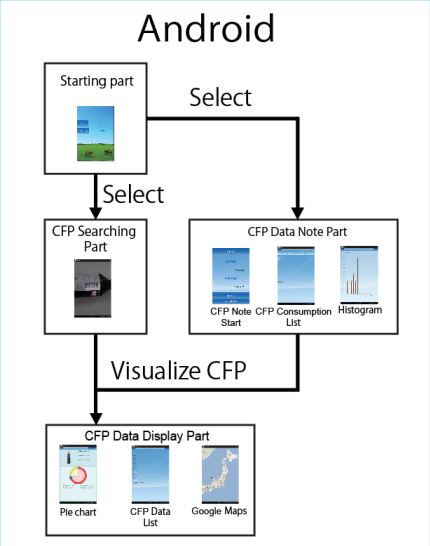


Figure.1 The Configuration diagram of the CFP data visualization system

in both a pie chart and a data list. Geographical data of the product are shown on Google maps. The pie chart is used to inform a ratio of four processes in the CFP data to consumers. The four processes are raw materials, raw materials transport, factory, and product transport.

CFP data note part is used for recording the CFP consumption history. From this data note, the consumers can be aware of how much CFP they spent. This information helps the consumers to control their CFP consumption. The data of the CFP, which the consumers spend in a month and in a day, are shown on the CFP note interface. Details of the CFP consumption data are shown on the CFP note list. The CFP consumption histogram is used to exhibit the CFP consumption by month.

The visualization system has a SQLite database to recode the CFP data. SQLite is a database system that works on the mobile devices. The CFP database was made by the authors. We calculate the CFP based on the product data and the GHG emission factor. CO-OP Sapporo and Muroran Institute of Technology collected the data to calculate the food CFP [3].

4. Summary

We have built the CFP data visualization system. We have 130 kinds of product data in our database. We hope the consumers can use this visualization system to know more about CFP and to realize their low carbon life.

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Forecasting Electricity Consumption of the Japanese Information and Communications Sector toward Green of ICT

Yusuke Kishita,*[1] Kohei Kuroda,[1] Yasushi Umeda,[2] Yohei Yamaguchi,[1] Yoshiyuki Shimoda,[1]
Minako Hara,[3] Hiroki Oka,[3] and Jiro Nakamura[3]

[1]*Osaka University, Japan*
[2]*The University of Tokyo, Japan*
[3] *NTT Energy and Environment Systems Laboratories, Japan*
*Corresponding author: kishita@ceids.osaka-u.ac.jp

1. Introduction

As the electricity consumption of information and communication technology (ICT) equipment (*e.g.*, personal computers and smartphones) is increasing, the concept of green of ICT is becoming more important for achieving a low-carbon society. Much work has been done to estimate the electricity consumption of ICT equipment. For example, Koomey [1] estimated the electricity consumption of servers in the world, while Hoshino [2] forecast the number of Internet users and personal computers in the world until 2025. Regardless of existing studies as partially listed above, analysis of the electricity consumption of a whole ICT sector is insufficient. An ICT sector here consists of four subsystems – (a) fixed-line network, (b) mobile network, (c) office, and (d) others.

For helping to reduce the electricity consumption of ICT sectors, it is needed to analyze (i) the electricity consumption of subsystems (a)-(d) in the future and (ii) the effects of electricity reduction by various countermeasures. To undertake the analysis of (i) and (ii), this paper aims to propose a method for forecasting the electricity consumption of ICT sectors. A case study is carried out to estimate the electricity consumption of the Japanese ICT sector from 2012-2020.

2. Methodology for forecasting electricity consumption of ICT sectors

Each of four subsystems (a)-(d) encompasses several facilities. For example, subsystem (a) is composed of four types of facilities, *i.e.*, fixed-telephone communication, IP (Internet Protocol) communication, air-conditioning, and power feeding facilities. We model each of the facilities in the four subsystems in the following formula:

$$E_i(n) = P_i(n) \times Q_i(n) \quad (1)$$

where $E_i(n)$ is the electricity consumption of facility i in year n, whereas $Q_i(n)$ and $P_i(n)$ are the amount of a dominant factor over the electricity consumption of facility i and the intensity of the electricity consumption of facility i per unit amount of $Q_i(n)$, respectively. For example, we choose broadband traffic as $Q_i(n)$ for IP communication facilities in subsystem (a) since, on an empirical basis, there is a strong correlation between broadband traffic and the electricity consumption of IP communication facilities.

3. Case study

We estimated the electricity consumption of the Japanese ICT sector in 2020. We collected past data mainly from CSR reports issued by three Japanese telecommunication companies (NTT, KDDI, and Softbank). Based on the collected data, we obtained concrete formula of Eq. (1) for each facility. For example, as described in Figure 1, we defined $P_i(n)$ for IP communication facilities as:

$$P_i(n) = 0.0291 \times Q_i(n)^{-0.522} \quad (2)$$

We assumed three scenarios (*i.e.*, Reference, Rapid, and Slow scenarios) responding to the amount of IP traffic as it is one of the most uncertain factors in the ICT sector. In Reference Scenario, we assumed that the IP traffic in 2020 increases by 10 times more than the 2012 level based on the Cisco's prediction [3]. On the other hand, we assumed Rapid and Slow Scenarios by changing the annual increase rate of IP traffic by +5% and -5% from Reference Scenario, respectively.

Figure 2 showed that the total electricity consumption in 2020 becomes 1.4-1.6 times more than in 2012. The fixed-line and mobile networks in 2020 will consume 1.2-1.6 times and 1.5-1.6 times more electricity than in 2012, respectively.

4. Summary

We presented a prototype model for forecasting the electricity consumption of ICT sectors. Future work includes sensitivity analysis of electricity reduction by countermeasures, *e.g.*, replacement of old equipment with more energy-efficient one.

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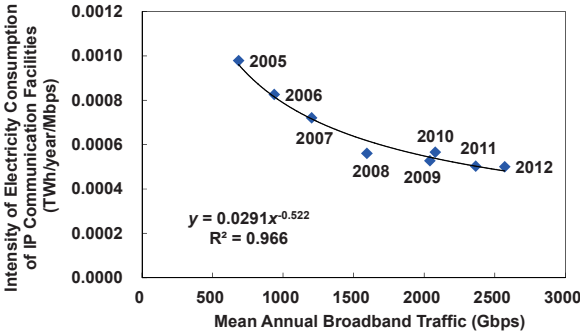


Figure 1. Relationship between broadband traffic and electricity consumption of IP communication facilities

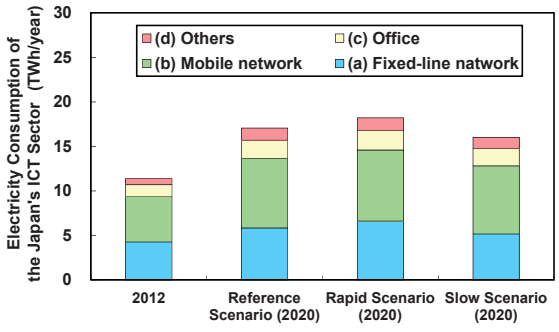


Figure 2. Electricity consumption of the Japanese ICT sector

Life Cycle Assessment of PVC Products Based on Material Flow Analysis (MFA) in Thailand: A Focus on End-of-life Management

Pomthong Malakul,*[1] Thanakorn Rodcharoen,[1] and Manit Nithithanakul[1]

[1]*The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok, Thailand*
*Corresponding author: Pomthong.m@chula.ac.th

1. Introduction

Polyvinyl-Chloride (PVC) is a plastic product which has matchless versatility. It effectively replaces wood, paper and metal in several applications due to its favorable balance of properties. PVC products are light in weight, suitable for use under pressure, easy to install, low maintenance cost, long service life, and recyclable. However, there are several concerns about the environmental problems of PVC that cannot be ignored such as a large amount of solid wastes generated from post consumption of PVC products. Therefore, The purposes of this research work were: 1) to study material flows of selected PVC products based on life cycle approach, covering raw materials, production, usage, and end-of-life; 2) to develop material flow analysis (MFA) [1] models in order to study the metabolism of PVC products in Thailand; and 3) to conduct LCA on PVC products based on MFA.

2. Methodology

For MFA study, the system boundary was set to cover all processes after the PVC products were produced and distributed to the consumers which includes material (product) input, product metabolism (use phase followed by disposal) and material (product) output (post consumption) [2]. The selected PVC products in this study were pipe, profile, cable, floor tile, floor covering, and foot wear which represent both hard and soft PVC products. Primary and secondary data such as actual resin consumption, the domestic production and consumption of PVC products in Thailand were used as input into the MFA models. Adjustable parameters of the model are the average service lifetime of each product, variation of the service lifetime, and different PVC waste management schemes (recycle, landfill, and incineration). The models were used to calculate and predict of the amount of PVC materials flow out to the environment in different pathways per year in the past, present, and future. The results from the MFA models were then compared with data collected at actual waste collection sites, disposal sites, and recycle shops.

For LCA study, since life cycle inventory (LCI) data of PVC resin already exist in the Thai National LCI Database, the scope covers processing, use and disposal of PVC products. Scenario analysis was used to assess and compare various waste management schemes for PVC products in Thailand.

3. Results and Discussion

Figure 1 shows the inflow and outflow of mixed PVC products from MFA model during 1971-2051. The results reveal significant increase of PVC wastes due to increasing consumption of PVC products. This dynamic MFA model also shows estimated amount of PVC waste outflow in the past, present and future. For example, in 2013 the outflow of mixed PVC products was equal to 128,934 tons. From MFA-based LCA study of pipe and fitting (Figure 2), scenario with 100% recycle of PVC (S1) is the best one which gives the lowest GWP and energy consumption whereas scenarios with incineration and landfill treatment are relatively unfavorable end-of-life management for PVC products.

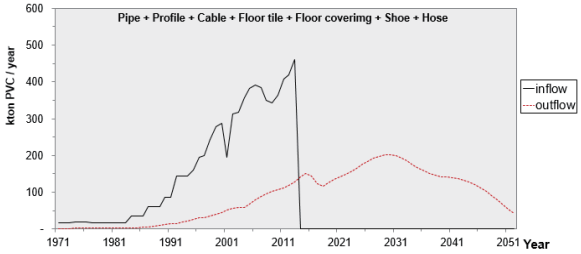


Figure 1. Profiles of PVC inflow and outflow of mixed PVC target products.

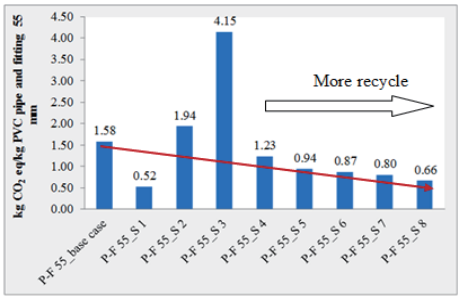


Figure 2. GWP of PVC pipes and fittings for various end-of-life scenarios

4. Conclusion

The results of MFA study indicated that significant amount of wastes from PVC products has been released every year, especially at increasing rate. The amount can reach several hundred thousand tons per year in the near future if no proper end-of-life management is not employed or enforced. Based on our MFA model which is the first one in Thailand for PVC products, the accumulative amount of PVC wastes can be as high as 7 million tons in 2051. This can cause serious waste and environmental problems to people and ecosystems in Thailand. The results from LCA study based on MFA of pipe and fitting clearly show that end-of-life management is an important factor affecting the whole life cycle environmental performance of PVC products and recycling has shown to be the best in both energy and environmental aspects.

Acknowledgments

We would like to thank ASEAN Vinyl Council (AVC) for the financial support and all providers of data used in this study.

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Sustainability of 3D Printing vs. Machining: Do Machine Type & Size Matter?

Jeremy Faludi*[1], Rishi Ganeriwala[1], Brett Kelly[1], Toril F. Rygg[1], Chi Yang[1]

[1]*University of California Berkeley, USA*
*Corresponding author: faludi@berkeley.edu

1. Introduction and Background

3D printing is booming, now competing with CNC machining and other methods, particularly for prototyping [1]. However, its environmental impacts are still poorly understood. Here, impacts of four 3D printers were compared to two CNC mills to find if larger or smaller, or certain types of machine (FDM vs. SLA vs. polyjet) are more sustainable for general prototyping, or if such statements can even be made.

Some environmental impacts of machining have been well studied [2, 3]. Likewise, some environmental impacts of 3D printers have been well studied [4, 5]. However, most of these studies are single-issue (e.g. just energy use), and few of them compare different 3D printers, much less compare them to machining. Also, some 3D printing enthusiasm has led to misleading comparisons (e.g. solar-powered printers vs. grid-electric injection molding [6]).

3. Methods and Results

This study continues recent work [7] providing the first life-cycle assessment (LCA) of multiple 3D printers using comprehensive multi-variable impacts, and the first such comparison of additive manufacturing vs. machining. In this study, new machines were measured and the functional unit was adjusted from the making of two solid parts to making one thin-walled part, for more realistic comparison of the prototyping most often performed by 3D printers, according to industry sources. See Figure 1.

Machines measured were a Mori Seiki NVD1500 DCG ("small" CNC mill), a Haas VF0 ("large" CNC mill), an Afinia H480 ("small" desktop FDM printer), a Dimension 1200BST ("large" commercial FDM), an Objet Connex 350 ("large" commercial polyjet), and a Projet 6000 ("large" commercial SLA). Scoring used ReCiPe Endpoint H. Printer usage varies widely, so scenarios included theoretically making parts 24 hrs/day, 7 days/wk, as well as making just one part per week, either leaving machines idling or turning them off when not in use (except the Objet, for which shutoff is prohibitive).

Figure 2 shows maximum utilization results. Only one part was printed per machine, but SLA and polyjet machines can print several parts in nearly the same time as one part, so this was modeled, denoted by (*). The Mori Seiki had anomalously long operation time, which may have been due to operator inexperience. Thus, an alternative was calculated for it with more optimal operation time, denoted by (**).

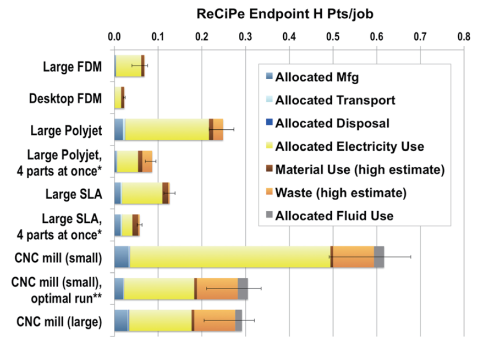


Figure 2. Impacts per part, operating at maximum utilization.

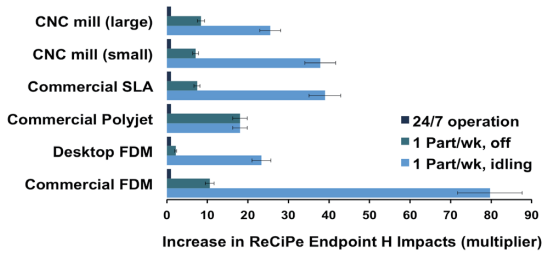


Figure 3. Impacts of idling vs. maximum utilization.

6. Discussion and Conclusion

Environmental impacts per part made depended much more on machine utilization than machine type or size (Figure 3 shows an 18x to 80x difference vs. Figure 2's 20% to 14x, or up to 27x if the anomalous datapoint is included.) Printing multiple parts at once in the polyjet and SLA also made larger differences than machine type (see Figure 2).

Thus, although some machine types do have lower impacts than others (e.g. the desktop FDM), sharing of machines to maximize utilization is the top-priority sustainability strategy for all machines, more important than machine type or size.

Acknowledgments

Thanks to Marco Teran and Patrick Dunne at 3D Systems, and Gordon Long of UC Berkeley, for machine access.

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Life Cycle-based Exergy Analysis and Its Application to Japanese Case

Ryota Ii,*[1] Eiji Yamasue,[2] Shinsuke Murakami,[3] Jun Nakatani,[3] Takeshi Matsuda,[1] Ken Horiguchi,[1]
Yuusuke Kousaka,[1] Rintarou Terada,[1] Kei Gomi[2] and Makoto Inari[4]

[1] *Pacific Consultants Co., Ltd., Japan*; [2] *Kyoto University, Japan*; [3]*The University of Tokyo, Japan;* [4] *Inari Consulting Office*
*Corresponding author: lcateam@ss.pacific.co.jp

1. Introduction

Studies on life cycle assessment (LCA) using exergy which is an indicator concerning 'available energy' correspond to the second law of thermodynamics [1]. This presentation summarized current studies based on some review papers outside Japan [2][3][4], and discussed availability and problems of exergy as an indicator.

2. Outlook of recent exergy LCA studies

Examples of LCA studies using exergy as an indicator are the followings;

- Cumulative Exergy Consumption (CExC) [5] is a method to cumulate exergy contained in all resources throughout a supply chain of reference products. Cumulative Exergy Demand (CExD) [6] is a result of a test calculation using Ecoinvent database.
- Exergy Life Cycle Assessment (ELCA) [7] implements exergy analysis within the framework of LCA. However essential differences with CExC do not seem to be clear.
- Life Cycle Exergy Analysis (LCEA) [8] is considered to cumulate input and output exergy and divide them into renewable / unrenewable.
- Ayres et al. (1998) took advantages of using exergy as an indicator of both inputs and outputs. What this method enables is: to calculate easily, to assess different kinds of environmental impacts with a single index, and to compare environmental performances with large scales such as industries and countries.
- Finnveden & Östlund (1997) [9] proposed to use exergy inventory data as an indicator of characterization factor of natural resources.

3. Availability of exergy indicator in the research field of environment and energy

The exergy indicator used for environment and energy realm can be categorized into the following three categories.

(1) Exergy efficiency

Exergy efficiency has more advantages than thermal efficiency, as it includes irreversible loss which can not be estimated by enthalpy.

(2) Exergy inputs

Exergy inputs can be gained to converse the amount of energy including input resources, hence it can be calculated easily in the exiting LCA infrastructure.

(3) Exergy outputs

The amount of exergy outputs is an indicator representing potential environmental impacts focusing on emissions whose balances with the environment have not been achieved yet. However environmental impacts caused by the same amount of exergy vary according to types of interventions such as thermal and concentration.

4. Discussion

After the Great East Japan Earthquake in 2011, enhancing independence of production systems and regional activities, in addition to improving energy efficiency, is required in Japan. In order to assess and design low-carbon society system and its infrastructure, it is valuable to apply exergy, which represents various quality of energy, for LCA as an assessment method to focus on the entire reference system. Moreover developing the way for its application and verifying the effectiveness is required. In LCA realm, input-output analysis is often applied. When exergy is included to the LCA practice, it is applicable to the same way. Some of the authors referred to in this study have begun to create a table including the amount of input and output exergy for each industrial sector in 2005 Input-Output Table of Japan as its annex table, and discussed how to create and use the annex table.

Acknowledgments

This presentation is based on our current papers, such as Yamasue et al. [10] and Ii et al. [11]. The authors are also grateful to Ms. Akiko Ohsawa for supporting this work.

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Compilation of Embodied CO_2 Emission Inventory Using China's Input-Output Tables: Implication for Environmental Public Utilities

Qian Zhang,* Jun Nakatani, and Yuichi Moriguchi

The University of Tokyo, Japan
*Corresponding author: zhang_qian@env.t.u-tokyo.ac.jp

1. Introduction

Accompanying rapid economic growth, the urbanization rate in China has dramatically increased to around 50% during the past 30 years. Energy-related CO_2 emission in China has also enlarged to 8 Gt, accounting for one quarter of the world's total CO_2 emission [1]. China needs more materials and energy to build or renovate numerous cities to supply clean living environment for people. Our motivation is to understand how much CO_2 emission and other environmental burdens cost in exchange for maintaining and expanding this kind of environmental public utilities in China's urbanization process. In this study, we adopted environmental input-output analysis to compile China's embodied CO_2 emission intensity and inventory as a basis for computation of CO_2 emissions related to environmental public utilities in cities. Impacts from water supply and wastewater treatment services were picked up in discussion as one of meaningful implications.

2. Data sources and methodology

Detailed fuel consumption in 2007 was cited from the China Energy Statistical Yearbook (CESY 2008), and the China Statistical Yearbook (CSY 2008) as a complement [2, 3]. Not only final use of energy in all sectors but also energy input in power and heat generation and energy loss in other transformation processes were taken into account. Most recent and specific 135-sector input-output (IO) tables of China in 2007 [4] were assembled with above energy consumption data to produce an "energy IO table". Based on carbon contents in fuels in IPCC's guideline [5] and heat values indicated as standard coal coefficients in CESY [2], the energy IO table could be transformed as a dataset of embodied CO_2 emissions of China (2007). Non-energy CO_2 emissions from industrial processes were collected from literature [6].

We mainly followed the instruction of 3EID database for Japan [7] to compile China's embodied CO_2 inventory in competitive model. Embodied CO_2 intensity $\mathbf{e}$ exclusively in domestic products and embodied CO_2 emission $\mathbf{E_{CO2}}$ induced by final demands could be calculated as follows [8].

$$\mathbf{e=d\ (I-(I-M)\ A)^{-1}} \quad (1)$$

$$\mathbf{E_{CO2}=e\ f=d\ B\ [(I-M)\ (f_c+f_k)+f_x)]} \quad (2)$$

where $\mathbf{d}$ represents direct CO_2 emission factors in sectors, $\mathbf{I}$ means unit matrix, $\mathbf{M}$ is a diagonal matrix of import ratio, $\mathbf{A}$ represents input coefficient matrix, $\mathbf{f}$ represents domestic final demand, and $\mathbf{B=(I-(I-M)\ A)^{-1}}$ for simplification of the formula.

We disaggregated final demand $\mathbf{f}$ into domestic consumption (urban, rural and governmental) $\mathbf{f_c}$, gross capital formation (fixed investment and storages) $\mathbf{f_k}$, and export $\mathbf{f_x}$ to evaluate relative importance in embodied CO_2 inventory.

3. Results and discussion

Based on our evaluation, China emitted 2.1 Gt of CO_2 (30%) induced by domestic consumption, 3.0 Gt (42%) by capital formation and 2.0 Gt (28%) by exports. Figure 1 shows the composition of this embodied CO_2 inventory via consumption perspective in category of final use (inner) and production perspective in economic sectors (middle and outer).

As a case, we found that 24 Mt CO_2 embodied in services of water supply and wastewater treatment, whereas 22 Mt CO_2 embodied in construction of related infrastructure in 2007. The decomposition results of these embodied emissions are shown in Figure 2. Maintaining the services of water supply and wastewater treatment requires dozens of times of carbon footprint than its direct CO_2 emission.

It demonstrates that China's own embodied CO_2 dataset could give more detailed and precise insights on consumption-based GHG responsibility, which is helpful to decision-making about effective potential of carbon abatement while keeping a healthy economy.

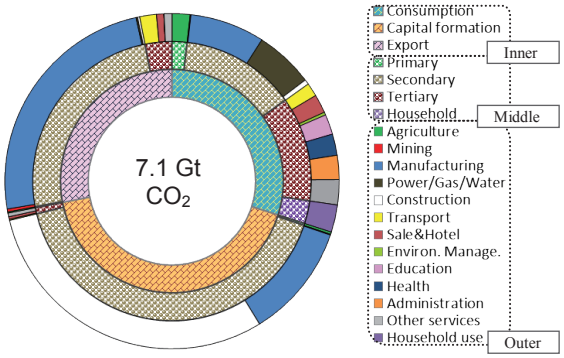


Figure 1. Embodied CO_2 of China, 2007

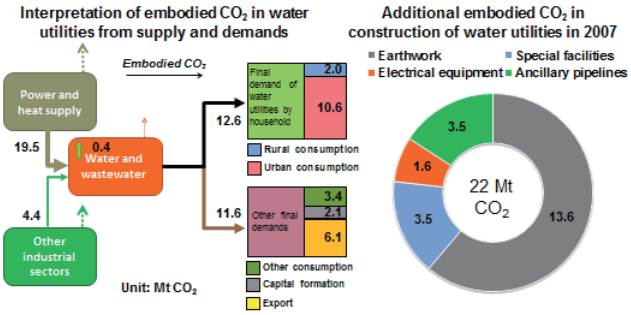


Figure 2. Embodied CO_2 in operation (left) and construction (right) activities of water supply and wastewater treatment in China, 2007

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Integration of material performance index for a comprehensive change-oriented LCA: the biopolymer case

Bruno De Benedetti,* Pierluigi Freni, Paolo Tecchio and Sara Rollino

Department of Applied Science and Technology, Politecnico di Torino, Torino, Italy
*Corresponding author: bruno.debenedetti@polito.it

1. Introduction

The fast pace of technological progress and the increasing pressure on natural ecosystems put forward the urgent need for the assessment of the impact of human activities, especially in the early stage of development. In particular, the possibility to estimate the potential impact that a new material could have on environment and human health, ahead of its adoption, is of fundamental importance during the design phase of a product [1].

The selection process of a new material, to be used in place of another, is mainly based on the intrinsic properties of the material itself (e.g. mechanical characteristics). Therefore, a proper comparison in a change-oriented perspective should take into account both the properties of the material and its environmental performance. In particular, to support the decision making process Life Cycle Assessment (LCA) should be complemented with other tools [2].

Currently, LCA is internationally considered the standard in environmental impact assessment and represents an extensive and comprehensive methodology. In order to perform such analysis, a complete and deep understanding of the overall life cycle of a product system is required. This condition can be satisfied only once the material itself has been already introduced onto the market.

Given the previous considerations, full-fledged LCA shows two major limitations: it can be performed only *ex-post* (i.e. after the development at industrial scale of the new material) and it accounts mainly for the environmental performance of the material, regardless of its intrinsic properties. To overcome such limitations and to forecast the potential impact of a product beforehand, a radical change of perspective must be prompted: a shift from an *ex-post* approach to an *ex-ante* analysis is needed. In the present work, it is proposed a comprehensive design tool, which is aimed at assessing the environmental sustainability and economic feasibility of the introduction of a new material onto the market. The developed method synergically combines the results deriving from *ex-ante* LCA with multi-criteria analysis for material selection, allowing a comprehensive and consistent comparison between the emerging material (e.g. new polymers produced from renewable sources) and the "traditional" materials that are intended to be replaced.

Interest in bio-based plastics as substitution materials for petroleum-based plastics has risen in past years and the global industrial production is expected to have 400% growth by 2017 [3]. This rise is due to a market demand for products with lower environmental burden compared to traditional plastics. Thus, the need to quantify biopolymers environmental impact is becoming meaningful in order to provide a concrete and objective answer to the market. Biopolymers production technologies are, in many cases, still at lab/pilot plant scale. Therefore, no reliable primary data are available in order to perform a proper environmental impact assessment, by means of LCA. For this reason, an *ex-ante* LCA approach is here proposed to assess the environmental performance of innovative bio-based products, starting from both primary data on lab/pilot scale and chemical/thermodynamic considerations.

The final goal of the authors' work is to integrate *ex-ante* LCA with multi criteria material selection, moving from an evaluation based on the unit of mass of the material to an assessment that takes into account at the same time both the intrinsic properties of the material and its environmental burden. This synergic integration represents a relevant novel element of the methodology proposed hereinafter.

2. Ex-ante LCA

The operational framework of *ex-ante* LCA is defined accordingly to ISO 14040 standards for full-fledged LCA. The *ex-ante* LCA strategy proposed in the present work is grounded on the *Generic Approach*, developed by Patel et al. and mainly focused on the analysis of bio-based products (fuels, chemicals and polymers) in the context of the *White Biotechnology* [4, 5]. In fact, most of the goods produced from biomass are subjected to similar processes. The *Generic Approach* is defined as a method that allows to estimate, *ex ante*, the environmental impacts and the basic economics of new biotechnological processes for which data from pilot plant or on laboratory scale are not yet available, or for which industrial scale data are not publicly accessible due to confidential agreements [4]. The authors of the current work implemented such methodology including primary data from pilot plant scale production and secondary data obtained from inventories in LCA databases and by means of a stoichiometric model of the chemical processes involved. The aim is to perform a multiscale analysis in order to gather enough results to enable a consistent scale-up of the environmental burden on industrial scale.

The main objective of such analysis is to evaluate the environmental burden associated with the production of goods and, in particular, to allow a comparison with traditional products of the chemical industry. In this context, the scope of investigation is limited *from cradle to factory gate*: i.e. the system boundaries are chosen so that the final output is the studied chemical. As far as biopolymers are concerned, the scope of the change-oriented assessment is extended to the *use phase* by means of material indices (detailed hereinafter § 3) that combines mechanical properties with environmental burdens for a straightforward comparison with oil-based polymers currently used. In the case of compostable or biodegradable polymers appropriate considerations are required and, possibly, the horizon of the analysis has to be extended *from cradle to grave*, in order to take into account also further benefits.

In a full-fledged LCA, consistently with the chosen level of detail and the quality and quantity of available data, manifold impact categories are considered. Each category summarizes the environmental effects associated with specific emissions. Due to the scarcity of data on which an *ex-ante* LCA is based, the impact categories used in the present work are limited to:

- *Cumulative Energy Demand* (CED). It measures the amount of energy involved in a system, considering the upper heating value, both from renewable and non-renewable source.
- *Greenhouse Gas emissions* (GHG). It takes into account, first and foremost, the emissions of carbon dioxide, and other greenhouse gases, such as CH_4, N_2O, etc.

The choice of such a small set of indicators, however, does not affect the validity and comprehensiveness of the analysis. In

fact, by linear regression, it is possible to associate the total energy consumption (CED) to most impact categories, such as acidification, eutrophication, human toxicity, etc. This correlation has been verified for a large number of products, in particular commodities, and it is justified by the fact that energy consumption (in particular from fossil sources) is the main source of all impacts associated with their production [6]. CED does not take into account the impacts resulting from land use and, for this reason, it cannot be regarded as a comprehensive indicator in the case of agricultural products and/or derivatives [7]. Therefore, in future works, the authors will complement the assessment of energy-related impact categories with land use and land use change indicators.

2.1. Scale-up protocol

The scale-up protocol is here presented in general terms and, afterwards, it is applied to the bio-based polymer chosen as case study: polybutylene succinate (PBS). This methodology is based on the identification of a proper mathematical relation between the environmental burden on stoichiometric scale, pilot scale and industrial scale. Such a relation is called *scale-up function* (f). The protocol is made up of five fundamental steps:

(1) Choice of reference polymer. Since data on industrial scale are missing for innovative bio-based products, the definition of the scale-up function requires the choice of a reference polymer. This is selected according to the following considerations: (a) the process of synthesis of the reference has to be analogous to the one of the biopolymer under analysis; (b) for the reference, data on industrial scale have to be available.

(2) Pilot scale production and assessment. One or more batches of the bio-based polymer have to be produced in a monitored pilot plant: all the inputs and outputs of the process and the pilot scale environmental impacts of the biopolymer are determined with the *ex-ante* LCA approach. Afterwards a batch of the reference polymer has to be produced in the same pilot plant, monitoring again all the inputs and outputs of the process, and the pilot scale environmental impacts of the reference are determined with the *ex-ante* LCA approach. This way two sets of data on the environmental burden of both the biopolymer and the reference are straightforwardly obtained, on the same production lab/pilot scale.

(3) Industrial scale assessment of the reference polymer. The environmental impact related to the production of the reference polymer on industrial scale is assessed, by means of full-fledged LCA, using available secondary data or product ecoprofiles.

(4) Stoichiometric baseline. Both for the bio-based polymer and for the reference it is possible to define stoichiometric models for the chemical conversions (e.g. polymerization), based on theoretical information. These models are representative of ideal systems, perfectly efficient, and therefore their environmental impact (assessed by means of *ex-ante* LCA) is the lowest possible for the production routes considered and it is used as baseline.

(5) Scale-up function definition. The result of previous steps is a set of environmental impact values on pilot, industrial and stoichiometric scale for the reference polymer, while the environmental burden on industrial scale is still missing for the new biopolymer. Therefore, considering the complete set of data about the reference polymer, a relation among different scales impacts (Environmental Impact, EI) is defined as function of the mass conversion yield (y_{mass}) of the chemical conversion process.

$$EI_{ref} = f(y_{mass,ref}) \quad (1)$$

The mass conversion yield is, in fact, a valid indicator for the scale of a chemical process: the pilot scale is characterized by high inefficiency and then it has a low y_{mass}, conversely the industrial production is optimized (hypothesis of Best Available Technology, BAT) and it has a much higher y_{mass}. Finally, the stoichiometric model is representative of the ideal process and y_{mass}^{stoic} represents the upper limit for the conversion. Since the stoichiometric mass conversion yield is characteristic of the specific process considered and it does not depend on factors other than chemical and physical ones, the y_{mass} at each scale is normalized with respect to y_{mass}^{stoic} in order to enable the following application of the function to slightly different processes. Therefore, equation (1) is rewritten as:

$$EI_{ref} = f(\bar{y}_{mass,ref}) \quad (2)$$

where $\bar{y}_{mass,ref}$ is the normalized mass conversion yield. Equation (2) is the *scale-up function* in the generalized form.

The set of data for the environmental impact of the reference is made up of discrete points, thus a regression or interpolation is required to obtain a proper mathematical function.

2.2. Case study: polybutylene succinate

The methodology previously described has been applied to polybutylene succinate (PBS), a biopolymer that is gaining interest, particularly in the packaging sector. PBS is an aliphatic polyester with mechanical properties and processability performances similar to those of widely used polymers. It is proposed as an alternative in the production of polymeric films for use in agriculture (mulching film), shopping bags, bags for composting, etc. [8].

PBS is obtained from succinic acid and 1,4-butanediol monomers by means of a polycondensation reaction that forms the polyester and water as byproduct. Currently, the monomers used are fossil, but alternatives from renewable sources have been studied to replace one or both of the reactants. In particular, succinic acid can be produced from starch, glucose or cellulose, through bacterial fermentation. Furthermore, bio-based succinic acid can become the source for a "green" C4 chemical derivatives platform, including 1,4-butanediol [4].

The Japanese company *Showa Highpolymer* successfully produced PBS on pilot scale, using bio-based succinic acid. The mechanical properties and processability (extrusion bubble test) of the resulting bio-based PBS are in line with the performance of the oil-based counterpart [8]. Since the production process of PBS from biomass is at pilot plant stage, an estimate of the environmental impact on industrial scale has significant interest.

The starting monomers for the production of PBS are a dicarboxylic acid and a diol that undergoes an esterification reaction. A common polymer obtained by means of the same chemical reaction is polyethylene terephthalate (PET): in particular it is produced starting from terephthalic acid (dicarboxylic acid) and ethylene glycol (diol). Therefore, PET is a suitable candidate to be used as reference polymer for the scale-up of the environmental impact of PBS.

Accordingly with the scale-up protocol previously described, some batches of PBS and PET were produced in a pilot plant [9], monitoring process parameters, i.e. input and output flows of reactants and products, as well as energy consumptions. These primary data were used to determine CED (EcoInvent v2.0) and GHG (IPCC 2007 GWP 100a) impact categories for both the polymers produced on pilot scale. Afterwards, the impact on industrial scale for the PET was assessed with secondary data (*Polyethylene terephthalate, granulate, amorphous, at plant/RER U*, EcoInvent). Finally, the stoichiometric baseline was evaluated from the chemical reactions involved in the polymerization of both PET and PBS.

Monte Carlo analysis was used to process uncertainty data for all of the assessments: this way, for each scale, there is not only one value representative of the impact, but a range of data points. Data uncertainty in the inventory tables was associated

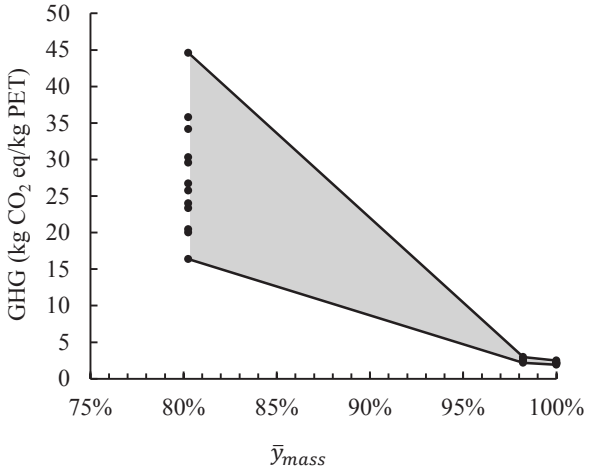


Figure 1. Linear interpolation of PET data points for GHG emissions at different production scales

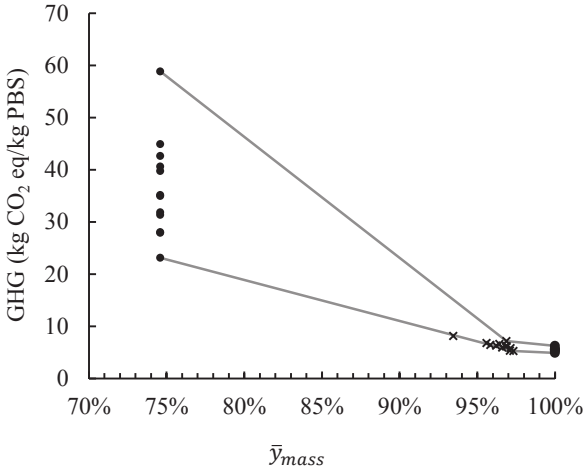


Figure 2.GHG emissions of PBS at different production scales

using Pedigree Matrix [10].

The scale-up functions were determined starting from the data points of the CED and GHG impacts of PET at pilot, industrial and stoichiometric scale. The functions are linear interpolations of data points and they are represented by the concatenation of the linear interpolants between each pair of points. In Figure 1 it is reported the resulting linear interpolation for GHG emissions of PET. Because of the large number of data points, the scale-up function is not limited to just one polygonal chain, but to a bundle of lines (grey area in Figure 1). Each scale-up function was then applied singularly to the respective data points representative of the environmental impact of PBS production at pilot scale and of the stoichiometric model. The intersections of such functions identify the GHG emissions of PBS produced from bio-based succinic acid (Figure 2). Finally, the Monte Carlo distribution of results for PBS is presented in Figure 3. Following the same methodology, the CED for bio-based PBS on industrial scale was assessed. The results are summarized in Table 1.

Table 1. Environmental impact of PBS at different production scales (mean values)

Production scale	CED (MJ/kg PBS)	GHG (kg CO_2 eq/kg PBS)
Pilot	893,55	36,57
Industrial	138,85	6,35
Stoichiometric	123,30	5,50

The outcomes of the scale-up protocol here proposed were used for a multi-criteria comparison between bio-based PBS and traditional polymers.

3. Multi-criteria material selection

The multi-criteria material selection aims at comparing different materials on the basis of more than one property. This method is grounded on the identification of a proper *material index*, defined combining solid mechanics and materials science. It is the result of considerations about the geometry of the component and the stress conditions. This index combines a set of properties (e.g. density, Young modulus, tensile strength, environmental impact, etc.) and it is used to compare alternative material options, targeting the maximization of the required performance. To carry out such a comparison, material indices

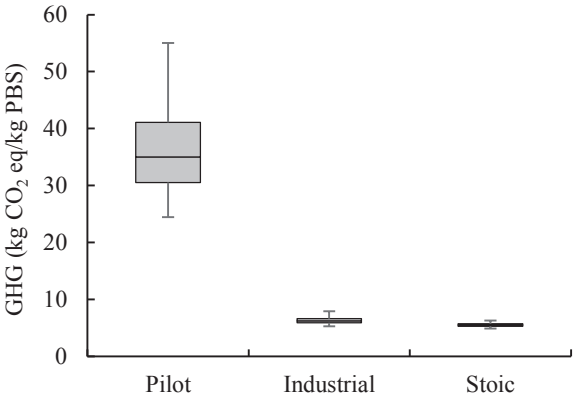


Figure 3. GHG emissions of PBS (Monte Carlo distribution from 5th to 95th percentile)

are implemented with the *bubble diagrams*. These are graphical representations in which a property, or a combination of properties, is plotted as a function of another: the materials are represented by bubbles localized within the area of the map [11].

Multi-criteria material selection can be integrated with LCA to extend the system boundaries and empower a comprehensive comparison among alternative materials (polymers in this particular case). The turning point of the methodology here proposed is the shift from the "kilogram based" analysis to a function oriented assessment, which is specifically necessary in the design step. This change in paradigm passes through the adoption of appropriate material indices which include LCA results. Once identified, these indices are used in combination with bubble diagrams for a final screening of available alternatives.

As far as PBS is concerned, in the present work it was performed a comparison between this bio-based polymer and the traditional polymers that are currently used in packaging sector. The definition of *material indices* was modelled considering a film of material undergoing a uniaxial planar tensile stress. The mechanical properties included in the model are Young modulus (Y) and tensile strength (σ_f), while the environmental performance is represented by CED and GHG impact categories.

Each index corresponds to a bubble diagram whose axes are respectively the numerator and the denominator of the index itself. Taking, for example, the index $\frac{\sigma_f}{GHG \cdot \rho}$, the resultant bubble diagram is presented in Figure 4. The sloping lines on the graph are called *iso-performance* lines since the points on such lines

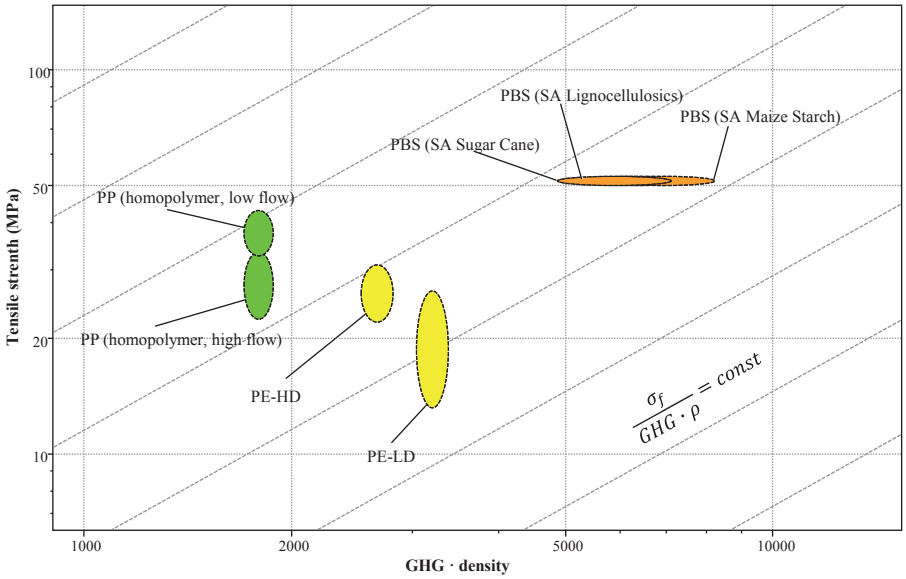


Figure 4. Bubble diagram Tensile strength vs GHG·density

are characterized by the same value of the material index. It follows that the bubbles lying on the same line are representative of materials with an equivalent eco-mechanical performance (with reference to tensile strength and GHG emissions for the particular case of Figure 4). At the same time, moving upwards perpendicularly to iso-performance lines, the eco-mechanical performance increases. The dispersion of values for GHG emissions of PBS produced at industrial scale (showed in Figure 3) defines the dimension of the PBS bubble (horizontal axis of PBS ellipses in Figure 4). Therefore, as it can be seen in Figure 4, bio-based PBS is comparable with Polyethylene (PE) and only slightly inferior to Polypropylene (PP).

Performing such analysis for the other indices previously identified, bio-based PBS proved to be a valuable candidate in the replacement of PE and PP for film packaging applications.

Conclusions

The proposed methodology, combining e*x-ante* LCA and multicriteria material selection, proved to be suitable to assess the environmental burden of newly developed bio-based polymers. The scale-up protocol developed by the authors is aimed to overcome the "scale issue" arising in the comparison between innovative processes, at early stage of development, and industrially optimized ones. Furthermore, the use of material indices as functional unit for LCA of materials shows a great potential that goes beyond the scope of the present work and that has to be explored for other materials.

As far as PBS and biopolymers in general are concerned, the methodology herein presented points out that it is not recommended an approach which indicates the biobased polymer to be the best choice by default. In fact, in the case study previously described PP performs better even if it is fossil based.

Finally, the method can be used to outline the targeting context in which the new material should be introduced. In practice, it is possible to define the constraints that the new material needs to respect, in order to be competitive with current solutions, in terms of material properties (mechanical, thermal, etc.) and environmental impact (CO_2 emissions, etc.).

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Environmental profile of Stone-Paper

Atsushi INABA[1]*, Nobuharu SHINOZAKI[1], Takumi KAWASHIMA[1], Masaharu MOTOSHITA[2,3]

[1]*Kogakuin University, Japan*;
[2]*National Institute of Advanced Industrial Science and Technology,Japan*; [3]*Technische Universitaet Berlin, Germany*
*Corresponding author: a-inaba@cc.kogakuin.ac.jp

1. Introduction (Goal and Scope Definition)

The environmental profiles of stone paper and conventional pulp paper were analyzed in this study. The functional unit was 1m^2 in size and 200μm thickness of each paper, which weights were 240g/m² and 155g/m² for stone paper and for pulp paper, respectively.

2. Inventory Analysis

2.1 System Boundary

The overseas crude oil is imported, and then polyethylene is produced in Japan, which is a raw material of stone paper. Lime stone, which is another raw material of stone paper, is mined in Japan.

The conventional pulp paper is made of woodchip imported in Japan. The overseas forestations and cultivations of wood are included, and the recycled waste paper is not used for the production of pulp paper in this study.

After the production, both papers are printed and used. The printing is included but the use stage is excluded because there are many options to use both papers.

On the end of life stage, pulp paper is incinerated in the facility with the electric power generation. For stone paper, two scenarios, the incineration with the power generation and the landfill, are assumed. The efficiency of the power generation in the incineration facility is assumed to be 15% for both papers.

2.2 Calculation

The data of materials and utility to manufacture stone paper is provided by TBM, the company importing stone paper to Japan. High density polyethylene of 0.048kg and lime stone of 0.192kg are used for 1 m^2 of stone paper.

The manufacturing data of pulp paper is cited from the database of the society of LCA, Japan[1]. Which is provided by Japan Paper Association. 0.246 kg of woodchip is used for 1m^2 of pulp paper.

The materials and energy to photogravure on pulp paper and on stone paper is not different, which is cited by Uchida[2]. For the other background data, Milca[3] by JEMAI is used.

3. Impact Assessment

LIME2[4] is applied for the impact assessment in this study. The environmental impact of the certified forest is not considered, but the damage to biodiversity and net primary production were assessed for uncertified forest. In addition, pulp paper is considered to be carbon neutral in this study.

The environmental impacts such as acidification and urban air pollution caused by SOx in the sea lane are not taken into account in this study, although it is not negligible compared to that in the other life cycle stages of pulp paper.

In this study, the environmental impacts for both papers were assessed firstly, and then the environmental impacts of the case if the forest was not certified as responsibly managed were analyzed. It might be useful to clarify the contribution of the certified forest.

3.1 Impact Assessment of the paper with certified forest.

Fig.1 shows the contributions of the emissions and resource consumption in the weighted result of the environmental impacts in the whole life cycle stages.

As pulp paper is carbon neutral, the CO_2 emission due to the incineration of pulp paper is not counted. For the case of stone paper (incineration), ashes after the incineration have to be landfilled and they give the significant effects on the damage of the social asset. The CO_2 emission of stone paper (landfilled) is a little smaller than stone paper (incineration), but the damage of the social asset due to the landfill of stone paper itself is larger than ashes of stone paper (incineration). As the result, the weighted result of stone paper (landfilled) is about 10 % larger than stone paper (incineration).

If the ashes obtained after incineration could be used as the recycled materials, the environmental impacts caused by the ashes could be avoided in the case of stone paper (incineration). The recycling of the ashes must be a target to be developed.

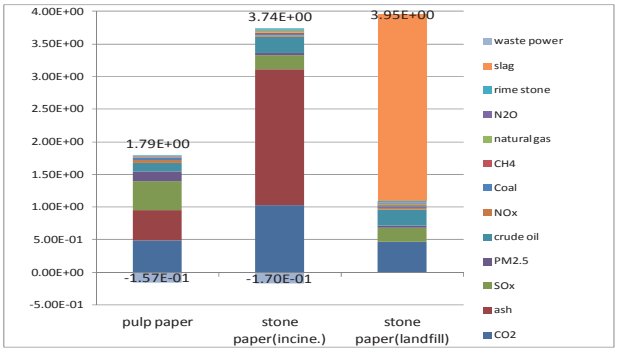


Fig.1 Weighted Impact using certified forest

3.2 Impct Assessment including the end of life

Fig.2 shows the weighted environmental impact for the case that 51.8% of the total forest is uncertified [5]. As the impacts for stone papers are the same as those shown in Fig.1, it is clear that the environmental impacts to biodiversity and net primary production of uncertified forest are very significant.

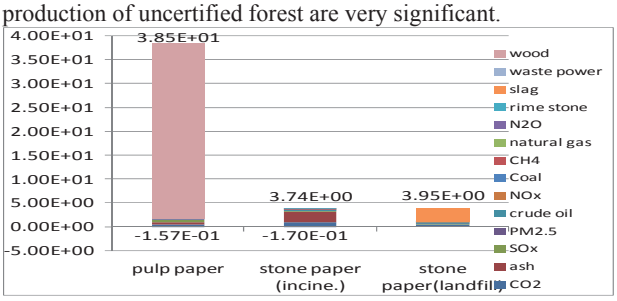


Fig.2 Weighted Impact using 51.8% of certified forest

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LCA for environmental policy in case of Japanese local governments

Yasuyoshi TARUTA,*[1] Yoshiteru NAKAMORI[1]

[1]*Japan Advanced Institute of Science and Technology*
*Corresponding author: y-taruta@jaist.ac.jp

1. Introduction

Human activities have produced many wastes. Those wastes need to be dealt with appropriately. Problems associated with them, have recently been studied in many fields of studies in terms of waste management and environmental policy. [1][2] Research of Life Cycle Assessment (LCA) gives significant attention to waste management, relevant decision-making and so on. [3] This research focuses on environmental policy of Japanese local governments. Nowadays many Japanese local districts are enforcing a project about biomass produced from (kitchen) garbage in each city unit. The purpose of this policy in each district is to make the best use of biomass and to promote it. Then, in terms of LCA, we examined the change in the CO2 emission by this project for a local city. This case study is expected to contribute to the improvement of local waste management.

2. Environmental load view point of LCA

This project started in 2007. A city government chose one dealer to promote this project. They have been collecting waste garbage from kitchen by trucks. Then they used mixer cars to ferment compost from garbage and applied it to farm in the city. We evaluated the project of CO2 emission from the viewpoint of environmental load in LCA.

The system boundaries are shown in figure 1 and figure 2. Fig 1 shows the system of compost-ization project. Fig 2 is about incinerator. The amount of garbage handled by incinerators has shown some declining trend due to the use of a biomass like compost.



Figure 1. System boundary of Compost-ization project.

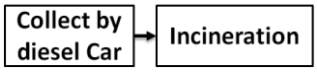


Figure 2. System boundary of incinerator.

The research aims at explicating through calculation CO2 emission of compost-ization project and incineration flow. The Units of CO2 emission factors in the boundaries of collection (to collect garbage), fermentation (to ferment as compost) and transportation (transport for farm).are shown in Table1. This project covered about 2,700 households (about 10% in city) as participants in 2008. And the amount of garbage collected was about 360 tons (2008).

Specific formula is not shown in the abstract due to the space limitation.

Table 1. CO2 emission factor

Boundary	Content	State	CO2emission-factor	Unit
Collection	Diesel-oil	Burn	$2.64*10^{-3}$	tCO2/L
Fermentation	Diesel-oil	Burn	$2.64*10^{-3}$	tCO2/L
Transportation	Gasoline	Burn	$2.31*10^{-3}$	tCO2/L

3. Results

The Result of CO2 emission in the compost-ization plan is shown in Chart1. The duration of time for data collection was from October 2006 to September 2009. In 2006 project was started as a demonstration. The CO2 emission of incineration is shown in Chart2. The city has 2 incinerators. One incinerator has an ability to burn 160tons of garbage par day and the other 20tons of garbage. Those incinerators use electrical power and fossil fuel (include kerosene and heavy oil) for their operation. Electrical power needed for CO2 emission unit is $5.55*10^{-1}$tCO2/MWh. Heavy oil needed for CO2 emission unit is 2.77*tCO2/kl.

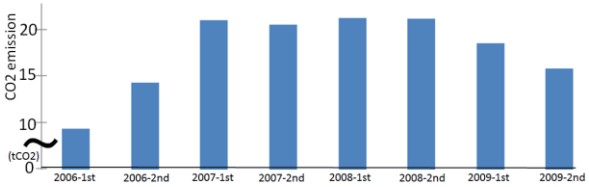


Chart1. CO2 emission of "Compost-ization project"

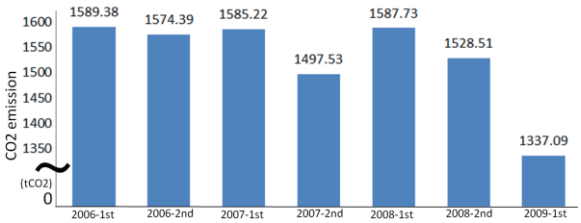


Chart2. CO2 emission of "Incinerator"

4. Summary and Conclusions

Our calculation result of life cycle CO2 emission of compost was about 20t-CO2/half-year in the first half of 2008 and that of incinerator about 1500t-CO2. In the following period the CO2 emission of incinerator was decreasing to 1330t-CO2/half-year in the first half of 2009 because the amount of general garbage was decreasing due to the biomass policy enforced in 2007. Another reason is that one of the two incinerators was abolished because of the decreased garbage. Actually this biomass policy was effective in lowering environmental load. Additional studies of the relations between governmental biomass policies and environmental impact are strongly suggested.

Acknowledgments

This paper use raw data as much as possible. They were supplied by the city government and the selected dealer. We express our gratitude to their cooperation.

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Eco-design of Tableware from Palm Fiber Bio-composite

Singh Intrachooto*[1],Rattanawan Mungkung[2,3], Kanokon Hancharoen[2], and Chiravoot Pechyen[4]

[1] Creative Centre for Eco-Design, Department of Building Technology, Faculty of Architecture; [2] Department of Environmental Technology and Management, Faculty of Environment; [3]Centre of Excellence on enVironmental strategy for GREEN business (VGREEN), Faculty of Environment; [4]Department of Packaging Technology and Materials, Faculty of Agro-industry,Kasetsart University, Bangkok, Thailand

*Corresponding author: archsit@ku.ac.th

1. Introduction

Thailand has a national policy to increase palm oil plantation areas for alternative energy production. As a result, a huge amount of palm wastes are being generated from both the plantationas well asfrom processing plants. This study explored potential uses of palm wastes - turning them into bio-composite materials for tableware. Life cycle assessment is conducted in parallel to the development of bio-composites. It is expected that the palm-fiber bio-composite and the resulted tableware will be commercially viable, which will eventually enhance sustainable consumption and production policy.

2. Methodology

Specific palm wastes, i.e., mesocarp and empty fruit bunch, were collected from the plantation and palm oil manufacturing facilities.Thesetwo palm wastes were selected because of theirlargewaste volumesof 5.4 million tons per year [1]and there is no alternative application aside from being incinerated for heat or being turned intoparticleboards[2, 3].These wastes were dried and grinded before being exploded with steam pressure to further reduce fibers into 3 different sizes (small, medium, large). In this study, matrix composites (i.e.,melamine, palm fibers, UV absorber, heat stabilizer and calcium carbonate) at different ratios are investigated by using Central Composite Design (CCD) program. The designed formulae are tested to identify optimal conditions for forming tableware and ensure that the composite material will meet all tableware safety requirements. Life Cycle Assessment (LCA) is a tool to assess the potential environmental impacts of product along its life cycle. Along with applying eco-design concept, LCA results are used as the inputs for design from the very early stage (i.e., conceptual design).By doing so, the environmental aspects are captured,so that the designed tableware will be environmental friendly. LCA of early prototypes provides supporting data for the refinement of composite formulae. It is worth mentioning here that the amount of palm fiberwill be at least 20% for recycled content requirement or 35% for bio-based material requirement.

3. Preliminary results

3.1 Potential formulae of palm-fiber bio-composite

Different ratios of various components were tested and designed by using CCD program based on 95% of confidence levelto identify the optimize conditions (Table 1). UV absorber is added to minimize discoloration,whereas Coad® 21 Zinc Stearate (clear melt) is used to increase tableware's heat resistant.

Table 1: Ratios of melamine matrix with palm fibers

Component	Level				
	-2	-1	0	1	2
Palm fiber	15.0%	20.0%	25.0%	30.0%	35.0%
UV absorber	0.0%	0.5%	1.0%	5.0%	10.0%
Heat stabilizer	1.0%	3.0%	5.0%	7.0%	10.0%
Calcium carbonate	0.1%	0.3%	0.5%	0.7%	1.0%

3.2 LCA results for the concept design

Figure 1 showed the results of LCA study which indicated that the life cycle impactof melamine composite with palm fibercould be reduced by 20-50%, if palm fibers are used in the melamine matrix (assuming that the quality of tableware made of 100% of melamine and melamine mixed with natural fibers are similar).

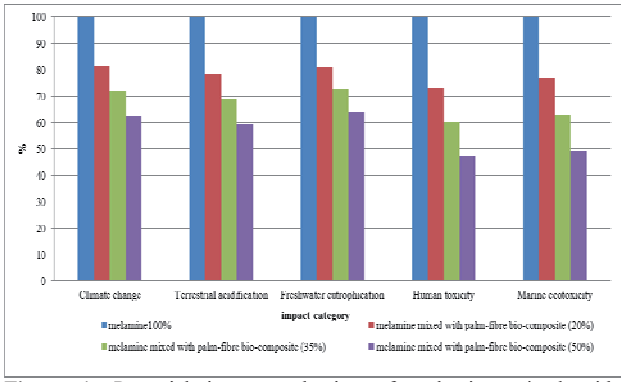


Figure 1: Potential impact reduction of melamine mixed with palm-fibrebio-composite (20%,35%, and 50%)

3.3 Design of tableware from palm- melamine composites

Tableware made with palm-melamine can give a natural aesthetics. Market studies have shown that Japanese food and restaurants have enjoyed popularity in Thailand with its growth of 15-20% since 2011, ranking 5th behind USA, China, South Korea and Taiwan, in terms of number of restaurants [4]. The designs of tableware cater toward Japanese cuisine sector. All of proposed designs will be evaluated in terms of quality and environmental performances as well as the design that meets potential markets.

Acknowledgments

Special thank is given to ARDA: Agricultural Research Development Agency (Thailand)for funding.

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Critical Material Footprint of Household Consumption

Stefan Pauliuk,*[1] Sebastiaan Deetman,[2] Richard Wood, [1] and Edgar Hertwich[1]

[1]*Norwegian University of Science and Technology (NTNU), Trondheim, Norway*; [2]*Institute of Environmental Science, Leiden University, Leiden, The Netherlands;* *Corresponding author: stefan.pauliuk@ntnu.no

1. Movitation

Critical materials or critical metals are used in moderate to small quantities only, but they are essential to modern technology. Massive use of critical materials in new energy technology and consumer electronics may lead to supply shortage, price shocks, and unwanted dependency from regions with exclusive mineral resources.

Recycling of materials is an important way to reduce primary material consumption, and hence it helps to reduce pressure on mineral resources. An illustration of the general metal system is provided in Figure 1.

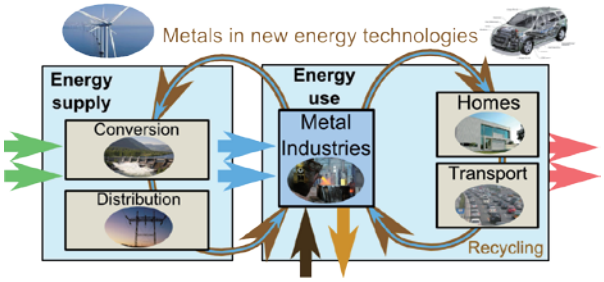


Figure 1. The connection between modern technology and metal cycles.

In developed countries, households are major driver of industrial activity. The contribution of goods for final use in households, especially consumer electronics, is significant in these countries [1].

To help to provide a scientific basis for the criticality debate, we conduct a prospective study of the material footprint of future household consumption. We assess the potential consequences of material recycling on imports of critical materials to the EU, and provide a discussion of how our results can inform policy makers and how they can be used to determine criticality indicators.

2. Methodology

Our study does not aim at forecasting future development. Rather, we conduct a scenario analysis using the GEO4 scenarios as a starting point [2]. This family of scenarios contains a set of socioeconomic parameters following four story lines termed “market first”, “policy first”, “security first”, and “sustainability first”. These parameters, including future population and per capita GDP, are fed into the system dynamics model TIMER [3] to obtain region-specific prospective time series for the end-user stocks for passenger vehicles (4 sub-categories) and domestic appliances (12 sub-categories). These stocks provide service to their users, and they represent valuable material deposits [4]. Using stock-driven dynamic MFA [5], time series for inflow and outflow of products are determined. From life cycle inventories and other published sources, we compiled the metal content of the different product groups for about 15 metals, including copper, cobalt, silver, gold, lead, zinc, and tin. We use these data to estimate the total metal content of the different product groups in the 26 regions of TIMER. We apply a simple model of material recycling or down-cycling, similar to the one used by Modaresi and colleagues [6], to estimate the future extent of secondary material production with the given outflow data. Two scenarios for recycling, “Business as usual” and “closed loop recycling”, are presented. The remaining result is the net demand for the metals that needs to be supplied by the metal producing industries.

3. Results and Discussion

We present time series of apparent metal consumption in 12 types of household appliances for about 15 potentially critical materials in 26 world regions. This level of detail allows us to get an overview over possible future consumption patterns. We compare the stocks of materials in appliances to the current global reserves to demonstrate how important anthropogenic stocks or ‘urban mines’ will become in the future.

We subtract the possible levels of material recycling from the apparent consumption and present time series of the resulting net metal demand for the different regions. This figure is an important indicator for the dependency of technology from material input, and we discuss how it could be used to inform policy makers about material criticality.

Acknowledgments

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Life Cycle Assessment (LCA) of the Supercritical Production of Barium Titanate

Michael Tsang[1,2], Gilles Philippot[3,4], Cyril Aymonier[3,4], Guido Sonnemann*[1,2]

[1]Univ. Bordeaux, ISM, UMR 5255, F-33400 Talence, France, [2]CNRS, ISM, UMR 5255, F-33400 Talence, France,
[3]Univ. Bordeaux, ICMCB, UPR 9048, F-33600 Pessac, France, [4]CNRS, ICMCB, UPR 9048, F-33600 Pessac, France
*Corresponding author: guido.sonnemann@u-bordeaux.fr

1. Introduction

The perovskite barium titanate ($BaTiO_3$) belongs to a group of materials categorized as ferroelectric. It has many applications in industry and electronics including computers, microspeakers, and optical communications devices, for example. In particular, barium titanate nanomaterials can be used as capacitors. Industry and technology are moving towards electronics with greater capabilities in smaller devices. Capacitors will have to become ever smaller to meet these goals. By reducing the size, but increasing the number of layers, a high capacitance can be met [1]. Decreasing the size of barium titanate should be done while preserving the crystallinity and narrowing the size distribution [1].

Currently there are three main synthesis routes for producing barium titanate in the nanomaterial size range: solid-state, sol-gel and hydrothermal [1]. These methods each have their advantages and disadvantages, but also they have limitations in desired material characteristics, costs, and time requirements that could be overcome by one other synthesis route; supercritical fluid synthesis [1]. This scalable technology is possible in a single step at moderate temperatures in only tens of seconds, while producing high quality nanomaterial.

The objective was to study the environmental footprint of this technology using life cycle assessment and identify what opportunities may exist over the other traditional methods.

2. Methods

The goal and scope of this life cycle assessment is to complete a life cycle assessment on the supercritical synthesis of barium titanate nanomaterials compared to the traditional solid-state, sol-gel, and hydrothermal synthesis routes. Production up to the creation of the nanomaterial as a dried particle is considered. The functional unit considered is 1 kg of dry barium titanate nanomaterial. Production of barium titanate using supercritial fluids is not currently practiced at the industrial scale. Data from the laboratory scale of this technology is used to complete the supercritical fluid inventory. Inventory data for the other synthesis routes are a mixture of industrial and lab scale data. These routes all produce nanomaterials with different size distributions but the pathways studied are assumed to produce materials in a similar size range.

It was acknowledged that the supercritical system uses a high volume of solvent in its lab scale process, which adversely affects its environmental footprint. To assess this situation further, a range of supercritical production scenarios were included in the LCA. This included comparing different solvents, recycling and regeneration of the solvent, or using only water.

The life cycle assessment was carried out in openLCA 1.4 using a combination of primary laboratory data, Ecoinvent 2.2, previously reported literature and stoichiometric calculations. ReCiPe is used to calculate the impact assessment.

3. Results

The initial results of the life cycle assessment demonstrate that the supercritical method is more impactful than the other synthesis routes. For example, Figure 1 shows the impact results for fossil fuel depletion. The major contributions to this impact are the large quantity of ethanol used as a solvent, the energy required for heating the solvent, and energy used for the set-up pumps. For instance, nearly 66% of the fossil fuel depletion in the default supercritical method (1st bar in Figure 1) is due to ethanol use. Figure 1 shows that a hypothetical supercritical method using water only as a solvent ("Super Sans EtOH") has a significantly reduced impact compared to the default supercritical method.

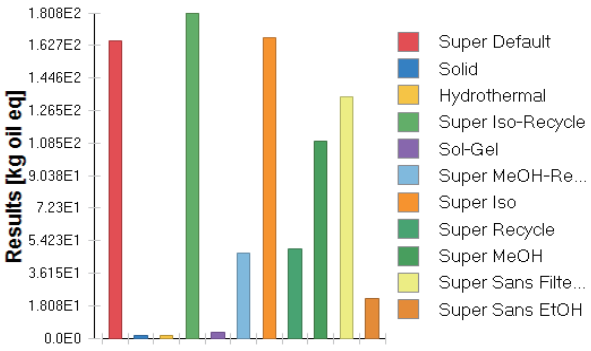


Figure 1. Fossil fuel depletion impact results

4. Discussion and Conclusion

The impacts for the supercritical method were overall much higher than the other synthesis routes. However, the inventory data used for this LCA was purely laboratory scale and provides a conservative baseline of worst-case impacts for this technology. The impact results demonstrate that there are a few key improvements in the synthesis route that can lead to a greener system overall. Ethanol use was a large contributor to many of the impact categories. In this LCA, solvent use was tested among a few scenarios. Regeneration of the solvent and or use of alternate solvents such as methanol can help lower impacts, and in the case of a synthesis route where only water is used as a solvent, the impacts are reduced significantly. The laboratory scale necessarily produces disadvantages to the supercritical method from a LCA standpoint. For example, solution concentrations must be kept low in order to keep the reaction tubes free of clogging and efficiently heated. A crucial step will be determining how nanomaterial output can be increased in the system using higher solution concentrations, and what the demands of such a system would be in terms of industrial scale setup and performance.

We feel that the supercritical route is still an important route to produce high quality, highly crystalline nanomaterials for capacitor production. The environmental profile can also be improved upon by learning from the results of this LCA.

Acknowledgments

The financial support of the Aquitaine Region for the Chair on LCA at the University of Bordeaux is acknowledged.

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Integration of geopolitical related criticality assessment for resources into the Life Cycle Assessment framework

Eskinder D. Gemechu[1,2], Christoph Helbig[3], Guido Sonnemann*[1,2], Andrea Thorenz[3] and Axel Tuma[3]

[1]*Univ. Bordeaux, ISM, UMR 5255, F-33400 Talence, France,* [2]*CNRS, ISM, UMR 5255, F-33400 Talence, France*
, [3]*University of Augsburg, Germany*
*Corresponding author: guido.sonnemann@u-bordeaux.fr

1. Introduction

Specific materials are becoming essential for the functioning of modern societies, as advanced technologies are highly dependent on them. Criticality assessment has been recently developed and used by material flow analysts as a stand-alone evaluation tool for resource strategies in response to growing concerns over sustainable supply of resources [1].

LCA has been used to quantify impacts from the direct use of resources by estimating their depletion time, an assessment limited to geological availability. Geopolitical, economic, social and other factors that put limits on the sustainable supply of resources are not meaningfully addressed. This paper, therefore, aims at looking how resource criticality could be brought under the framework of life cycle sustainability assessment (LCSA). A method to assess geopolitical related supply risk is proposed and applied to selected resources.

2. Method

The geopolitical related supply risk is calculated using the following equation:

$$SR_{c,i} = \left[\left(\sum_{k=1}^{n} s_k^2\right) * \left(\sum_{k=1}^{n} g_k * f_{i,k}\right)\right] \quad (1)$$

where $SR_{c,i}$ expresses the supply risk of country i for commodity c. s_k is the global production share of country k of the commodity c. g_k referees to the political instability indicator of country k. It is derived from the Worldwide Governance Indicators (WGI) of the World Bank. $f_{i,k}$ is import share of country k in the supply-chain of country i. The geopolitical related supply risks are then expressed as an LCA midpoint characterization factors with values between 0 and 1, indicating a share of the commodity supply being at risk.

3. Results and discussion

Table 1 summarizes the geopolitical supply risk of resources. Rare Earths Elements (REE), Sb, Nb, and Be are the most crtical resources that are subjected to high supply risk. They are also among the 20 resources indentified as critical by the EU report on critical raw materials [2].

Figure 1 highlights the risk contribution assocoated with the import of REE for France. The largest portion of the risk comes from China. It is due to the global market concentration of REE, in which China holds more than 90% of production share, and high import dependency of France for REE on China. In most criticality assessments, the geopolitical supply risk is addressed by weighting the WGI scores by average production share; whereas in this method the import share is considered. It is in line with way of doing LCA, in which the resource flows to a product system are taken into account to determine the proportional environmental burden associated to the inputs and outputs. In the same way, the overall geopolitical supply risk at national, regional or company level is estimated to be the sum of risks from different regions proportional to the import contributions and political stabilities. The risk would have been lower if France imports REE from other countries with relatively lower WGI values than China.

Table 1. Geopolitical related supply risk for selected countries

	CA	BR	EU	FR	IN	UK	US
Sb	.41	.39	.42	.42	.41	.27	.43
Be	.31	.26	.43	.32	.21	.41	.45
Co	.12	.19	.27	.12	.12	.12	.14
Ge	.25	.28	.26	.22	.28	.14	.27
C	.18	.17	.23	.25	.19	.20	.24
In	.20	.24	.27	.24	.30	.22	.27
Mg	.17	.21	.17	.16	.21	.14	.17
PGM	.28	.24	.30	.26	.30	.26	.25
REE	.19	.19	.17	.13	.16	.13	.19
Se	.55	.55	.50	.53	.54	.45	.48
Ta	.08	.09	.11	.08	.09	.08	.10
U	.10	.14	.10	.08	.07	.10	.11
W	.08	.07	.09	.10	-	.05	.07

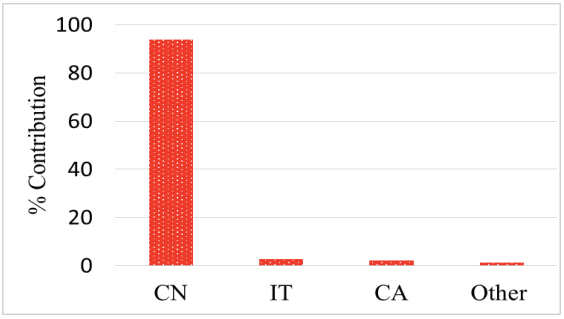


Figure 1.Supply risk contribution of REE for France

4. Conclusions

The proposed method allows assessing the accessibility of resources in LCSA, which is beyond the geological availability. It helps countries and companies to identify geopolitical related supply risk of resources so that they can take relevant measures to avoid any potential supply disruption. Inclusion of such indicator could broaden the scope of mainstream LCA under the LCSA framework by complementing the usually reported environmental dimension on resource depletion with geopolitical and socio-economic aspects related to resources.

Acknowledgments

The financial support of the Aquitaine Region for the Chair on LCA at the University of Bordeaux is acknowledged.

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Toward Sustainable Energy Business Using Woody Biomass in Rural Communities

Yusuke Kishita,*[1] Noriaki Nakatsuka,[1] Yukari Fuchigami,[1] and Fumiteru Akamatsu[1]

[1]*Osaka University, Japan*
*Corresponding author: kishita@ceids.osaka-u.ac.jp

1. Introduction

After the Feed-in tariff (FIT) scheme was enforced in 2012 in Japan, much attention is being paid to renewable energy sources, such as solar, wind, and woody biomass. While the expansion of renewable energy would reduce CO_2 emissions, on critical problem is how to ensure economic sustainability of renewable energy businesses in a long run (*e.g.*, 20 years). In this paper, a renewable energy business refers to economic activities where various actors (*e.g.*, business provider, consumer, government, and non-governmental organization (NGO)) exchange materials, energy, money, and information which are associated with renewable energy.

When attempting to design sustainable renewable energy businesses, we are faced with many unpredictable factors that may support or inhibit the business, such as national energy policies (*e.g.*, nuclear power policies), lifestyles, economic situations, and technological advancements. Aiming to clarify conditions for sustainable renewable energy business, this paper undertakes scenario analysis for evaluating the profits and environmental impacts of the business. For enabling scenario analysis, we develop a method for modeling renewable energy businesses. A case study of a woody biomass energy business in a rural community in Japan is demonstrated.

2. A method for modeling renewable energy businesses

We model a renewable energy business as a process network based on the concept of the life cycle simulation (LCS) [1] to evaluate various scenarios of renewable energy businesses. LCS is a method to analyze the flow of a product, money, and information throughout a product life cycle based on a discrete event simulation technique.

We define five categories of processes – material extraction, production, collection/distribution, selling, and end-of-life (EOL). In each process, we define equations to calculate costs, sales, and CO_2 emissions based on the relationship of inlet and outlet flows between neighboring processes.

3. Case study

We conducted a case study to assess the profit and CO_2 emissions of the woody biomass energy business. The region of interest is Maniwa City, Okayama Prefecture, Japan. The population and the area of the city are 47,096 and 828.4 km^2, respectively. The period covered ranges from 2013 to 2032 (*i.e.*, 20 years). We collected relevant data through interviews and literature review (see [2] in details). We assumed two scenarios for analyzing the impacts of the biomass energy business:

- (A) Baseline Scenario: The wood residues (*e.g.*, shaving and bark, 76 thousand ton/year) from the timber mills are incinerated and landfilled, while thinned wood (90 thousand ton/year) is discarded in forests.
- (B) Energy Business Scenario: The wood residues from the timber mills are used for producing wood pellets (18 thousand ton/year) and electricity (58 thousand ton/year) that is sent to the electrical grid based on the FIT scheme. In addition, a larger amount of virgin timber (90 thousand ton/year) is collected from domestic wood producers for generating electricity.

Figure 1 shows the cost structures in the two scenarios. The annual profit of Scenario A is -456 million JPY, while that of Scenario B is 958 million JPY. Since the profit of the biomass energy business in Scenario B heavily depends on electricity sales (2,100 million JPY/year), critical factors of driving the business include "the amount of inflow wood for electricity generation" and "the price of electricity from woody biomass to sell." According to our sensitivity analysis, it is pointed out that the business becomes economically unfeasible if "the price of the electricity from woody biomass to sell" decreases to 50% of the price as of 2013.

As shown in Figure 2, the CO_2 emissions in Scenarios A and B are 203,000 tCO_2/year and 136,000 tCO_2/year, respectively. That is, Scenario B reduces CO_2 by 32.8 % from Scenario A. This reduction comes from electricity sales and pellet sales, which contributes to saving fossil fuels.

4. Summary

We evaluated scenarios of woody biomass business in a Japanese rural community. Future work includes evaluating scenario variants to clarify conditions for sustainable energy businesses from economic and environmental viewpoints.

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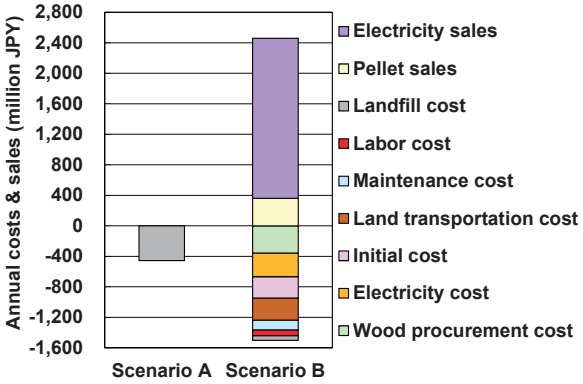


Figure 1. Cost structures in Scenarios A and B

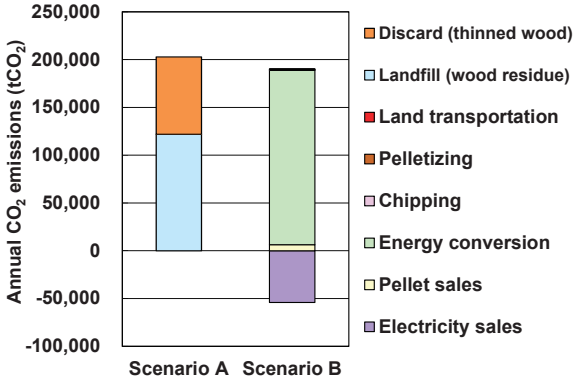


Figure 2. CO_2 structures in Scenarios A and B

System Dynamics Model for Sustainability Assessment of Mineral Resource Consumption Considering both Environmental and Resource Constraints

Tatsuhiko Kawamoto,*[1] Shinsuke Murakami[1], and Jiro Yamatomi[1]

[1]*The University of Tokyo, Japan*
*Corresponding author: 1196824376@mail.ecc.u-tokyo.ac.jp

1. Introduction

Millennium Development Goals (MDGs) with target date of 2015 were set in 2000, which include eradicating extreme poverty and hunger. While Ensure Environmental Sustainability is one of the MDGs, in order to put more emphasis on the issue, setting Sustainable Development Goals (SDGs) was agreed at Rio+20 Conference. MDGs and SDGs will ultimately converge in Post-2015 Development Agenda.

One of the goals discussed in SDGs is "ensure access to affordable, reliable, sustainable, and modern energy for all". Increasing energy demand usually means more demands for some mineral resources and may realize the resource constraint, which means we will fail to achieve the goal itself.

The ultimate goal of this study is to check the consistency between multiple goals and resource constraints. Therefore, the supply and demand balance of the resources and the associated environmental impacts to the areas in Planetary Boundaries [1] will be simulated under the scenarios to achieve the energy related SDGs.

2. Simulation Methods

In this research, a system dynamics model is constructed to simulate the supply-demand balance of the targeted resources and related environmental impacts under the energy scenarios, which make the energy-related SDGs come true. For example, the electricity supply system consists of generators and transmission cables. The model can reflect the detailed scenarios such as the grid access ratio and the share of renewable energy and even on-grid/off-grid scenarios.

Three minerals of copper, steel and PGM (platinum group metals) are selected as targets. The simulation period is set to until 2050, and all countries are categorized into 6 regions.

3. Case study for transmission cable

In this paper, the analysis for transmission cable is introduced as a case study. **Figure 1** shows the relationship between electricity consumption and transmission cable length by countries. Developing countries have relatively small values in both parameters. On the other hand, the cable length of developed countries are scattered in wide range even for similar electricity consumption. **Table 1** shows the result of multiple regression analysis. It shows that transmission cable length is correlative to generator capacity per capita and land area per capita (the reciprocal of population density). GDP per capita, even though we often forecast minerals demand with this parameter, is not statistically significant. These coefficients are used in the estimation and simulation hereafter. Unfortunately, sufficient time-series data of transmission cable length is not available.

Figure **2** shows the forecast of the amount of copper demands for transmission cable by regions until 2050 based on the demand forecast of transmission cable. Asia grows outstandingly until 2050, but Africa has the highest growth rate, which suggests huge demand after 2050. In 2010, total copper demand for electricity system including generators accounts for about 30% of all copper demand [2], so it is significant for this model to cover the whole system.

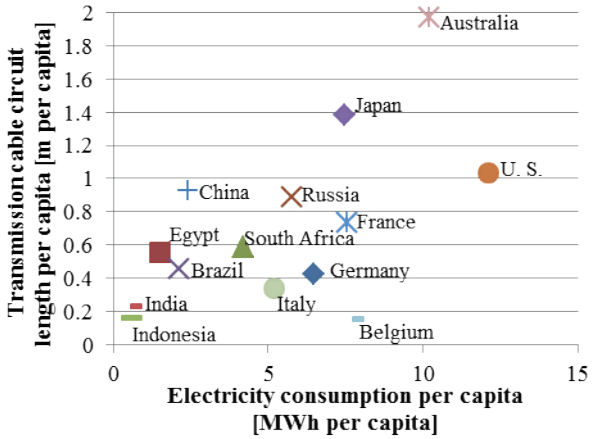


Figure 1. Electricity consumption and transmission cable length by countries

Table 1. The result of multiple regression analysis

	Estimate	Pr(>|t|)
(Intercept)	0.3462	0.00012***
Generator Capacity per capita [kW per capita]	0.2153	0.00050***
Land area per capita [ha per capita]	0.0253	0.00720**
GDP per capita [current 1000 US$ per capita]	-0.0009	0.81487

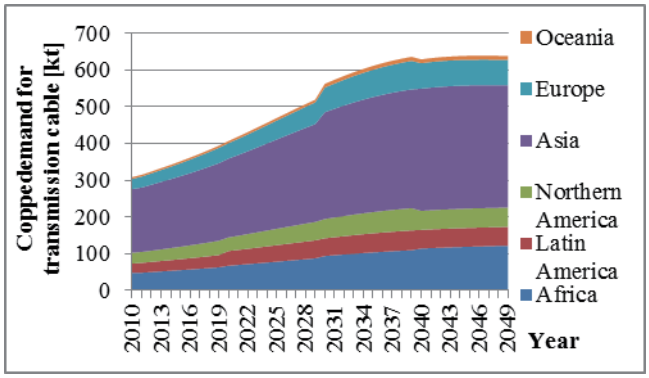


Figure 2. Copper input to transmission cable

4. Conclusion

This paper introduced the case study for transmission cable length estimation and the associated copper demand until 2050. The electricity infrastructures and the demands of mineral resources for it in developing countries grow rapidly in the near future and this is essential for their economic growth. In order to avoid realizing the resource constraint, we need to increase the resource efficiency in other sectors.

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Global supply chain analysis for sustainable utilization of nickel

Yuto Ohtsuka*[1], Hajime Ohno[2], Kazuyo Matsubae[1], Kenichi Nakajima[3], Keisuke Nansai[3], Tetsuya Nagasaka[1]

[1]*Tohoku University, Japan*; [2]*Yale University, the United States*; [3] *National Institute for Environmental Studies, Japan*;
*Corresponding author: b3tm5004@s.tohoku.ne.jp

1. Introduction

Nickel is one of the most important and widely used metals which are used for various industrial products and steel materials including stainless steel, heat and corrosion resistant alloys, electroplating, and a secondary battery. Thus the demand forecast of nickel will become increasingly important in the future [1]. Considering the sustainable supply of nickel resource, the reserves that can be economically mined are estimated about 219,500kt. This might suggest the low possibility of resource depletion in near future. However, looking at the mining area of nickel resources, major nickel mines are in tropical areas including Indonesia and New Caledonia, this strongly suggests that there is a big possibility of biodiversity loss caused by the nickel mining activity. In addition, the dissipation of resources and hazardous elements associated with the life cycle of nickel has been becoming a serious problem. Cobalt, for example, is one of the most concerned elements which are being lost to the tailing during in the hydro-process of laterite ore [3]. Heavy metals such as chromium are also deposited on the soil at Cu-Ni refinery in Russia or ferronickel smelter in Greece [4-5]. In this study, we identified (1) the worldwide nickel flow in global supply chain, and (2) flows of cobalt and chromium with nickel production.

2. Worldwide nickel flow in global supply chain

This study estimated the amount of nickel accompanied with each item traded among 231 countries and regions with the equation (1). 123 nickel containing products were chosen from HS code (the number indicating the classification of international trade items unified worldwide).

$$F_{i,j} = T_{i,j}(1-W_i)C_i \quad (1)$$

$F_{i,j}$: Flow of nickel from country i to j, $T_{i,j}$: Flow of commodity from county i to j, W_i: Moisture content rate of commodity I, C_i: Nickel content rate of commodity i,
$F_{i,j}$ was calculated by using the BACI (Base pour l'Analyse du Commerce International, CEPII). C_i was availed from various sources and the WIO-MFA model [6].

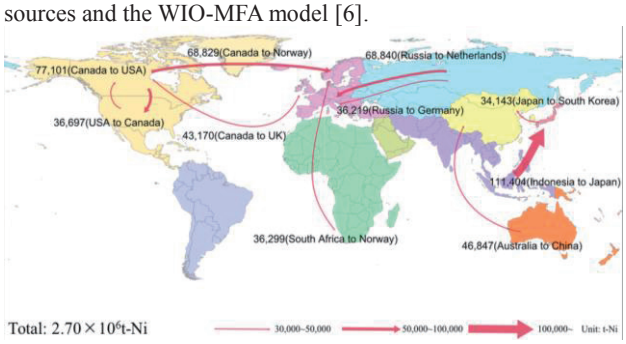


Figure 1 Worldwide nickel flow in 2005

The result of estimation indicated that the amount of nickel though the trade in 2005 was 2.7×10^6 t-Ni (Figure 1). And Japan was the top importer with more than 10% of global flows of nickel. So Japan is the most influential in global supply chain of nickel.

3. Flows of nickel depended on final demand in Japan

This study estimated the flow of nickel which directly and indirectly caused by Japanese final demand, which is the biggest nickel resource consumer, on the basis of GLIO analysis [7] (Figure 2). The nickel flows which caused by Japanese final demand was 223,256t-Ni (accounted for 8.3% of the flows all over the world). Direct flows to Japan was originated from Indonesia, Philippine, and New Caledonia, where are the laterite mines. On the other hand, indirect flows have been originated from Australia, Canada, Russia, and South Africa.

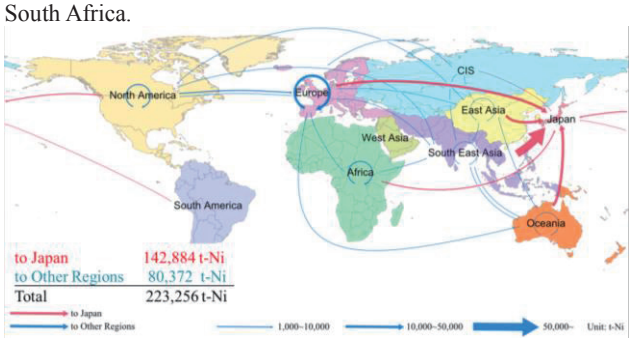


Figure 2 Flows of nickel depended on final demand in Japan

4. Substance flow of Co and Cr associated with Ni production

Figure 3 shows the estimated amount of a) nickel, chromium, and cobalt contained in nickel laterite ore imported into Japan, and b) those in nickel laterite ore for imported ferronickel production. For the estimation, we assumed the laterite ore contains 0.57-3.37 mass%-Ni, 0.31-2.2 mass%-Cr, and 0.02-0.18 mass%-Co (available from such as [7]), and 1kg of Ferronickel is produced from 22kg of nickel ore [8].

Our result shows that 20-100 kt-Cr and 650-900 t-Co were imported to Japan contained in nickel ore. Looking at the Japanese import of ferronickel, 4-23 kt-Cr and 150-200 t-Co were imported with ferronickel or remained at nickel mine or ferronickel smelter. This gives us the important suggestion to utilize nickel-ore contained resources in more efficient way. For this, the material flow of these metal associated with Ni production must be investigated in more detail.

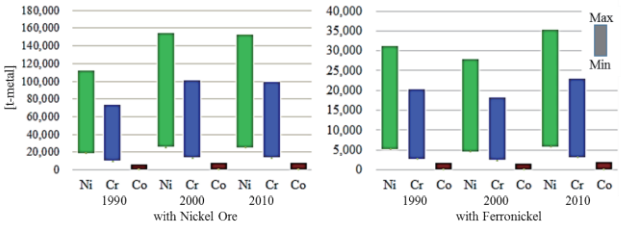


Figure 3 Estimated amount of Ni, Cr and Co contained in a) nickel ore imported into Japan, and b) nickel ore for imported ferronickel production.

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Mining impact on the changes in land use measured by satellite images analysis

Yasunori Iwatsuki,*[1] Hiroya Yamano,[2] Kenichi Nakajima,[2] Shinsuke Murakami[1]

[1]*The University of Tokyo, Japan*; [2]*National Institute for Environmental Studies, Japan*
*Corresponding author: yasunori_i0617@yahoo.co.jp

1. Background

Mining activities often cause a major change in land use around the sites. Land use change is one of the major reasons for the impacts on biodiversity by mining activity, as well as the heavy metal pollution in acid mine drainage and so on.

In the field of forest policy or urban planning, direct observations through satellite images are conducted to quantify land use changes [1]. There are a few researches which evaluate the mining impact on land use changes, but the observations in those researches are less precise [2].

Several life-cycle impact assessment tools prepare the coefficients of land use change [3]. However, the coefficients are standardized and therefore we cannot see the each mine site's specific situation. Environmental impact from mining activities is usually site-specific. Therefore, more detailed researches to evaluate and compare the land use change at individual mine sites are useful to understand the mining impact on land use change.

2. Purpose of this study

In this study, we focused on nickel mines in New Caledonia. New Caledonia is the 4th largest nickel producer in the world and it also is a biodiversity hotspot [4]. Therefore, we chose the nickel mines, owned by Societe Le Nickel (SLN) in New Caledonia [5] and compared the changes of land use and its nickel ore productions.

We evaluated the mining impact on land use change through a direct observation. We analyzed the satellite images in 3 years (1986, 1999, and 2012), and measured each scale of bare land area to be compared. The stripped area in a mine site can be measured by quantifying the changes of bare land area in historical satellite images. We used various historical satellite images, including those of Landsat /TM/ETM+, SPOT HRV, and Terra ASTER, to reconstruct temporal changes in bare land areas due to mining activities during each period (1st : 1986~1995, 2nd : 1996~2012).

In order to distinguish bare land from others, we used red band data that is expected to show greater difference between bare soil and vegetation than other bands. After gorthorectifying the images by referring to orthorectificed ASTER Level 3 products and ASTER GDEM data, density slicing was performed based on the threshold values between bare land and adjacent vegetated areas calculated by Otsu (1979) [6-7]. Enclosed boundary lines, extracted based on the threshold value, were converted to polygons, and the areas were calculated using the software ArcGIS version 10 (ESRI, 380 New York Street, Redlands, 92373).

Operation data (ore production, total excavation) was obtained from commercial databases (Raw Materials Data, minecost) to analyze the relationship between mining activities and land use change.

3. Result

Figure 1 shows the result of satellite images analysis for two mime sites (Tiebaghi [8] and Thio). Thio mine has operated since 1875 and Tiebaghi mine has operated since 1997. Stripped areas can be categorized into two types, pits and related facilities such as stockyards or exporting ports. The areas for facilities built in bare lands vary among the sites. Tiebaghi mine has two pits: pit 1 being operated and pit 2 in a development stage.

Figure 2 shows the area of land alienated for mining in each mine site during the 2nd period. In the graph, the area of land for the site in Tiebaghi is much bigger than others. During the 2nd period, the area for the pits sharply increased in a short term. Moreover, a construction of related facilities started and finished during this period. Figure 3 shows the amount of Ni ore and waste extracted during the 2nd period. Ni ore and waste extracted in Tiebaghi mine is not so huge despite the presence of large scale land use change in a short term. Using these data, we calculated the scale of land use change expressed as square meters per nickel in ore in each mine site. Compared to a value shown by Nickel Institute (0.0018m^2/kg [9]), estimated values for all mine sites except for Tiebaghi have the same order of magnitude. In Tiebaghi mine, top soils in a huge area can be stripped in advance of extracting ore.

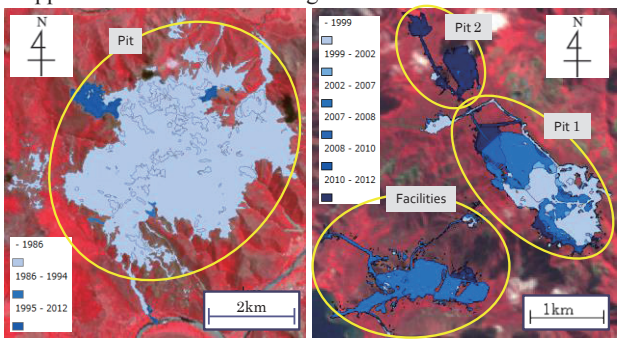


Figure 1. Satellite images analysis (Left: Thio, Right: Tiebaghi)

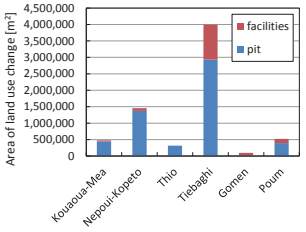


Figure 2. Area of land use change

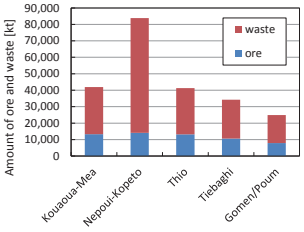


Figure 3. Amount of ore and waste

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Potential Self Supply of Local Resources towards Regional Sustainability: Case Study of Shinjo Village in Okayama prefecture, Japan

Kazutoshi Tsuda,*[1] Hirokazu Makino, Keishiro Hara,[2] and Michinori Uwasu[2]

[1]*School/Graduate School of Engineering, Osaka University, Japan*;
[2]*Center for Environmental Innovation Design for Sustainability (CEIDS), Osaka University, Japan*
*Corresponding author: tsudakazutoshi@lce.mech.eng.osaka-u.ac.jp

1. Introduction

Ensuring regional sustainability is becoming increasingly important. In Japanese context, because hilly and mountainous areas are approximately three-quarters of the total land areas and cover the forty percent of the total cultivated areas, these areas hold the key to regional sustainability. In pursuit of regional sustainability, securing the potential of self supply for essential commodities of daily life within local communities is one of the essential conditions. In order to discuss such potential of self supply for these commodities, re-valuing local natural resources and enhancing a proper balance between supply and demand of renewable resources within a region is of critical importance.

In our previous studies [1, 2], we investigated the stocks and flows of natural resources with a focus on forestry and agriculture sectors in Shinjo village of Okayama Prefecture. We found that Shinjo village has sufficient food production while it heavily relies on energy inflow for fossil fuels. On the other hand, the village has large supply potentials for renewable materials and energy. In order to explore the potential of self supply for commodities, however, further investigation is needed to understand the balance between potential of supply and demand.

In this study, we aim to look into the potential utilization of local natural resources to understand demand levels for essential commodities of daily life and then to discuss the potential of self supply of such resources within the boundary of Shinjo village. To this end, it is significant to understand the historical transitions of energy resource use of the villagers.

2. Methods

We first conducted interviews and narrative recordings to residents in Shinjo village, from which we obtained invaluable data for assessing the potential utilization of local natural resources. We also developed inventory data of renewable energy and commodities available within the region by applying material flow analysis methodology and results from past studies. Based upon the information obtained from the inventory as well as results of stocks and flows of natural resources within the village, we demonstrated the assessment of the regional sustainability from the viewpoint of demand and supply balance for commodities as well as self reliance of economic conditions, addressing the transitions of energy use including recent introduction of renewable energy sources in the village.

3. Example results

Historical transition of energy production and utilization in Shinjo village was estimated through interviews and narrative recordings. During that field research, collecting photos taken from the 1960s onwards and interviewing with that were an effective way to reflect on that time for residents. As for biomass energy, production of wood charcoal was one of important forestry work for almost residents. However, traditional charcoal producers have decreased since the 1960s, and there are only 10 producers in the village these days. Demand of firewood for thermal energy utilization has also decreased because of electrification and dissemination of electric appliances and gas-driven equipment.

As for other renewable energy, the small scale water-power plant was introduced in 1923 by the Chugoku Electric Power Company. For household use, solar-powered hot water heater has been introduced around since the 1980s, and solar power generation system has been introduced by around 10 households recently. Meanwhile, renewable energies highly depend on the local conditions such as natural resource endowments. Thus, this paper investigated an energy balance of supply and demand of a household as a case study.

Figure 1 shows an example data of the monthly amount of electricity generated by the solar power generation system (4kW of capacity) and that consumed by one household (three-member family), and the electricity self-sufficiency ratio. The average yearly temperature in Shinjo village is 11 degrees Celsius and refrigerated air conditioning is less than necessary in summer season. Even though the heating demand is quite high during the winter season, the power generation amount is low and not sufficient to meet demand because the solar panel was covered with snow from December to March. The total yearly amount of selling and purchasing electricity is more or less the same; however the gap between supply and demand is significant. There is a need for figuring out the supply potentials more precisely and the ways to balance between supply and demand of energy utilization.

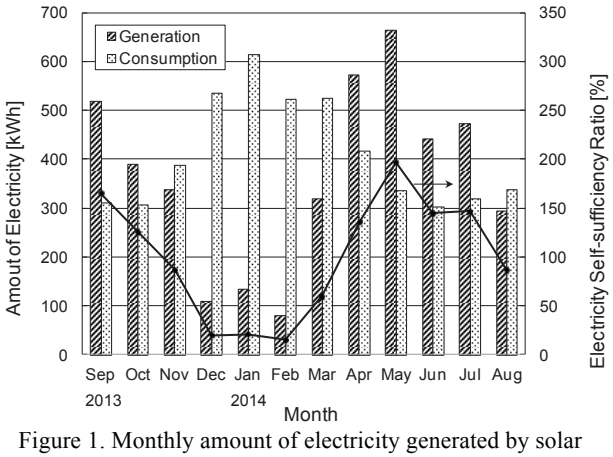


Figure 1. Monthly amount of electricity generated by solar power generation system (4kW) and that consumed by one household, and electricity self-sufficiency ratio.

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Anthropogenic Earth Movement Analysis Based on Geomorphological Change by Digital Elevation Model

Keisuke Yoshida*[1], Keijiro Okuoka[2], Kenji Sugimoto[3] and Hiroki Tanikawa[4]

[1,2,3,4] *Nagoya University, Japan, Japan*
*Corresponding author: keisuke.cf@gmail.com

1. Introduction

Material Flow Analysis (MFA) would be interaction between economy and the environment by analyzing and quantifying material use of national and regional scale. However Hidden Material Flow (HMF) do not enter the economy. It is known as displacement of environmental assets without absorption into the economic sphere, such as plant and overburden flow caused by mining, farming and construction. Generally, HMF is estimated by using statistics data, whereas the geospatial data and the amount of exact HMF is not included the estimation. In this study, amount of anthropogenic earth movement was estimated by using Geographic Information System (GIS) and Digital Elevation Model (DEM). DEM is known as height map, which represents the bare ground surface without any objects such as plants and buildings. Large scale of anthropogenic earth movement is observed as elevation change by using time series DEM. In this study, quarry in west Japan where the producing site of construction resources, such as gravel, sand and aggregate is focused on as a study area.

2. Methodology

Two types of DEM, 10m mesh and 50m mesh were used and 10m mesh was resampled into the 50m mesh. Then the raster surface model would be created. It represents the elevation change, and with surface imagery data, those two contributed to distinct and extract quarries (Fig.1).

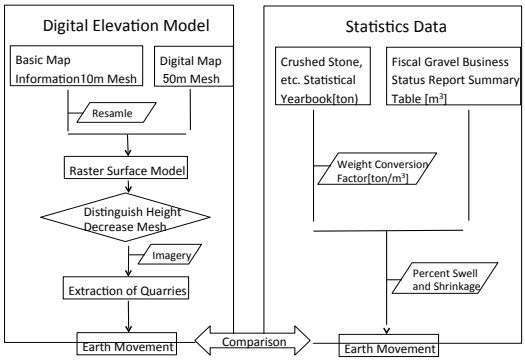


Figure 1. Research Flow

Amount of anthropogenic earth movement is estimated through the use of following equation:

$$MF(soil,sand) = \sum_i \left(V_{0,i} - V_{1,i}\right) \quad (1)$$

$MF(soil,sand)$: amount of earth movement[m^3], $V_{0,i}$: volume [m^3] (point i, at the time of 0), $V_{1,i}$: volume [m^3] (point i, at the time of 1)

3. Result and Discussion

This results show amount of anthropogenic earth movement of quarry, 1.8 billion m^3 in west Japan (Table.1). In addition to this, the number of quarry, 279 and the total quarry area, 50 million m^2 are also estimated. Each quarries are distinguished and it is spreading all over the west Japan (Fig.2). Amount of earth movement estimation is bank measure, mass of soil and rock before excavation.

Table 1. Result of the Earth movement

District	Kinki	Shikoku	Chugoku	Total
Quarry	153	37	89	279
Area [million m^2]	20.2	8.6	21.2	50
Earth Movement [million m^3]	900	275	633	1808



Figure 2. Distribution map of quarry

Basically, HMF is not quantified by statistics data, such as Crushed Stone, etc. And Statistical Yearbook and Fiscal Gravel Business Status Report Summary Table in Japan. In this study, HMF is included into the results of amount of earth movement. Therefore, the potential of HMF would be estimated by comparing DEM based estimation and statistics based calculation of amount of earth movement. For global anthropogenic earth movement quantification, high accurate and automatic estimation system should be build.

Acknowledgement

This research was supported by the Environment Research and Technology Development fund (1-1402) of the Ministry of Environment, and Grants-in-Aid for Scientific Research A(25241027) and B(26281056) of JSPS, Japan.

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A Review of Methodology for Critical Materials Evaluation

Lu-Yen Chen,*[1] Jia-Huei Huang,[1] and Mei-Chiun Chou[2]

[1] *National United University, Taiwan*; [2]*National Taiwan University, Taiwan*
*Corresponding author: lychen@nuu.edu.tw

1. Introduction

Several works were reviewed to illustrate the methodology used for assessing critical substances assessment in this study. The economic importance and the demand for clean energy of critical materials were emphasized in the report by the U.S. DOE [1]. In contrast, the impact of the supply constraints and the availability risk were chosen as assessment indicators by the National Research Council of the National Academics of the U.S.[2]. However, the economic importance the supply risk and environmental the countries risk received more attention by the European Commission [3]. The critical substances used in low-carbon energy technologies were examined by Dawkins et al. (2012) to show supply and demand of critical substances [4]. The evaluation of mineral deficiency and geopolitical impact were performed by HCSS to show the price dynamics, primary/secondary production and reserves[5]. The mining amount was surveyed with the supply and demand information to present the status as quo in global scale[6]. Hatch predicted the future economic importance of several key materials used in clean energy[7], especially emphasized on the rare earth.

2. Page layout

As summarized in figure 1, the supply risk and the potential demand were found to be the most common adopted indicators. The economic importance of critical substances should also be considered to resolve the market dynamics. As shown in Figure 1, different indicators were used in different reports based on the purpose of assessment. These indicators can be classified into two main categories considering the material supply risks and the potential demand.

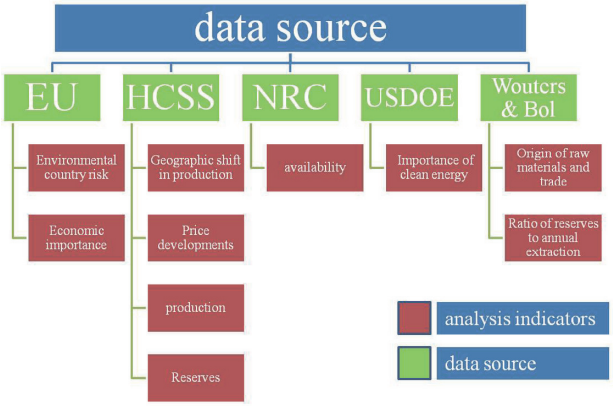


Figure 1. Indicators proposed by different works.

Further inspection of these indicators demonstrated the utilization of these factors were different in different works, as shown in Figure 2, the upgrading of recycling technologies was the most common adopted strategy, which was mentioned in at least four reports. In addition, the trade cooperation with restrictions was adopted by U.S., EU, and Netherland; the effort to find the substitute materials was considered by both EU and Sweden.

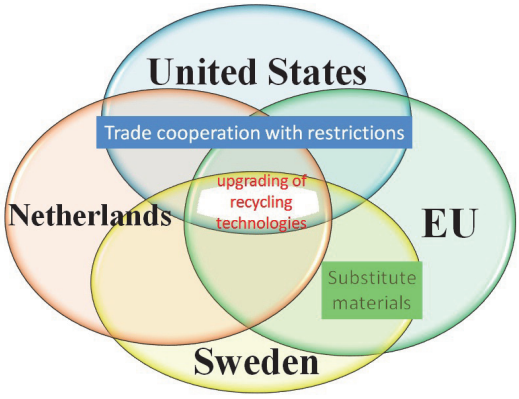


Figure 2. Policy alternatives raised by different countries and/or regions.

3. Summary

The critical substances will be the important elements with higher indicators, especially the indicators adopted by more countries. In conclusion, the supply risk and potential demand are important to indicate the critical of material scarcity, they are important for cases in different nations, different technology levels, and the capacity of recycling. In addition, the restrictions on trade and adoption of alternative substances are also good choices.

Acknowledgments

Acknowledgments may be made right before the reference section. This heading should not be numbered.

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Modeling climate effects of biogenic carbon flows from forests and wood products at the national level

Bernhard Steubing,*[1] Esther Thürig,[2] Golo Stadelmann,[2] Florian Suter[1]and Stefanie Hellweg[1]

[1]*ETH Zurich, Switzerland*
[2]*Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland*
*Corresponding author: steubing@ifu.baug.ethz.ch

1. Introduction

Most LCA studies have in the past assumed biomass from sustainably managed production systems to be carbon neutral and therefore climate neutral. More recent research has shown that next to carbon stock changes, it is essential to account for the timing of emissions in order to assess the effects on climate change. Cherubini et al. [1] introduced GWPbio factors that reflect the global warming impact of biomass relative to that of fossil carbon emissions depending on a given rotation period and time horizon. Their subsequent work extends this to include other factors, such as carbon stock changes and temporary carbon storage.

Within the research project "Ecological use of wood resources in Switzerland" we assess the optimal uses of wood among a multitude of applications, ranging from direct energy to cascade uses. We tried to directly implement the method of Cherubini et al., however, we encountered some challenges.

The first one relates to data for the calculation of the GWPbio: while Cherubini and colleagues calculate GWPbio values generally at the stand level, for which the forest growth, rotation period, carbon stock changes, and subsequent temporary carbon storage duration can be more readily described, our scope was a nation-wide assessment of wood product flows from forests with high spatial variability.

The second challenge relates to calculating the GWPbio in the case of temporary carbon storage. Due to cascade use and mixing of wood sources in between each use (e.g. if waste wood is collected from several sources, mixed, and then reused for several products) it is impossible to keep track of the storage time of biogenic carbon relating to a specific harvest site, which would be needed for a proper calculation (see [2]).

The methodology section describes how these challenges were met. We then use a simplified model of the Swiss wood use to calculate the climate impacts including biogenic carbon.

2. Methodology

In order to work with Swiss-specific GWPbio factors at the landscape level, i.e. for a larger area or the total national forest area, average growth curves and rotation periods were needed. These were empirically derived based on Swiss National Forest Inventory data for different forest types and elevations. GWPbio factors were subsequently calculated from this data and applied to biogenic carbon emissions (e.g. from combustion/disposal of wood products).

To solve the problem of tracking carbon stored in wood products, we calculated an annual storage benefit (a reduction of the GWPbio) and used this value in our model. Since the per year storage benefit is originally a non-linear function of time [2], we had to first linearize this function. This does lead to an underestimation of the GWPbio for short storage times, which is, however, rather small, especially if long time horizons are considered (e.g. 500 years). The advantage is, however, that it is sufficient to know the lifetimes of different wood products instead of having to track forest carbon throughout its entire lifecycle of possibly different products. This allows a model to contain "mixing" processes with several inputs and outputs. It also enables the modeler to select the lifetime of wood products as a decision variable in an optimization model.

The modified approach of Cherubini was then used in a simplified model of the Swiss wood use. Differences with regards to a theoretical optimal wood use are also analyzed.

3. Preliminary results

GWPbio factors depend to a great extent on the following key factors (see also Table 1):

- Tree species
- Altitudinal vegetation zone
- Rotation period length
- Choice of time horizon (TH)

Table 1. GWPbio values as a function of different parameters

Forest type	Altitudinal vegetation zone	Rotation period (years)	GWPbio TH=100	GWPbio TH=500
Theoretical;Cherubini 2011		100	0.42	0.07
Coniferous	Submontane	120	0.53	0.08
Deciduous	Submontane	140	0.66	0.11
Coniferous	Montane	160	0.64	0.11
Deciduous	Montane	140	0.66	0.11
Coniferous	Subalpine	180	0.73	0.14

The reason why all Swiss GWPbio values are higher than the theoretical values calculated in [1] is to a large extent due to more realistic growth curves and longer rotation periods.

The annualization procedure for the temporary carbon storage was successfully implemented in a model of the Swiss national wood use.

Considering biogenic carbon exchanges with the atmosphere due to the timing of the release and removal of carbon from the atmosphere leads to considerably higher climate change impacts than if this was ignored. Considering temporary carbon storage in wood products leads, naturally, to a decrease in climate impacts. However, the temporary carbon storage was not enough to offset the climate effect of the additional temporary carbon in the atmosphere from wood incineration, at least in the context of our model.

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Material flow analysis of Swiss waste management

Melanie Haupt,*[1] Carl Vadenbo,[1] Bernhard Steubing,[1] and Stefanie Hellweg[1]

[1]*ETH Zurich, Switzerland*
*Corresponding author: haupt@ifu.baug.ethz.ch

1. Introduction

Closing material cycles can help to mitigate many of the adverse effects associated with the ever-increasing demand for materials. To map the present material recovery potential of solid waste in Switzerland, a national material flow analysis (MFA) of waste streams originating in households and from commercial sources, as well as in construction and demolition (C&D) was performed. The work presented here is part of a larger project on the Swiss municipal solid waste (MSW) management, based on MFA, life cycle assessment and optimization. The project includes all waste streams with detailed studies of some recycling fractions and recovered materials. The recovery of secondary resources from MSW incineration (MSWI) is also considered as it has been shown that there is still a considerable improvement potential for metal recovery from MSWI bottom ash [2].

2. Method

MFA was used to analyze the material turnover of the Swiss waste management for the year 2012, including all waste streams occurring in Switzerland. In addition to thermal treatments, paper, cardboard, PET bottles, glass, tinplate and aluminum recycling were analyzed. The residues from MSWI were also included. Data for material recycling was found in national statistics from the Federal Office for Environment and gathered in collaboration with recycling associations and companies. As the consistency of the data available varied significantly between waste streams, data reconciliation was performed together with the respective industries.

3. Results

In total, 70% of all occurring waste was sent to recycling, including 2 million tons from households and 13 million tons of C&D waste (Figure 1). 4% of all wastes were treated in biological processes, and 22% were thermally treated and energetically utilized in industrial furnaces, cement production, and MSWI. The remaining 5% were exported for either material or energy recovery. The MFA showed a significant share of separately collected fractions from households to be exported. 40% of collected paper, 100% of separately collected aluminum and 52% of cullet's were exported (see Figure 2).

Although recycling networks are well-established in Switzerland, a significant amount of reusable material ends up in MSWI. While only 13,000 tons of tinplate were collected from households, 19,000 tons of ferrous scrap are found in MSW. 48,000 tons of ferrous scrap were recovered from MSWI bottom ash (also including scrap from industrial and directly delivered waste for incineration).

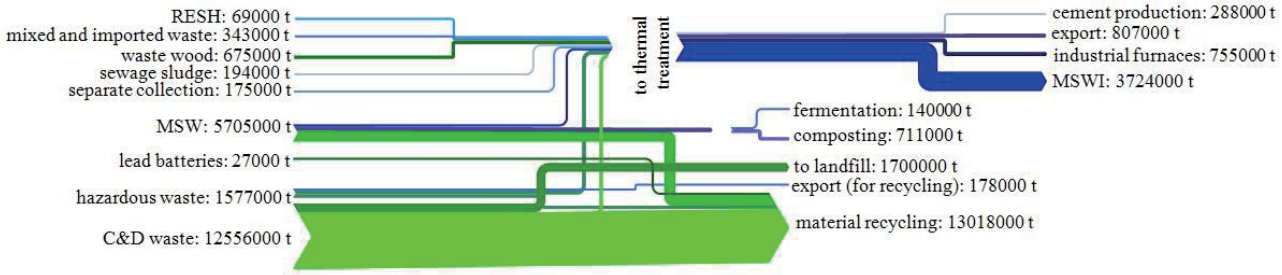


Figure 1. MFA of the primary treatment routes of the Swiss waste management system 2012, based on [1].

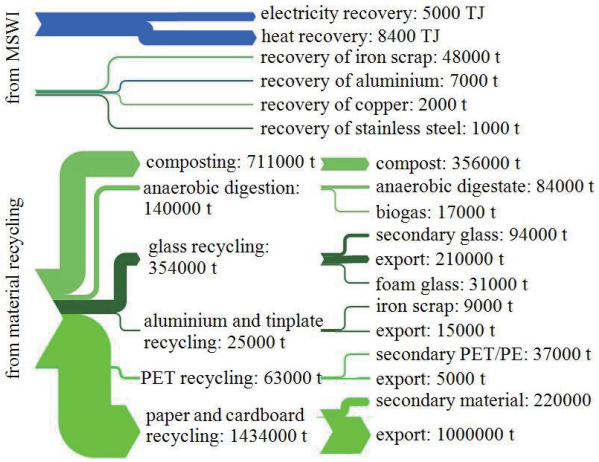


Figure 2. Recycling and recovery from Swiss MSW in 2012. Fractions marked as *export* are recovered and recycled outside of Switzerland. Residues from recycling processes going to MSWI are not shown.

4. Discussion

The MFA highlighted important decision nodes with implications for further treatment and use of secondary materials. The point of separation is, for example, decisive for the quality of the recovered product and, therefore, its reusability. The MFA results do not, however, offer any insights to the environmental relevance of the mass flows, but will in a subsequent step serve as the basis to assess the related environmental impact. Designing sound material cycles is of great importance and environmental impacts should be compared using a life cycle perspective: Indicators like energy demand, climate change, toxicity, and resource depletion should be analyzed. Guidance for policymaking and for optimal waste management should only be provided after obtaining a holistic view of the relevant environmental impacts and may benefit greatly from the application of optimization techniques.

Acknowledgments

The authors would like to thank Rytec AG and econcept AG for their support in data collection.

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Metrics for Performance Measurement of Advanced Repair-To-Order, Disassembly-To-Order and Refurbishment-To-Order

Ammar Y. Alqahtani,*[1] Surendra M. Gupta,[2] Kenichi Nakashima[3]

[1]*King Abdulaziz University, Saudi Arabia;* [2]*Northeastern University, USA;* [3]*Kanagawa University, Japan*
*Corresponding author: aaylqahtani@kau.edu.sa

1. Introduction

This paper presents an Advanced Repair-To-Order, Disassembly-To-Order and Refurbishment-To-Order (ARTODTORTO) model with disassembly precedence relationships among components of an air conditioner (AC). It also inspects and analyzes the impact of using smart sensors in End-of-Life products (EOLPs) on system performance. Various experimental design studies are run based on orthogonal arrays (OAs). The customers' demands may be satisfied either by purchasing new components, reassembling components from the returned used products, refurbishing product, or remanufacturing used products based on customer's remaining life needs. Discrete event simulation models are used to calculate various performance measures under different experimental conditions.

2. Literature review

ARTODTORTO system built in this study is based on disassembly-to-order research. Ondemir and Gupta (2013) proposed a multi-criteria decision making model for advanced repair-to-order and disassembly-to-order system with products that are embedded with sensors and radio frequency identification (RFID) tags. In a comprehensive study incorporating quantitative evaluation of sensor embedded products (SEPs) on the performance of a disassembly line (Ilgin and Gupta in 2010), it was showed that smart SEPs are better in handling remanufacturing uncertainties.

3. Objective of the study

The objectives of this study include examining and determining the influence of SEPs and RFID tags on various performance measures (viz., disassembly cost, disposal cost, backorder cost, holding cost, testing cost, transportation cost, total cost, total revenue, and profit) and determining how to process EOLPs to meet product, component and material recovery demands of ACs. Specifically, there are four objectives for the ARTODTORTO system to optimize viz., minimize the total cost, minimize the number of disposed items, maximize the material sales revenue, and maximize the customer's satisfaction level by meeting the demand.

4. System Description

ARTODTORTO system considered in this study is shown in figure 1. Based on the arriving EOLP's condition, it will go through a series of recovery operations. ARTODTORTO system not only considers EOLPs disassembly, it also refurbishes and repairs the EOLPs. Refurbishing and Repair processes may require reusable components to meet the demand of the product. Nine components of AC are considered viz., evaporator, control box, blower, air guide, motor, condenser, fan, protector, and compressor precedence relationships. Exponential distributions are used to determine disassembly times at each station, interarrival times of each component's demand, and interarrival time of EOLPs. Two different types of disassembly operations are performed, viz., destructive and nondestructive depending on the component's condition. ARTODTORTO model assumes that the demands and life cycle information are known. It is also assumed that retrieval of information costs less than inspection and testing.

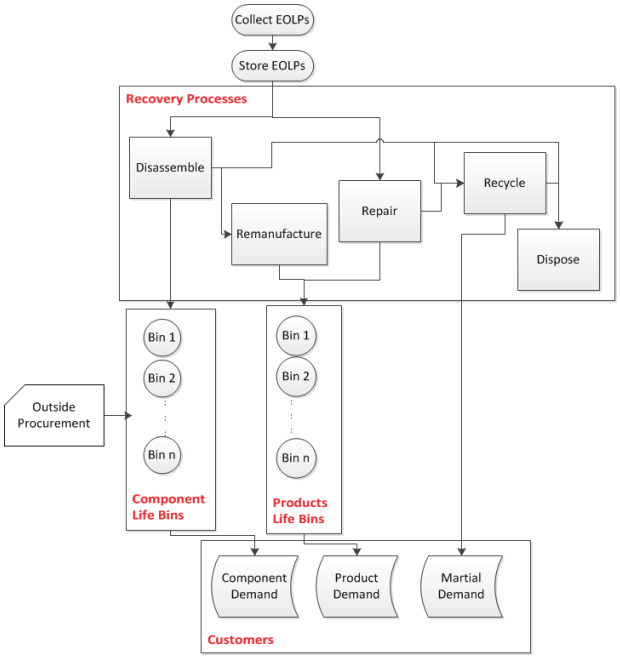


Figure 1: ARTODTO system material Flow

Recovered product, components and materials are characterized based on their remaining life times and are placed in different life-bins (e.g. 1 year, 2 years, etc.) waiting to be retrieved via a customer demand.

5. Methodology

A simulation model was built to represent the full recovery system and observe its behavior under different experimental conditions. Arena version 14.5 was used to build the discrete-event simulation models. A full-factorial design with 69 factors at 3 levels each would require an extensive number of experiments. To reduce the number of experiments to a practical level, a smaller set of all the possible experiments (139) was picked using orthogonal arrays designed by Taguchi.

6. Results

Metrics for performance measurement of ARTODTORTO for the 139 experiments was collected. Table 1 shows a sample of the performance measures.

Table 1: Performance measures of the ARTODTO system

Experiment #	Total Revenue	Total Cost	Profit
1	$1,452,500	$1,113,805	$338,694
:	:	:	:
139	$1,400,444	$944,146	$456,298
Average	$1,278,555	$1,006,844	$271,711

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An Estimation of Ship Waste Quantities at Port: A Case Study in Haiphong, Vietnam

To Ngoc Thang, Takaaki Kato

Graduate School of Environment Engineering, The University of Kitakyushu, 808-0135, Japan

1. Introduction

Marine transportation affects to environment in number of ways including emission, oil spills risk, sewage and garbage from ship. Among them, garbage including domestic and maintenance waste from ship are significant sources of marine pollution. To prevent marine environment from pollution, the Annex V of the International Convention for the Prevention of Pollution from ship (MARPOL) has been released. It requests the responsibility of Port Authorities and Ship Operators for making garbage management plans, which are necessary to control and monitor procedures for storing and disposing of garbage. To make garbage management plan, quantities of ship-generated garbage is essential data. Currently, a few studies to calculate ship-garbage was conducted in Mediterranean Sea (REMPEC, Activity A, 2003) and Serbia (Vladanka et al., 2011). However, these studies contain limitation because of ignoring influence factors on calculation processes, for instance, garbage generation during voyage and maintenance waste on ship.

My research shows an advanced study method that has considered almost influence factor on calculation process. The research uses Haiphong port – one of the biggest port of Vietnam as case study, where they do not have specialized research on calculating the quantities of garbage from ship. Quantitative estimate was carried out to determine amount of garbage that has been generated from ships at 03 terminals of Haiphong port from 2009 to 2013.

2. Methodology

In the first stage, calculation formula for quantity of ship-generated waste was established. Then, input data including the number of vessel docking, type of ships, number of crewmember and generating rate of daily garbage were defined. Because main types of docking ships in Haiphong port are bulk ships and container ships, we did the survey with 150 container ships and 150 bulk ships to gather the average number of crew per ship and average time in voyage. Number of ships and time spent in port of every ship during 2009-2013 period were collected from Port Operation. Garbage generating rate from ship is based on the guideline of International standard, ISO 21070 (Handling of ship generated garbage). There are 03 scenarios (low, medium, high) of domestic waste while one ship generates approximately 11 kg for maintenance waste per day.

3. Results and Discussion

3.1. Difference between data of bulk ships and container ships

Two main types of ship in Haiphong port have specified characteristic that require calculating quantity of garbage separately. From 2009 to 2013, while bulk ships docked mainly at HoangDieu terminal, container ships were trending to dock at Chuave and Tancang terminals.

Table 1. Distinguish between bulk ship and container ship

	Average member	Time in voyage *(days)*	Time spent in port *(days)*
Bulk ships	16.18	6.44	3.08
Container ships	23.04	3.03	1.09

Table 1 provides the difference on input parameters between bulk ships and container ships. We observe that both "time in voyage" and "time spent in port" of bulk ships were almost twice to three times longer than those of container ships. That also explains one reason why there were more crewmember of container ships than bulk ships.

3.2. Quantity of ship waste in medium scenario

From 2009 to 2013, although HoangDieu terminal had the biggest volume of garbage from ship, its number was decreasing because of the decline of docking vessels. The same trend was observed in Chuave terminal whereas it recorded the upward trend in the number of garbage in Tancang terminal. In total, the highest quantity of garbage was 1072.6 tons during the year 2010 before decreasing to 803.7 tons in 2013. (Figure 1)

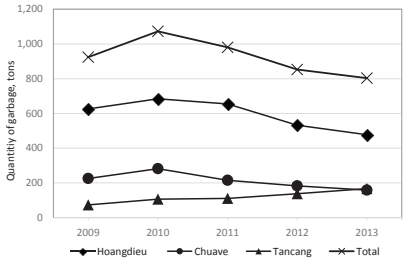


Figure 1. Quantity of garbage in medium scenario

3.3. Assessment of collected rate by port reception

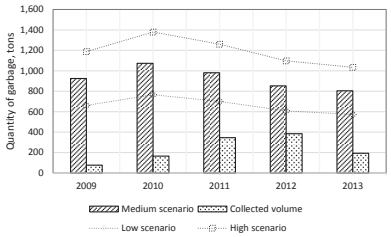


Figure 2. Quantity of generated collected garbage

Based on the data from a collecting company collecting ship garbage from 2009 to 2013, volume of collected garbage from ship in Haiphong port are shown in Figure 2. Compared with medium scenario, garbage collected rate at the port was fluctuated between 10% and 45% of total generated volume. This percentage is obviously lower than collected rate in urban area of Haiphong (more than 80%).

4. Conclusion

This study has provided quantity estimation for ship waste in Haiphong port. The garbage quantity data is need for establishing waste management plan at port as well as on ship. Even the total amount of garbage in Haiphong port was decreasing from 2009 to 2013, the collected rate of garbage by port reception facilities was still low. Therefore, Haiphong's port authority should improve reception facilities of garbage and encourage ships to bring back garbage to shore, which help to reduce illegal dumping garbage into sea.

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Optimal Improvement of Waste Plastics Recycling System in Tianjin Based on Environmental Evaluation and GIS

Richao Cong,*[1] Toru Matsumoto,[1] Takamasa Hayashi,[2] Wenchao Li[3]

[1]*The University of Kitakyushu, Japan*; [2]*NTT DATA, Japan;* [3]*Nankai University, China*

*u3dac404@eng.kitakyushu-u.ac.jp

1. Introduction

Zi'ya Circular Economy Industrial Park, a waste home appliance dismantling base, was recently established in Tianjin to handle domestic and imported waste. However, it was said more than half of the waste plastics (WPs) was transported outside of Tianjin after treatment [1]. To solve the problems arising from the current recycling system, we have suggested Tianjin set up a WP recycling factory in Zi'ya Industrial Park that uses recycling technology from Japan and improve the current collection and processing system.

2. Methodology

Based on an investigation we conducted in August 2011, we estimated the amount of WPs generated from households to be 35,760 t per year.

In our study, GIS technology was used to determine the optimal locations for WP recovery stations and intermediate disposal plants, as well as to simulate the recovery transportation process and calculate transportation distances. The resolution processes are shown in Figure 1[2]. The CO2 emissions reduction was obtained from comparison between the proposed case and present case. Finally, a life cycle analysis (LCA) was conducted for a projected scenario and a baseline scenario [3-4].

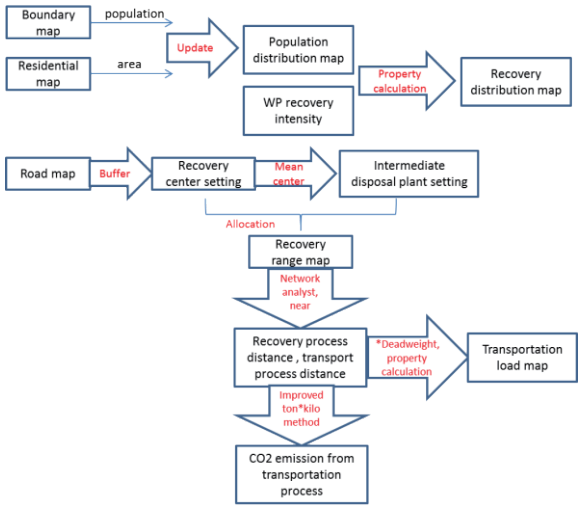


Figure 1. Schematic flow of the GIS analysis

3. Conclusions

The CO2 emissions reduction between the proposed case (90% loading rate) and the present case (50% loading rate) is about 3,977 t per year, or about 46% of present emissions. As shown in Figure 2, the reduction in CO2 emissions in the projected scenario was 111,621 t per year as compared to the baseline scenario.

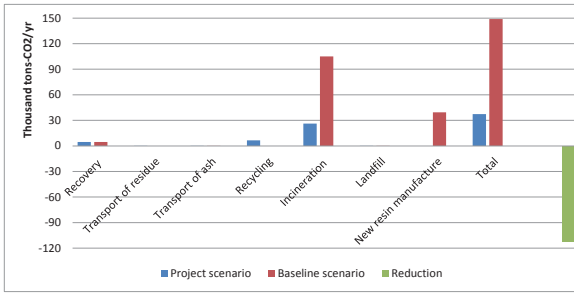


Figure 2, The result of LCA

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Life Cycle Assessment of Reuse System for Surgical Gowns

Naoki Yoshikawa,*[1] Nobumitsu Kitanishi,[1,2] Koji Amano,[1] and Koji Shimada[1]

[1]*Ritsumeikan University, Japan;* [2]*Takasago Thermal Engineering Co., Ltd., Japan*
*Corresponding author: n-yoshik@fc.ritsumei.ac.jp

1. Introduction

An important role of surgical gowns is preventing the medical staffs and patients from infection. Suppliers must ensure that standards of sterilization and liquid barrier performance meet this function. Disposable products have a large share of the surgical gown market in Japan. However, reusable products and systems recently developed by some companies, which have same level of the function, seem to be able to reduce medical waste and the consumption of fossil resources because both products are made from chemical fibers. However, no existing study evaluates the life cycle environmental load of surgical linen reuse systems, including commercial laundries. This study evaluates the life cycle environmental load of reusable surgical gowns as compared to disposable gowns. We also surveyed the interest of medical institutions in introducing reuse systems and estimated the potential reduction of greenhouse gases (GHG) emissions.

2. Methodology

This study evaluated two types of surgical gown, disposable and reusable. Details of the gowns are shown in Table 1. Both gowns have roughly the same level of liquid barrier performance. Figure 1 illustrates the system boundaries of the two products. The life cycle stages of the reusable products consist of raw material procurement, manufacturing, delivery, maintenance, and waste management (disposal). The disposable product stages are raw material procurement, manufacturing, delivery and waste management (disposal). The average number of uses of reusable products in a life cycle is assumed to be 50 times. After using the reusable gowns 50 tim es and the disposable gowns once, both types of gowns are incinerated. Foreground data of reusable products was obtained from a questionnaire presented to manufacturers of gowns and service providers and deliverers of laundry. Data related to disposable products in raw material procurement and manufacturing processes is based on Ponder [1] and METI [2].

Table 1. Detail of products compared

	Reusable	Disposable
Material	Polyester (100%)	Polypropylene (100%)
Liquid barrier performance	Level 3 or 2 (AAMI Standard)	Level 3 (AAMI Standard)
Usage (time)	50	1
Weight	0.460kg	0.115kg
Sterilization	Autoclaving	EOG

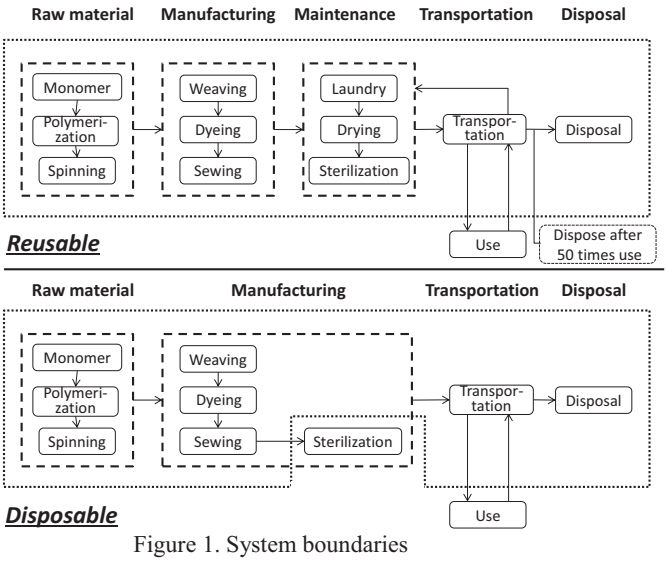


Figure 1. System boundaries

The potential of GHG emission reduction was based on a questionnaire to medical institutions. Questionnaires were sent to 994 facilities, of which 9.2% responded. The survey asked about their awareness of reuse systems and the conditions they would need to have met to change to such systems.

3. Results

Figure 2 shows the life cycle GHG emissions of the reusable and disposable products per use. Most GHG emissions come from the washing, drying, and sterilizing processes for the reusable products. Manufacturing and waste management (incineration) processes are the main factors in GHG emissions for the disposable products. Results showed that the reuse systems can reduce life cycle GHG emissions (0.38kg-CO_2eq/use) by 35% in case of 50-times use. GHG emissions start to diminish after 14-times use, which is lower than expected.

The results of the questionnaire to medical institutions showed that about 11% of gowns used are supplied by a reuse system. Additionally, 11% of medical institutions are considering introducing reuse systems, if the liquid barrier performance and cost of the system meet their demands. This way, about 500t-CO_2eq of GHG can be reduced per year.

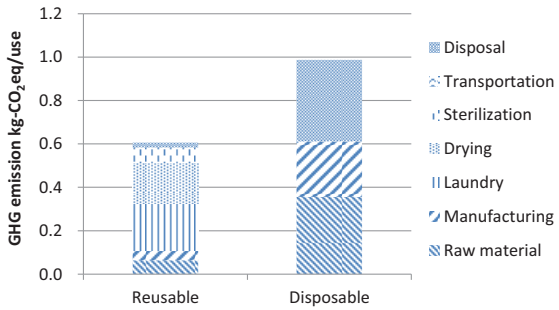


Figure 2. Comparison of GHG emissions from reusable and disposable products

6. Conclusion

This study compared life cycle environmental loads of reusable and disposable surgical gowns. Results showed that after 50-times use, reusable products reduce GHG emission from disposable products by 35%. Comprehensive assessment covering other medical supplies is needed to support decision making for sustainable procurement by medical institutions.

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Analysis of Contamination of Impurities in Steel Recycling

Chihiro Murayama [1], Ichiro Daigo [*1] and Yoshikazu Goto [1]

[1] *Graduate School of Engineering, The University of Tokyo, Japan*
*Corresponding author: daigo@material.t.u-tokyo.ac.jp

1. Introduction

When steel scrap is recovered from end-of-life products, components containing Cu and Sn are mixed into the scrap. The elements; Cu and Sn, cannot be extracted in EAFs (electric arc furnaces), which are regarded as tramp elements. The contents of the tramp elements may become higher due to repeated recycling. High contents of the tramp elements cause surface cracks in the hot strip being manufactured, known as surface hot shortness. Therefore, it is preferable to mechanically remove the components containing the tramp elements from steel scrap before melting in EAFs.

Although there are problems in the contamination of tramp elements, there is very few information about contents of tramp elements in steel scrap. One of the reasons is difficulty of observing and quantifying the tramp elements in steel scrap[1]. Another reason is that many steelmakers do not seriously think about the problems because contents of tramp elements in currently produced steel can be diluted by using high purity scraps, DRI (direct reduction iron) and/or pig iron[2]. In this study, we aim to understand the behavior of tramp elements in a steel recycling system with modeling the relation between the tramp elements contents in recycled steel and contents of unintentionally mixed components containing tramp elements in steel scrap.

2. Development of a steel recycling model

We developed quite a simple model to observe the behavior of tramp elements in a repeated steel recycling system. In our model, we suppose that steel is repeatedly recycled in one and only one furnace and that there is no trade with outside of the recycling system. Figure 1 shows a schematic illustration of the supposed recycling system at the nth time recycling.

Portions of inputs in the furnace; old scrap, a tramp element contained in mixed components, processing scrap and pig iron, are set to x, y, z and w, respectively, as shown in figure 1. The balance of tramp elements in raw materials and steel products at nth time recycling can be formulated by a recursion formula expressed as equation 1.

$$C_n = xC_{n-1} + y + zC_n \quad (1)$$

where C is a content of tramp elements in materials and n is the number of recycling times in the system.

Consequently, solving the recursion formula, the content of tramp element in the steel product after recycling any number of times can be expressed as equation 2.

$$C_n = \left(\frac{x}{1-z}\right)^n \left(C_0 - \frac{y}{1-x-z}\right) + \frac{y}{1-x-z} \quad (2)$$

3. Results and Discussions

On the basis of the developed mode, Monte-Carlo simulation was employed to estimate distributions of the tramp elements content in recycled steel during repeated recycling by giving random values obeying standard distributions to x and y in the equation 2.

In a case of relatively large y, a symmetrical distribution like standard distribution was shown, as shown in figure 2(a). On the other hand, in a case of relatively small y, an unsymmetrical distribution spreading for high content direction was shown, as shown in figure 2 (b). We compared the shapes of distribution with the distributions of tramp elements contents in EAF steel bars observed in Japan[3]. The shapes of distributions for Cu and Ni contents were symmetrical, and for Sn content was unsymmetrical, as shown in figures 3 (a) to (c). According to our model, Cu and Ni contents are influenced by mixing components despite Sn content is not likely influenced by them. Thus, behavior of contaminating tramp elements could be estimated from the shapes of distribution of impurity content by using our developed model.

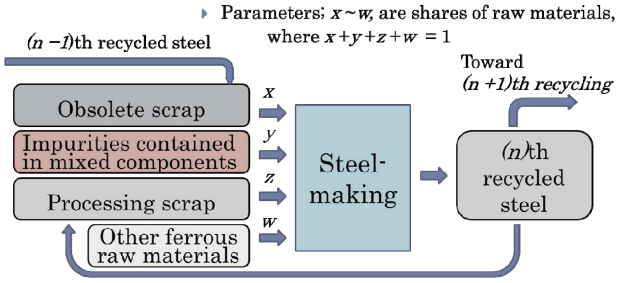


Figure 1. Schematic illustration of the supposed recycling system at the nth recycling.

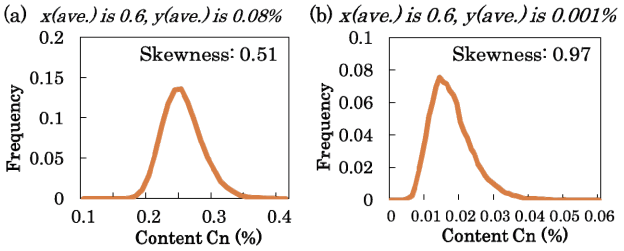


Figure 2. Distributions of impurity contents in cases of relatively large y (a) and small y (b), estimated by Monte-Carlo simulation.

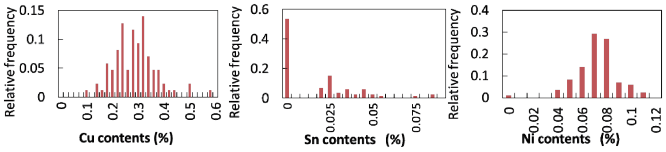


Figure 3. Distributions of Cu (a), Ni (b), and Sn (c) contents in steel bars in Japan.

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Matching Reused Products with Users Considering Their Satisfaction

Yuki Yamamori*[1], Keisuke Nanjo, and Hiroyuki Hiraoka

[1]*Chuo University, Japan*
*Corresponding author: yamamori@lcps.chuo-u.ac.jp

1. Introduction

In order to change the consumption society to the recycling society, we focus on promotion of reuse of parts and machines. We are developing a part agent system for management of individual parts that is required for an effective reuse [1]. A part agent is a network agent applied to each part. A part agent follows its corresponding part through the network and manages the information on state of the part as well as place and situation where it is used. The agent advises the user of the part on its reuse based on the information on other parts obtained from other agents.

In this paper, a function of part agent is described that matches a seller, i.e., a user who has a reused product, and a buyer, i.e., a user who wants to use it. Further, a new function is proposed based on the discussion of the scheme.

2. A Scheme that matches reused products with users considering their satisfaction

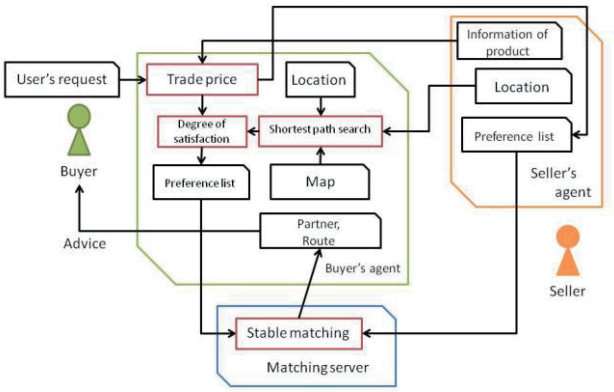


Fig. 2 Concept of the reuse of products using matching function based on user's satisfaction

We focus on reuse of used home electric appliances among neighboring homes. A part agent advises the user on replacement of its product when the product deteriorates. The part agent proposes to the user a used product that a seller possesses by the following procedure.

A part agent collects information on the same kind of products that are on sale by sellers as candidates to be purchased. The agent evaluates every candidate products using an index of degree of satisfaction described later. Each agent transmits the evaluated results to a matching-server as a preference list of its user. The matching-server matches a buyer and a seller based on this preference list using Gale-Shapley method [2] and notifies every matched users via their agents. Thereby, a buyer can purchase a used product from an appropriate seller.

Degree of satisfaction: A buyer's agent calculates he degree of satisfaction using a formula (1) on a home appliance owned by a seller. It is assumed that a buyer's satisfaction is determined by the following four elements; 1) the distance to the seller, 2) the difference between the price of candidate product and the price the buyer wishes (shown as X in the formula), 3) the difference between the specification of candidate product and the specification the buyer wishes (shown as Y), and 4) residual life of candidate product.

$$Degree\ of\ satisfaction \equiv \frac{1}{a_1 X + a_2 Y + a_3 (Distance\ to\ seller)} + a_4 (Product's\ residual\ life) \quad (1)$$

$$X \equiv \frac{|\ Price\ of\ product - Buyer's\ desirable\ price|}{Buyer's\ desirable\ price}$$

$$Y \equiv \frac{|Specification\ of\ product - Buyer's\ desirable\ specification|}{Buyer's\ desirable\ specification}$$

3. Simulation of the proposed scheme based on user's satisfaction

We performed a simulation on the reuse of refrigerators based on this scheme [3]. In the simulation, each user has a refrigerator and resides at an intersection of roads composing a grid pattern. The result reveals a positive effect when the matching is made with the proposed method and when the distance is considered in calculating the degree of satisfaction.

4. Discussion: multiple groups for the reuse

One of the problems of the proposed method is that a single matching server is assumed for all the users, which requires enormous capacity of the server and may cause a matching of users with low satisfaction in, for example, distance. Instead, it would be practical to divide users in multiple groups, for each of which a matching server is provided. For this purpose, we consider a new function is required for part agent that enables part agents to create an appropriate group by themselves and any part agent to take the role of matching server.

Taking the distance as an example, we are developing a method for part agents to create multiple groups autonomously. If we assume that distances among agents in a group must be less than a predefined value, a part agent decides by itself whether it joins a neighboring existing group based on the maximum distance.

5. Conclusion

We developed a function of the part agent who chooses a reuse partner in consideration of the user's satisfaction. Problem of the method with a single matching server is discussed and a new method with multiple groups of agents is proposed. We will validate the proposed method by conducting further experiments.

Other remaining issues include revision of the formula representing user's satisfaction and selection of matching algorithm.

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Review of Excessive Packaging Restriction Implementation in Taiwan

Chih-Ku Chen,*[1] Chin-Wei Tang,[1] Ying-Hsuan Lin[1] and Yen-Lin Chen[1]

[1]*Sustainable Environmental Technology and Management, Taiwan*
*Corresponding author: ckchen@sustainable.com.tw

1.Abstract

To reduce the packaging material consumption and the environmental impact of packaging waste at source, Excessive Packaging Restriction (EPR) has been enforced by the Taiwan Environmental Protection Administration (TEPA) since 2006 in Taiwan. Aimed on excessive gift box packaging, the EPR restricts the packaging volume and packaging layer of 5 designated products by numerical standards. The analyzed result of EPR implementation shows that 26% gift box packaging material consumption is eliminated. Moreover, the industry voluntary packaging reduction champion is triggered that unlocks the innovations for more integrative environmental management on product packaging via green packaging design in Taiwan.

2.Introduction

After deposit-and-refund recycling scheme on post-consuming container was established in 1999, effective reduction on packaging gift box was highly concerned and promoted. Several product packaging surveys and public polls were conducted. 60.9% of the public felt that excessive product packaging was severe which may be the reason why 77.5% of people were unwilling to pay more for excessive packaging product. Designated products were selected to reduce gift box packaging at source by restriction. Extensive enforcement scope, audit procedure, examination mechanism and implementation framework was achieved. Legal promulgation roadshow, green design seminar and green packaging contest were organized to encourage more business recognition and participation during 2004-2008.

3.Excessive Packaging Restriction Design

Gift box packaging of 5 products (pastry, cosmetic, alcoholic, processed food and computer software disk) are designated to restrict in prior.

Packaging Volume Ratio (PVR), the calculation as shown in equation 1 (eq.1), and the number of packaging layer of designated product packaging are regulated. The standard is harmonized and localized from related international standards. Reporting on World Trade Organization (WTO) is proceeded to avoid possible Non-Technical Barrier on Trade (TBT). The standard content is shown in Figure 1.

$$\text{Packaging Volume Ration(PVR)} = \frac{Volume\ of\ Packaging(VP)}{Allowable\ Volume\ of\ Packaging(AVP)} \quad \text{.....Eq.1}$$

$$\text{A. V. P.} = \sum volume\ of\ unit\ product\ (VuP) \times Coef.\ of\ Necessary\ space \quad \text{.....Eq.2}$$

VP= the volume of the minimum cuboid that circumscribes the product
VuP= the Volume of the minimum cuboid that circumscribes the unit product

Gift Box or Multiple Gift Box	
Packaging Volume Ratio	Under 1.0
Number of Packaging Layer	cake and pastry: ≧ 3 cosmetics, alcoholic products, processed foods: ≧ 2
Multiple Gift Box	Each gift box in a multiple gift box shall conform to its limits to its limits of space volume ratio of packaging and number of packaging layers
Disk of Computer Program Work	
Packaging Volume Ratio	Under 1.0
Number of Packaging Layer	≧ 3



Figure 1:EPR regulation contents

The designated industry includes the manufacturer, importer and seller of designated products. However, product designed for export, packaging for insulation or transportation purpose, such as carrying bag, logistic cartons and packaging requested by consumers are exempted from EPR.

4.Implementation and Results

A serial communication to designated industries and design association member were taken before EPR announcement and enforcement. Necessary assistance was deployed to support packaging redesign.

Training program on local municipalities' auditors was held for proper auditing.

Promotions like (1) international management information, (2)green packaging contest, (3)green packaging assessment procedure, handbook and tool were developed (Figure 2), (4) sharing case studies, (5) encourage industry's participation and (6) green packaging workshop were proceeded.

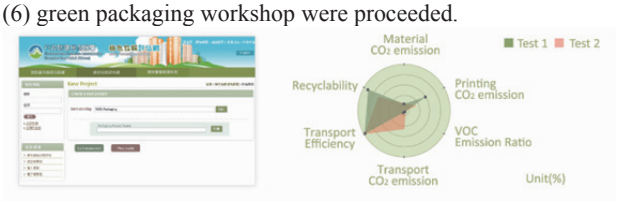


Figure 2. Green packaging assessment

It was estimated that 6,900 tons of packaging material could be reduced per year, a reduction rate of 26% was estimated.

To empower EPR implementation, the Department of Environmental Protection of Taipei City Government (TDEP) organized Packaging Reduction Declaration agreement with major retailers in 2006. It was required the product vendors not to supply excessive packaging product. Total 6,893 retailer stores were inspired to join the agreement.

Since 2010, TEPA actively encourages computer notebook and LCD panel manufacturers to sign voluntary packaging reduction agreement (VPRA) with TEPA. An accumulated 8,600 tons packaging material consumption elimination is achieve, as shown in Figure 3. The sources reduction from VPRA is not focused on weight reduction, but also through the use of eco-friendly printing and light weighting.



Figure3. the voluntary packaging reduction results

5.Conclusions and Recommendations

The experience of promoting EPR regulation in Taiwan showed that restricting excessive packaging was feasible through careful design and planning, and developing programs that would give support and flexibility for enterprises to comply with the law and gradually shifting to management conformity with its supply chain members. The EPR implementation during these past few years set the foundation to the adoption of green package concept, in the coming years, voluntary agreement could be further enhanced as an incentive for the enterprises to expand collaboration.

International Interdependencies Analysis using Detailed Asian International Input-Output Table

Hiroshi Yamaguchi*, Norihiro Itsubo
Tokyo City University, Japan;
*Corresponding author: hirosy@tcu.ac.jp

1. Introduction

Recently, Asian countries are developing rapidly in very tight connections with each other. Therefore to perform the material flow cost accounting in Asia, it is most important visualizing the environmental loads for Asian supply chains and products. To estimate the environmental emissions and resource consumption, inventory databases are necessary to be developed for GHGs, air pollutant substances and water of Asian countries by using IO (Input Output) method applicable for comprehensive and quick estimation of environmental loads.

2. Purpose

Using Asian International Input-Output Table (AIIO) with 76 sectors for each country[1] GHG database has been developed and used for the interdependence analysis of products in Asia.[3] Because of rather rough classification of 76 sectors, the results can be used mainly for screening analysis. To make a precise analysis, detailed GHG database are necessary. Thus detailed AIIO using each country's Input-Output Table (IOT) are under development[4,5].

3. Method

Firstly, detailed AIIO for Japan is developed. Classification of Japan is divided into 405 sectors from 76 sectors of AIIO using IOT of Japan[2] by each sectional production amount of money, while other countries stay with 76 sections.

Inputs from Japan into other countries and outputs from other countries into Japan are divided using Japanese trade statistics[7].

Number of Sectors			405	76	76						
			I Endogenous Sectors.	J Endogenous Sectors.	K Endogenous Sectors.	I Final Demmand.	J Final Demmand.	K Final Demmand.	Exports to Exogenous Countries	Statistical Error	Total Output
Number of Sectors			A·····AA I ····· II 0·····n 0 0·····n 0 1·····n 0	A·····AA J·····JJ 0·····n 0 0·····n 0 1·····n 0	A·····AA K·····KK 0·····n 0 0·····n 0 1·····n 0	F·····FF I ····· II 0·····n 0 0·····n 0 1·····n 0	F·····FF J·····JJ 0·····n 0 0·····n 0 1·····n 0	F·····FF K·····KK 0·····n 0 0·····n 0 1·····n 0	LL HH 00····· 00 11	Q X 0 0 1	X X 0 0 0
405	Coutry I Endogenous Sectors	AI 001 AI nnn AI 800	A^{II}	A^{IJ}	A^{IK}	F^{II}	F^{IJ}	F^{IK}	L^{I}	Q^{I}	X^{I}
76	Coutry J Endogenous Sectors	AJ 001 AJ nnn AJ 800	A^{JI}	A^{JJ}	A^{JK}	F^{JI}	F^{JJ}	F^{JK}	L^{J}	Q^{J}	X^{J}
76	Coutry K Endogenous Sectors	AK 001 AK nnn AK800	A^{KI}	A^{KJ}	A^{KK}	F^{KI}	F^{KJ}	F^{KK}	L^{K}	Q^{K}	X^{K}
Freight, Insurance		BF 001	BA^{I}	BA^{J}	BA^{K}	HF^{I}	HF^{J}	HF^{K}			
Imports from Hong Kong		OH 001 OH nnn OH 800	HA^{I}	HA^{J}	HA^{K}	HF^{KI}	HF^{KJ}	HF^{KK}			
Imports from Other Countries		OW 001 OW nnn OW 800	WA^{I}	WA^{J}	WA^{K}	WF^{KI}	WF^{KJ}	WF^{KK}			
Customs		DT 001	DA^{I}	DA^{J}	DA^{K}	DF^{KI}	DF^{KJ}	DF^{KK}			
Value Added		VV 001 VV 004 VV 800	V^{I}	V^{J}	V^{K}						
Total Input		XX 800	X^{I}	X^{J}	X^{K}						

Figure1 Detailed Asian AIIO

The direct GHG emission coefficient derived from IEA/OECD[8,9] and EDGAR[10] statistics are used for calculating the enveloped GHG emission database[6].

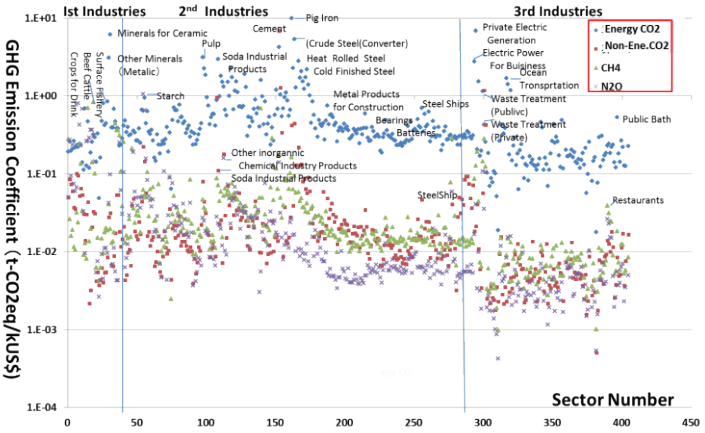


Fig.2 GHG Emission Coefficient Database for Japan using Detailed AIIO

4. Results

The results of the GHG database developed by detailed AIIO are shown in Fig.2

Then, using the details of indirect GHG emission coefficient of each sectional GHG emission, interdependence of resources, products and services of Asian countries are analyzed.

These results shows the detailed AIIO using each country's IOT will work well for developing Asian environmental load database including GHG, water, air polluting material and so on.

The analysis using AIIO 2005[11] and comparison with 3EID[12] will be discussed.

Acknowledgments

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Study on framework of life cycle sustainability assessment and social life cycle assessment: As a subject of biorefinery

Tomoko Fuchigami,*[1] Xiao-Zheng Sun,[2] and Yutaka Genchi[2]

[1]*The University of Tokyo, Japan*; [2]*National Institute of Advanced Industrial Science and Technology, Japan*
*Corresponding author: tomoko_fuchigami@bs.s.u-tokyo.ac.jp

1. Introduction

Sustainability assessments are required for technologies, products, and human activities to realize sustainable society., Standards and guidelines for sustainability assessment have been presented by many countries and international organizations. However, the specific discussions of the assessment methodologies based on lifecycle thinking are not enough.

Biomass is a promising industrial feedstock for both energy production and materials production because of its renewability. However, the social impacts of a large-scale utilization of biomass on local agriculture and food market as well as the impacts on agricultural field and ecosystem cannot be ignored.

The purpose of this study is to propose a framework for sustainability assessment based on lifecycle thinking through a case study on biomass refinery. Social impact assessment, which is necessary for sustainability assessment, is performed using Social Hotspot Database (SHDB) developed by New Earth [1]. SHDB goes back to upstream and calculates work hours by country and by sector, and indicates potential of social risk which the sectors with high contributing ratio hold, according to the Input Data given in amount of money. The SHDB assessment on biorefinery process from sorghum cultivation to phenyllactic acid production is conducted considering two cases of production in Vietnam or in Japan.

2. Scope of SHDB assessment and inventory data

The subjects for this assessment are a cultivation process of sorghum [2] and a fermentation process of phenyllactic acid with glucose as a raw material [3]. Table 1 shows the inventory data for the assessment presented by amount of dollars. The mass data are obtained from the published literature of Shimizu et al. (2009) and Fujita et al. (2013). The price data are collected from catalogs and inquiries. Finally, they are all converted to dollars data using the exchange rate. All input are assumed to be collected from the country in which the process is carried out. Calculations are performed using the SimaPro8 software implementing SHDB.

Table 1. Inventory data for SHDB analysis

I. Sorghum cultivation process

Input process	Material	Amount /USD
Crops	Grain	0.039
Chemical, rubber, plastic products	Fertilizer	0.15
Petroleum, coal products	Fuel	0.093
Electricity	Electricity	0.00051
Output process		
Sugar cane, sugar beet	Cultivation	1

II. Phenyllactic acid production process

Input process	Material	Amount /USD
Electricity	Electricity	0.096
Petroleum, coal products	Fuel	0.0024
Chemical, rubber, plastic products	Chemicals	0.31
Food products	Medium additive	0.22
Water	Water	0.00033
Sorghum cultivation process	Glucose	0.15
Output process		
Food products	Production	1

3. Results of SHDB assessment

The sectors with a lot of work hours (WH) and potential social risks are calculated when assumes that the phenyllactic acid is produced in Japan or in Vietnam. Table 2 shows the higher potential social risks with higher WH.

The work hours for production in Vietnam are much longer than that for production in Japan. The social risks with high contribution rate for production in Japan are related to labor rights in many cases. On the other hand, the characteristic social risks for production in Vietnam are risk of forced labor and risk of HIV.

Table 2. High social risk items with high contributing ratio

I. High risk items for the production in JP	WH
Risk that Country does not ratify ILO conventions	0.057
Risk of LLY by silicosis due to atm. Part. in occupation	0.047
Risk of LLY by asbestosis due to atm. Part. in occupation	0.046
Characterization. of Global Gender Gap	0.045
Risk that a country lacks or does not enforce Freed. Of Ass. rights	0.042
Risk that a country lacks or does not enforce the Right to Strike	0.041
Risk of Tuberculosis	0.041
Risk of excessive working time by sector	0.040
Risk of Mumps	0.040
II. High risk items for the production in VN	**WH**
Risk that Country does not ratify ILO conventions	2.872
Risk of Forced Labor in Country	2.871
Characterization of People Under Threat Score	2.869
Risk of HIV	2.858
Risk of LLY by asthma due to atm. Part. in occupation	2.858
Risk of LLY by chronic obstructive pulmonary disease due to atm. Part.	2.858
Risk of LLY by airborne particulates in occupation	2.858
Risk of LLY by mesothelioma in occupation	2.858
Risk of Tuberculosis	2.856

With regard to the sector contribution of each risk, the process of phenyllactic acid production and the process of sorghum cultivation show a large contribution ratio in the case of production in Vietnam, however each sector shows the same ratio in the case of production in Japan.

4. Future work

It is necessary to evaluate both risks and values for sustainability assessment. The first step is to meet the risk criteria. We will investigate the statistical data that is used to evaluate each risk in SHDB, and determine whether it is suitable as the assessment criteria or not. Then, the criteria improvement for sustainability assessment will be conducted to apply the assessment results from SHDB.

Acknowledgments

This work was supported by the NC-CARP project of the Ministry of Education, Culture, Sports, Science and Technology in Japan.

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Global Scale Fate Factor of Nitrogen for Aquatic Eutrophication Using Water Circulation Model

Yuya Ono, *[1] Masaharu Motoshita, [2, 3] Norihiro Itsubo[1]

[1]*Tokyo City University, Japan*; [2]*National Institute of Advanced Industrial Science and Technology, Japan*; [3]*Technische Universitaet Berlin, Berlin, Germany*

*g1293101@tcu.ac.jp

1. Introduction

Eutrophication is a serious problem by heavy consumption of fertilizer and population increase. The Water Resource Institute sum up an eutrophication and hypoxia influence map that occurred in 762 area of the world from 2000 to 2010. Nitrogen cycle due to human activities has been pointed out as necessary items to be managed urgently by Johan et al [1]. From such a background, public concern for eutrophication is increasing.

Though LIME2(Life-cycle Impact assessment Method based on Endpoint modeling 2), EDIP(Environmental Development of Industrial Products), TRACI(The Tool for the Reduction and Assessment of Chemical and other environmental Impacts) and Recipe have been developed as methods for assessing eutrophication in LCA, these methods have been developed using model for one region or country. The aim of this study is to develop eutrophication assessment factors on a global level.

In this study eutrophication is defined as a degradation of dissolved oxygen with nitrogen. And degradation of dissolved oxygen relate to nitrogen fertilizer is calculated in each water catchment area globally. It is assumed that after fertilization related to nitrogen, nitrogen becomes nitrate and moves to catchment area like a lakes or seas by water circulation. Water catchment area consists of 8 regions and 66 sea area. This study used mainly data of NOAA (Large Marine Ecosystems of the World) data. In this study global map is divided into a mesh size of 0.5 ° * 0.5 ° and simulations are performed on daily basis.

It is possible to apply consistent assessment globally by this study.

2. Development of eutrophication assessment methods

This study are tried to estimate amount of dissolved oxygen reduction per unit of nitrogen in the catchment area. Each data are divided into a mesh size of 0.5 ° * 0.5 ° (length 360, width 720, total 259,200) using the GIS, and simulations were performed in each day. Process of method development are shown by below (Fig.1).

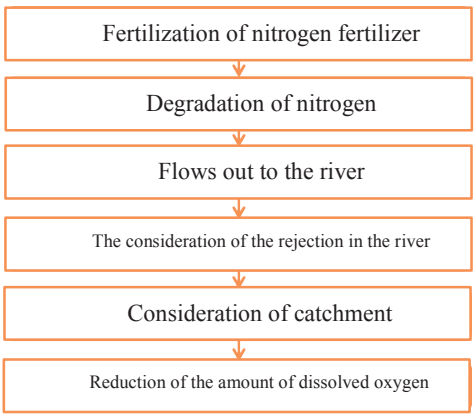


Figure.1 Process flow for method development

It was assumed that after nitrogen are applied fertilizer in each country, nitrogen becomes nitrate nitrogen and these nitrate nitrogen are moved catchment such as sea or lake with water circulation. These flow are modeled in this study. Nitrate nitrogen are estimated by using simulation results of TBNC-Updated model (Lin, et al. [2]). Amount of world nitrate nitrogen are calculated by multiplying farmland area [3] and nitrate nitrogen. Secondly river inflow was set at 70% of the amount of leaching, nitrogen removal rate in the river was 0.06day^{-1}(Suga et al [4]). Process until the water catchment area from each grid was applied TRIP (Total river channel network). TRIP (Oki et al [5]) shows falling-sequence, falling-direction and under a stream of dates map. The amount of nitrogen that reaches to each catchment area are estimated by sea ID data (Large Marine Ecosystems of the World) and lakes ID. The catchment area is divided into 74 areas. Finally, reduction of dissolved oxygen concentration are calculated by using the Redfield ratio.

3. Result and conclusion

Result of simulation, Patagonia coastal, Gulf of Mexico, Bay of Bengal, Black Sea, Yellow Sea, Arabian Sea and Mediterranean show large amount of nitrogen. As a common point, farmland area and amount of nitrate nitrogen per area are larger than other area and cover huge catchment (Fig. 2).

This study aimed development of impact assessment factor which focus on eutrophication (characteristic factor) in global level. Though global map are divided into grid of 259200 and Nitrogen movement were simulated, this study reflect the regional characteristics.

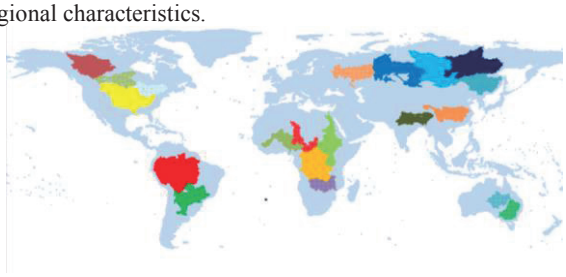


Figure.2 Catchment area of the world

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Methodology to Assess Sustainability of Biomass Utilisation in East Asia

Yuki Kudoh[*1], Masayuki Sagisaka[1], Sau Soon Chen[2], Jessie C. Elauria[3], Shabbir H. Gheewala[4], Udin, Hasanudin[5], Jane Romero[6], Vinod K. Sharma[7] and Xunpeng Shi[8]

[1]*National Institute of Advanced Industrial Science and Technology, Japan;* [2]*SIRIM Berhad, Malaysia;* [3]*University of the Philippines Los Baños, Philippines;* [4]*The Joint Graduate School of Energy and Environment, Thailand;* [5]*University of Lampung, Indonesia;* [6]*Asian Development Bank, Philippines;* [7]*Indira Gandhi Institute of Development Research, India;* [8]*National University of Singapore, Singapore*

*Corresponding author: kudoh.yuki@aist.go.jp

1. Introduction

Utilisation of biomass resources both as energy and materials has attracted worldwide attention for its potential to improve environment and to contribute to rural development and employment generation. However, some potentially negative issues have also been recognised with the increased demand of biomass resources and the implementation of policies for the enhanced the use of biomass. These issues are mainly related to environmental or social concerns about increased greenhouse gas (GHG) emissions, loss of diversity, unwanted impacts on the livelihoods of local communities, and increased food insecurity. As concerns over these issues increase, especially as they relate to the utilisation of biomass for energy, several initiatives on the assessment of bioenergy sustainability have emerged in recent years [1]. These initiatives are working to develop sustainability criteria, indicators, certification schemes, and legislation for the processing bioenergy feedstock as well as the production and consumption of bioenergy.

Although some stakeholders from East Asia are involved in some of the bioenergy sustainability initiatives, most of those are led by developed countries. To develop sustainability assessment methodologies for biomass utilisation suitable for East Asian countries that are rich in biomass resources, it is important to consider the feedstock availability and socio-economic conditions in this diverse group of countries.

Given this context, an expert working group (WG) of researchers from East Asian countries was formed in 2007 and worked towards a sustainability assessment methodology of biomass utilisation in East Asia until 2013 [2]. This article introduces the indicators WG has identified to assess sustainability of biomass utilisation in East Asia.

2. The Methodology and Its Way Forward

In response to increasing needs for utilisaion of biomass resources in East Asia and growing worldwide discussions for sustainable use of biomass, the WG aimed at proposing an academically-sound and practically-relevant methodology to evaluate the sustainability of biomass utilisation in East Asia from environmental, economic and social pillars. Since the target users of the methodology is the decision makers (not academia or experts) in this region, the sustainability indicators comprising the WG methodology should be relevant and applicable to any kinds of biomass utilisation initiatives; the WG thinks those indicators that are too scientific, complicated and have high uncertainties should not be included.

The sustainability indicators are classified to main and sub indicators (Figure 1). GHG emissions as environmental, total value added (TVA) as economic and Human Development Index (HDI) as social indicator are identified from the earlier phase of the project and checked the relevance and the applicability at the field studies conducted in four selected East Asian countries. From the lessons learned from the field studies, HDI was found to be applicable mainly at large-scale initiatives and employment generation and access to modern energy were identified as more practicable indicators for assessing social impact of biomass utilisation in the local level. In line with the latest discussions made at the other initiatives for biomass sustainability, the WG finally added sets of sub indicators to complement the main indicators.

The project was ended in 2013 but the methodology can contribute to policy support on what kinds of and how biomass should be utilized and implemented in a sustainable manner in East Asian counties. In this context, the WG thinks it important to assess the sustainability of biomass utilisation using the WG methodology and share the results in East Asian counties.

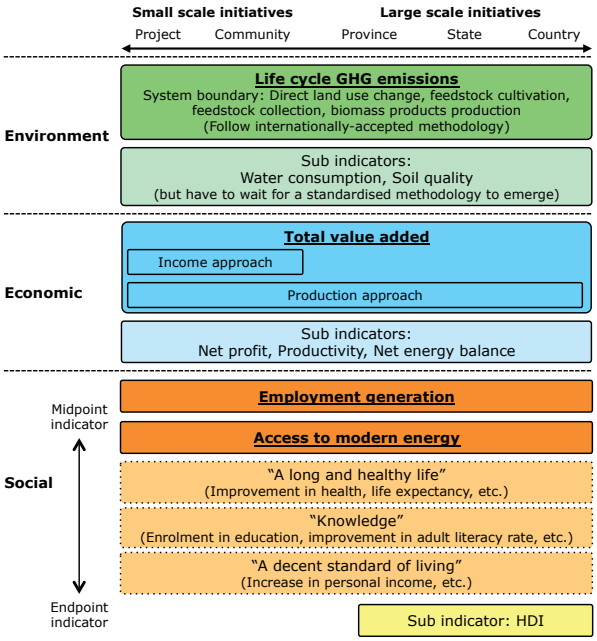


Figure 1. Sustainability Indicators for Biomass Utilisation in East Asian Context

Acknowledgments

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New Version of Simple LCA Software Including a Comprehensive Inventory Database (IDEA)

Kuan Jay Bartel,*[1] and Kiyotaka Tahara[1]

[1]*National Institute of Advanced Industrial Science and Technology (AIST), Japan*
*Corresponding author: k.bartel@aist.go.jp

1. Motivation and overview

The goal of Simple LCA has been to provide an LCA software package for use in education and small to medium enterprises to support the further expansion of LCA use within Japan. It provides an easy to use interface to assist non-LCA professionals to conduct an ISO14040 based LCA project, including inventory analysis and impact assessment.

Traditionally, LCA software has been designed for trained LCA professionals who undertake extensive studies of large complex systems. For professionals it is important for their software to provide advanced functionality to support them in their work. However for non-LCA professionals, and those learning the LCA methodology, these software packages can be difficult to use and can be a barrier to the understanding and use of LCA.

There are now many LCA software programs and online tools available which could be considered simple or easy to use. For use in Japan however these tools are not appropriate as they do not have a Japanese user interface and include limited or no background data, or the data included is not specific to Japanese industry. The first version of Simple LCA, released in 2007 [1], was available in English and Japanese releases and included limit background data. Version 2 now provides user interfaces in both English and Japanese in a single release and includes a comprehensive background database, version two of IDEA (Inventory Database for Environmental Assessment), developed in Japan [2].

2. Software features

Simple LCA has the following key features:

- Model product and service systems using a visual system diagram
- Undertake an LCA study of a system following the ISO 14040 series of standards producing results for LCI and LCIA
- Updated easy to use user interface making entering of activity data quick and easy
- User interface in English and Japanese
- Version 2 of IDEA providing comprehensive background data [2]
- Impact assessment methodologies including LIME2 [3] and ReCiPe 2008 [4]

3. System modelling

In modelling a system it has become the normal practice for the system to be split into foreground and background activities. Foreground activities being the activities which the LCA practitioner has specific data for, such as production and use, and background data for activities which the practitioner does not have specific data for and are used as inputs to the foreground activities, such as electricity and materials. Simple LCA is thus also divided into two sections: 'Assessment' and 'Database'. The 'Assessment' section is the main section which users will use for entering foreground activities and calculating results which are part of a target system. The 'Database' section allows for viewing of background data, environmental flows, impact methods and units.

4. Background database (IDEA)

The first version of Simple LCA only included 189 background activities for some of the most commonly used materials and processes and only a limited number of environmental flows. The included activities are a small subset of those in AIST-LCA Version 4 (JEMAI-LCA Pro) [5].

Version 2 now includes the complete set of system processes from version 2 of the IDEA database [2]. This database includes over 3800 activities with inventory data for over 500 environmental flows. The database is very comprehensive covering all products classified within the scope of the Japan Standard Commodity Classification and additional services and processing activities.

Due to the large increase in activity and environmental flow numbers compared to the original version a completely new database engine was used in version 2 so as to still provide the same fast and efficient searching and selection of data.

5. LCA results

Simple LCA allows for the quick easy calculation of LCI and LCIA results of a system. Results can be viewed for each activity, stage or the total system. LCIA results are calculated using the LIME2 [3] and ReCiPe 2008 [4] impact assessment methodologies with characterization, mid-point, end-point and single index results for each activity, stage and the total system. Results may be exported for use in Microsoft Excel.

6. Technical details

System Requirements

- Microsoft Windows 7, 8, 8.1 (x86 or x64)
- 1 GHz or faster processor
- 1 GB of RAM
- 8 GB of available hard disk space

Software architecture

- Simple LCA was developed in C# targeting the Microsoft .Net Framework version 4.5.2
- Backend database engine uses Microsoft SQL Server 2014 Express LocalDB and SQLite version 3.8.6

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Land Use, an Important Midpoint Category Indicator in Agriculture: How Should We Deal with It?

Takahiro Nakashima* and Shoko Ishikawa

NARO Agricultural Research Center, Japan
*Corresponding author: tnakasim@affrc.go.jp

Increased attention has been paid to agriculture as one of the targets to apply life cycle assessment (LCA). Midpoint impact categories that are popular in this field includes fossil-fuel energy demand, global warming, acidification, eutrophication and land use [1]. In the present study, we paid special attention to the last mentioned impact category, land use, as unlike most of other categories that are "outputs" of a crop/product production, it is also an "input" and therefore could be manipulated by farmers. Farmers allocate their land to different crops in such a way that they could obtain what they aim in their farming (e.g., maximization of profit) while taking into consideration technical and resource constraints as well as market conditions such as prices of crops, fuels and chemical fertilizers. To treat multi-dimensional aspects of land use in a balanced manner, we proposed, in Ecobalance 2008, an idea of linking agricultural LCA to activity-based economic model of farming [2, 3], with the aid of positive mathematical programming (PMP) initially formulated by Howitt [4]. The linkage gives us a theoretical framework to examine impacts of changes in the technical and economic conditions on environmental loads, thereby to quantify trade-offs (or perhaps complementary relationships) between economic gain and negative environmental impacts from farming. This line of multidisciplinary study is considered to be of particular importance for policymakers, who need to design and implement agricultural and environmental policies that balance such economic gain and consequential loads released to the environment. In addition, the employment of PMP enables us to calibrate an economic model of farming which is formulated by nonlinear programming (NLP) so as to exactly represent observed levels of the land area allocated to each crop grown at the reference point where the model is calibrated [5]. This function in static analysis allows us to calculate the amount of environmental loads on farms or regions, multiplying the land area allocated to each crop by the midpoint environmental impact category indicators on area basis, for example, the amount of CO_2-equivalent greenhouse gas emitted on hector basis. As reported by Nakashima [3], however, orthodox PMP does not always ensure reliable or "positive" results when it comes to comparative statics. In PMP, the objective function of a NLP model is calibrated on the basis of Kuhn-Tucker conditions for the NLP model and for a linear programming (LP) model, which is prepared hypothetically for the calibration of the NLP model, and then the two types of optimum conditions derived are combined to derive equations for the calibration, which are linear in parameters to be calibrated when the NLP model is quadratic programming (QP), the simplest and probably most frequently employed in this field. The equations for the calibration are indefinite as the number of the parameters to be calibrated surpasses the number of equations [6], meaning that there are numerous ways of representing the original land-use pattern as the result of optimization, but that the calibrated models can yield different simulation paths in terms of both economic and environmental aspects. This is not necessarily welcomed by policy makers, who need sound basis to implement measures effectively. Nakashima [4] has pointed out the need to develop procedures for selecting the appropriate calibration method in the light of comparative statics, and proposed a simple and tractable framework to deal with the issue (but verification with empirical data remaining the subject of future research). In the present study, we applied the proposed framework to upland cropping systems of winter wheat, beat, bean, potato, and cabbage in Hokkaido, Japan, and investigated the extent to which a selection of calibration methods influences on simulation results on land-use allocation and resultant calculation of environmental load on an area basis. The impact category considered in the present study was global warming, and the functional unit was one hector of land. The LCA data was cited from the study conducted by Koga et al. [7], while farm management data was collected from statistics published from the Ministry of Agriculture, Forestry and Fisheries, the regional government and related sources to calibrate an economic model of farming. By showing strength obtainable through the numerical application, some implication to conduct agricultural LCA will be discussed.

Acknowledgments

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Setting Method of the Evaluation Boundary from the Viewpoint of Uncertainty Management in LCA for Transport System Development

Ryoko Morimoto*, Hirokazu Kato[1], Naoki Shibahara[2] and Yuki Masuda[3]

[1]*Nagoya University, Japan;* [2]*Japan Environmental Management Association for Industry, Japan;*
[3]*JR-Central Consultants Company, Japan*
*ryosoup@gmail.com

1. Introduction

In order to reduce the environmental load from transport infrastructure provision, it is necessary to evaluate the environmental load emissions at an early stage in the project planning. However, the earlier an evaluation is carried out, the more it becomes necessary to use values with large uncertainties as input data such as the predicted or estimated values of demand.

This paper proposes a method of managing uncertainties for decision making by LCA for transport system provision. Setting the evaluation is investigated using an example from the viewpoint of the reducing uncertainties, and it is shown what setting scope of evaluation boundary is desirable for ensuring accuracy in the judgment of the relative merits of alternatives.

2. Uncertainty Analysis Methods

A crossing removal of road and railway evaluated by the authors boundary[1] a case study is evaluation boundary included the construction of a railway elevated bridge (including 1 station) associated with removal of the crossing, and the necessary changes in the driving conditions for cars after commencement of service. However, here the relationship between setting the system boundary and the uncertainty in the results is investigated. The system boundary was set in 3 stages, and the uncertainties in the judgment results were calculated and compared (See Figure 1). The environmental load evaluated was CO_2 only, and the life time was assumed to be 60 years.

From the result of life cycle CO_2 (LC-CO_2) estimation, emissions from automobiles account for a large proportion of the total. Therefore an uncertainty analysis was carried out for the input data relating to automobiles.

Probability distributions obtained from previous research [2] were used as input data of road traffic volume and traveling speed of automobiles. Using the Monte Carlo method, the effect of uncertainties of the data on the estimation results was analyzed. The number of trials was 10,000.

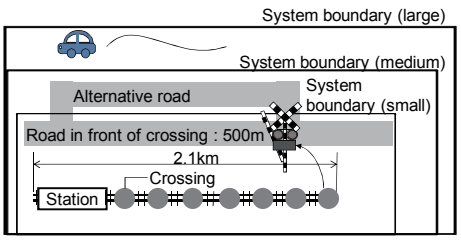


Figure 1. Setting the evaluation boundary

3. Results

The difference in LC-CO_2 between the case with and without crossing removal project was represented as ΔE. When the sign of ΔE is positive, it means there is a reduction in LC-CO_2 due to the project.

Figure 2 shows the probability distribution of ΔE obtained. It is considered important to judge whether or not it is possible to reduce CO_2 (ΔE<0) by implementing the project. Hence the reduction probability is used as an index expressing the reliability of the judgment result. Although there is not a major difference in the variation of ΔE, it increases from 'small' evaluation boundary to 'large' evaluation boundary. This is because as the evaluation boundary becomes broader more uncertainty factors are included. As a result, the reduction probability for the 'large' evaluation boundary is 74%. The next section discusses the potential for reducing uncertainty.

If it is not possible to obtain the required reduction probability even though the data accuracy is improved, it is possible to deal with this by either making the decision recognizing that the result is uncertain, or by re-examining the evaluation boundary to reduce the uncertainty. From Figure 2, if a reduction probability of 95% is required, it is appropriate to use the 'medium' evaluation boundary for decision making. However, in that case it is important to provide a comment to the effect that the important load generating factor of induced traffic has not been included in the estimate.

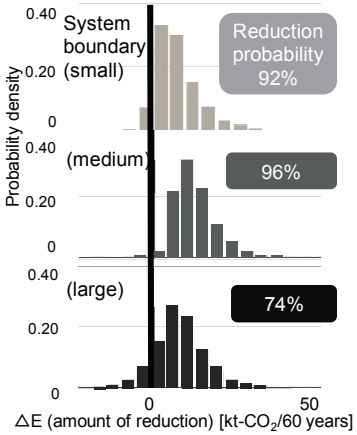


Figure 2. Probability distribution of reduction amount ΔE and probability of reduction

4. Conclusion

A method managing uncertainty in LCA for transport infrastructure provision has been constructed, and a method of setting the evaluation has been proposed. Consequently, it is possible to improve the concern that it is difficult to use for decision making because the uncertainties are large.

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Uncertainty Analysis for Infrastructure LCA

Hirokazu KATO, [1]* Yuki MASUDA,[2] Naoki SHIBAHARA,[3]
Ryoko MORIMOTO, Koh KANAI,[1]

[1]*Nagoya University, Japan*; [2]*JR-Central Consultants Company, Japan*
[3] *Japan Environmental Management Association for Industry*
*Corresponding author: kato@genv.nagoya-uac.ac.jp

1. Introduction

It is important to consider uncertainties during decision making regarding infrastructure development. Decision makers select better alternatives among at the stages of conception, design, and construction. The information that can be obtained and the options available vary depending on the stage, so it is necessary to consider the uncertainties in accordance with the respective stages. This research analyzes a specific example in transport infrastructure development. The uncertainties in the life cycle CO_2 emission estimation results are analyzed at each decision making stage.

2. Analysis Method

This paper discusses the uncertainties in the inventory analysis stage for estimating the environmental loads in the LCA. A Monte Carlo simulation was applied to obtain the variation of results. The number of trials was 1,000.

The following decision making stages were determined to infrastructure development. There are concept stage, design stage and construction stage. The uncertainties in each stage were set and the uncertainty analysis in each stage was carried out.

(a)Analysis of uncertainty during construction

1) Concept stage: From among the accumulated emissions data for each transport infrastructure project, one project is selected at random.

2) Design stage: From among the basic data on materials and equipment in the database, one type is selected at random. Analysis is carried out for errors in the quantities of materials and equipment and measurement of emission factors, in the same way as for the construction stage.

3) Construction stage: Estimation is conducted by the authors' methods[1] based on the summation method, with reference to the LCA database.

(b)Analysis of uncertainty during service

Uncertainties were allocated to a) errors in measurement of emission factors for fuel in public transport, b) errors in emission factors for fuel for automobiles and transport volumes, and c) errors between the relation equations and measured data.

For the errors in measurement of emission factors for fuel, the probability distribution in the emission factors data in the database was used. For the errors in traffic volumes, the difference between the planned values and the actual measured values was represented as a probability distribution[2]. The Q-V equation and the V-fuel consumption equation were obtained from the measured data, and errors between measured data were represented by applying a probability distribution based on the variance in the parameters.

3. Results of Analysis

This paper an uncertainty in the design and construction stages after it has been decided to develop an LRT in the concept stage. An alternative to replace existing route bus service by railway is examined. In addition to the public transport system as a whole, the evaluation boundary also included the quantity of automobile traffic on the road alongside the LRT, with reference to Morimoto et al[2]. The life time was set to 60 years for infrastructure and 20 years for vehicles.

The results of the uncertainty analysis for the design stage is that reduction probability of the life cycle CO_2 emission after introduction of the LRT is 84.2%. (See Fig. 1)

If it is not possible to obtain a sufficient probability of reduction, it is necessary to take further measures. This paper considers the more reduction probability in the construction stage by selection of construction materials and construction methods with low emissions. Fig. 2 shows the results of the uncertainty analysis during construction for the design and construction stages. Compared with the design stage, the variation in the construction stage is reduced, as the materials, equipment, and construction methods are decided. Also, the total emissions are reduced because materials and equipment and construction methods with low emissions are selected.

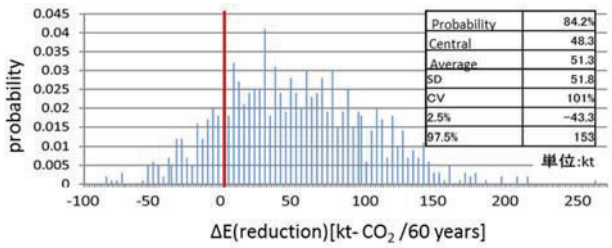


Figure 1. Results of uncertainty analysis in the design stage

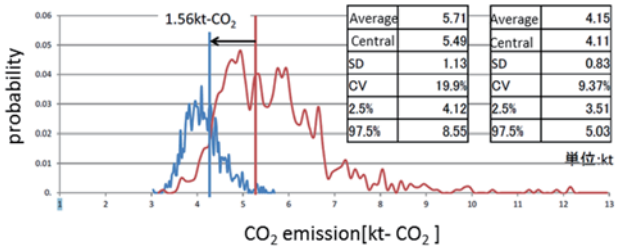


Figure 2. Results of uncertainty analysis for construction in each stage

4. Summary

By taking uncertainty into consideration, there is a possibility that the relative merits of alternative schemes could be reversed, and that by taking appropriate measures it is possible to reduce the possibility of a reversal.

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Calculation and Comparison of Weighting Factors Based on Different Approaches in LCIA

Ryosuke Yokoi,*[1] Jun Nakatani,[1] Masaharu Motoshita,[2] and Yuichi Moriguchi[1]

[1] *The University of Tokyo, Japan*; [2] *The National Institute of Advanced Industrial Science and Technology, Japan*
*Corresponding author: yokoi@env.t.u-tokyo.ac.jp

1. Introduction

Though weighting in life cycle impact assessment (LCIA) is widely used in practice, it is still a controversial issue. There are many kinds of weighting approaches and the choice of the weighting approaches influence the interpretation of the LCIA results. Approaches for weighting can be classified into distance-to-target (DtT), panel, and monetization approaches. From the other viewpoint, approaches for weighting can be classified into midpoint and endpoint approaches. There exist previous studies that compare LCIA results based on multiple methods including weighting phases. However those studies have compared their weighting factors and/or calculated results without considering the difference in weighting approaches or frameworks of LCIA methods.

The objective of this study is to calculate multiple sets of weighting factors using different approaches based on the identical LCIA framework, and to investigate the difference in weighting factors among the type of weighting approaches.

2. Methods

Weighting factors of both midpoint and endpoint impact categories were calculated using a panel approach and a DtT approach based on the framework of LIME2 [1].

Three types of questionnaire surveys for panel approaches were conducted for different respondent groups including LCA specialists and practitioners in Japan. (1) For calculation of weighting factors of endpoints, which are called "safeguard subjects" in the LIME2 framework, each respondent was asked to give weights directly to four safeguard subjects of LIME2, by following the weighting approach of Eco-indicator 99 [2]. (2) For calculation of weighting factors of midpoints in relation to endpoints, each respondent was asked to compare the importance of midpoint impact categories of LIME2 from the viewpoint of damages on the respective safeguard subjects. Weighting factors were calculated by combining its results with the above-mentioned weights of the safeguard subjects. This method is referred to as "paired comparison". (3) Besides, each respondent was asked to evaluate the importance of midpoint impact categories into four grades without information on the relationship between midpoint and endpoint impact categories. Weighting factors were calculated by following the weighting approach of BEES [3]. This method is referred to as "classification of importance".

In calculating weighting factors based on a DtT approach, target levels of respective impact categories were defined based on the environmental standard or policy objectives of Japan.

3. Result and discussion

Figures 1 and 2 show the results of calculating weighting factors for midpoints based on panel approach. The variability of calculated weighting factors among specialists was larger than that among practitioners. The weighting factors from paired comparison and classification of importance were different. This may mean the difference between the midpoint and endpoint approaches. For example, noise, as one of the midpoint impact categories of LIME2, was evaluated to be more important by paired comparison than classification of importance. It is because noise was associated with multiple endpoint impact categories in paired comparison, though quantitative relationship between noise and endpoint categories other than human health have not been presented in LIME2. On the other hand, it is considered that importance of the noise issue was more intuitively evaluated in classification of importance.

Compared with the weighting factors based on DtT approaches, there was less difference among the weights of impact categories calculated based on panel approaches.

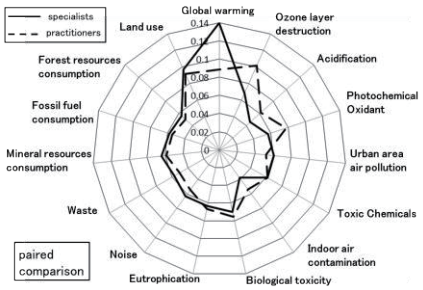


Figure 1. Weighting factors from paired comparison

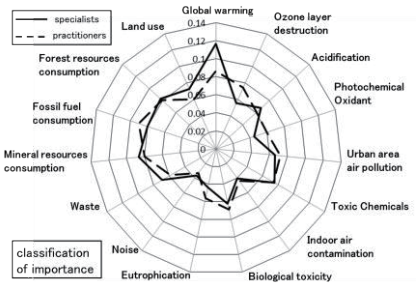


Figure 2. Weighting factors from classification of importance

4. Conclusions

The results suggest that weighting factors can be affected by various factors such as the choice of weighting approaches. It was found that weighting factors obtained from the panel approach were variable depending on the style of questionnaires and respondent groups. When practicing LCIA, interpreting or using the results of LCIA, it is important to understand the characteristics of weighting approaches behind the variability of weighting factors.

Acknowledgments

The authors are grateful to the members of The Institute of Life Cycle Assessment, Japan, the study group of Life Cycle Impact Assessment (ILCAJ), a private enterprise for answering the questionnaire surveys.

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Spatial Variation of Health Damage Factors for $PM_{2.5}$ on a Continent Level

Longlong Tang*[1], Tatsuya Nagashima[1], Kouichi Hasegawa[2], Toshimasa Ohara[1], Kengo Sudo[3] and Norihiro Itsubo [4]

[1] *National Institute for Environmental Studies, Japan*; [2] *Chuden CTI Co.,Ltd., Japan*; [3] *Nagoya University, Japan*; [4] *Tokyo City University, Japan*

*Corresponding author: tang.longlong@nies.go.jp

1. Introduction

$PM_{2.5}$ emitted in local area can move on an intercontinental or hemispheric scale. Furthermore, concentration and long-range transportation of $PM_{2.5}$ have significant spatial variations due to different meteorological conditions of the area where it emitted. However existing damage factors on human health in life cycle assessment (LCA) are calculated for several limited regions and based on different regional chemical transport models [1,2]. The aim of this research is to estimate human health damage factors of $PM_{2.5}$ on 10 regions of the world by using one global chemical transport model.

2. Method and data

The damage factors express the change in disability adjusted life years (DALYs) of the world due to change in emissions of organic carbon and black carbon (OCBC), nitrogen oxides (NO_x) and sulfur dioxide (SO_2). The 10 regions' damage factors were calculated by three steps below.

Firstly, after we divide the whole world into 10 regions (Fig. 1), the change of concentration of $PM_{2.5}$ on whole world per kg targeted pollutant emitted from one region is estimated by dividing the difference between a base concentration and an additional concentration due to a 20% increased emission by the amount of pollutant emitted additionally. The non-linear atmospheric fate model MIROC-ESM-CHEM, which includes an aerosol component (SPRINTARS) and an atmospheric chemistry component (CHASER), was used to calculate both of base and additional concentration of $PM_{2.5}$ [3].

Secondly, increment of mortality and morbidity of the world per unit of concentration of $PM_{2.5}$ are calculated by using concentration response functions (CRFs) which estimated by epidemiologic studies [4]. CRFs of both mortality and morbidity are assumed as linearity and with no threshold and regional variation.

Finally, data of population and DALY per case of mortality and morbidity are collected to calculate DALYs as health damage from results of the above. DALY per case of diseases for all regions are rough estimated by data from WHO (2008) [5] and Hofstetter (1998) [6]. Based on the method above, damage factors of SO_2, NO_x and OCBC for 10 regions were estimated.

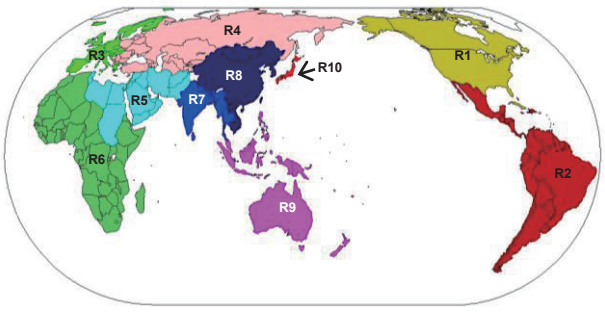


Figure 1. Boundary of 10 regions considering in this research

3. Results

Damage factors for NO_x, SO_2 and OCBC on all regions were estimated as 0.1~3.3, 0.3~2.2 and 0.8~15.8 (10^{-4} DALY/kg) respectively (Fig. 2). The difference of DFs among 10 regions can be up to 1 order of magnitude. DFs of regions of India and China were biggest due to the higher exposure population.

Influence on DFs due to considering the transboundary effects of $PM_{2.5}$ for each substance and each region was shown in figure 3. For most of regions, the share of damage occurred in the outside of the emission region for SO_2 was estimated as the biggest and the smallest for OCBC. This is because that the secondly $PM_{2.5}$ can move to a larger range of area than the case of primary $PM_{2.5}$. Especially regions of Europe, Russia and Middle East showed large shares of damage outside emission region around 1/4, 1/4 and 1/3. It is disclosed that the DFs will be underestimated when the transport of $PM_{2.5}$ to outside is not taken into account in those regions. For further research to quantify regional differences, it is important to consider the regional values of CRF and DALY loss per case of disease or death.

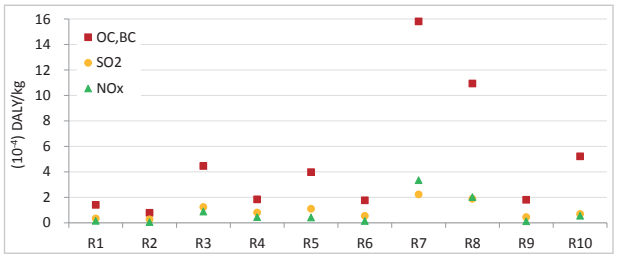


Figure 2. Damage factors of SO_2, NO_x, OCBC for 10 regions

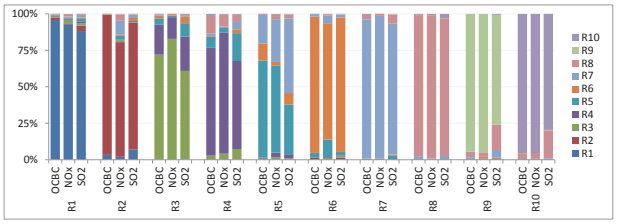


Figure 3. Ratio of damage effect on 10 regions caused by one source region for SO_2, NO_x and OCBC

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The role of world structural changes on CO_2 emissions

Kayoko Shironitta†*, Shunsuke Okamoto†, Shigemi Kagawa†

†Faculty of Economics, Kyushu University, 6-19-1 Hakozaki, Higashi-ku, Fukuoka, 812-8581 Japan

*kayoko.s137@gmail.com

1. Introduction

Global territorial emissions of CO_2 have been continuously on the rise as nations pursue economic growth, averaging a 2.2% annual increase in emissions in the decade from 2000 through 2010 (IPCC, 2014). The increases in emissions accompanying economic growth have been offset by reductions in emission intensities and energy consumption. The process of industrialization, one of the sources of economic growth, is also known to contribute to reductions in emissions. The shift to a service economy (*i.e.*, the expansion of service industries as a fraction of domestic production) strongly affects the domestic emissions of greenhouse gases. Needless to say, these structural changes in economy are greatly swayed by the scale of a country's imports and its import structure.

In this study, we focus on production-based CO_2 emissions from domestic industries and import-based CO_2 emissions in foreign countries and analyze the effects of the changes in the following seven factors: economic scale, industrial output compositions, import scale of intermediate products, import compositions of intermediate products, import scale of final products, import compositions of final products, and emission intensities on the CO_2 emissions.

2. Methodology

We applied the Shapley-Sun decomposition method and the Logarithmic Mean Divisia Index decomposition method to the linked world input-output tables during 1995 to 2009 and decomposed the changes in the production- and import-based CO_2 emissions of 40 countries into those seven factors. Using the time series multiregional input–output tables, total territorial emissions due to manufacturing in country *s* in year *t* are expressed as follows:

$$\begin{aligned} Q_d^t(s) &= \sum_{i=1}^{N} e_i^t(s)\theta_i^t(s)X_d^t(s) \\ &= \mathbf{e}^t(s)\boldsymbol{\theta}^t(s)X_d^t(s) \end{aligned} \tag{1}$$

where $\mathbf{e}^t(s)=\{e_i^t(s)\}$, $\boldsymbol{\theta}^t(s)=\{\theta_i^t(s)\}$, and $X_d^t(s)$ are the emission intensity row vector showing CO2 emissions per unit of output of industry sector *i* in country *s* in year *t*, the industrial composition column vector showing the fraction of output of industry sector *i* of total production across all industries in country *s* in year *t*, and total industrial output summed over all industry sectors in country *s* in year *t*, respectively. N is the number of industrial sectors.

The annual change in total territorial emissions from year *t* to year *t*+1 is then,

$$\Delta Q_d(s) = \mathbf{e}^{t+1}(s)\boldsymbol{\theta}^{t+1}(s)X_d^{t+1}(s) - \mathbf{e}^t(s)\boldsymbol{\theta}^t(s)X_d^t(s) \tag{2}$$

which can be re-arranged as

$$\begin{aligned} \Delta Q_d(s) = {} & \Delta\mathbf{e}(s)\boldsymbol{\theta}^t(s)X_d^t(s) + \mathbf{e}^t(s)\Delta\boldsymbol{\theta}(s)X_d^t(s) \\ & + \mathbf{e}^t(s)\boldsymbol{\theta}^t(s)\Delta X_d(s) + \Delta\mathbf{e}(s)\Delta\boldsymbol{\theta}(s)X_d^t(s) \\ & + \mathbf{e}^t(s)\Delta\boldsymbol{\theta}(s)\Delta X_d(s) + \Delta\mathbf{e}(s)\boldsymbol{\theta}^t(s)\Delta X_d(s) \\ & + \Delta\mathbf{e}(s)\Delta\boldsymbol{\theta}(s)\Delta X_d(s) \end{aligned} \tag{3}$$

The first term on the right-hand side of Eq. (3) represents the effects of changes in CO_2 emission intensities on the estimated CO_2 emissions, and the second and third terms represent the influences of changes in industrial composition and in gross output, respectively, on CO_2 emissions. The remaining four terms are interaction terms. Using Shapley–Sun–Dietzenbacher–Los decomposition to classify the seven terms (including the interaction terms among the technology effect, the industrial composition effect, and the economic scale effect), the following is obtained:

$$\begin{aligned} \Delta Q_d = {} & \underbrace{\Delta\mathbf{e}\boldsymbol{\theta}^t X_d^t + \frac{1}{2}\left(\Delta\mathbf{e}\Delta\boldsymbol{\theta}X_d^t + \Delta\mathbf{e}\boldsymbol{\theta}^t\Delta X_d^t\right) + \frac{1}{3}\Delta\mathbf{e}\Delta\boldsymbol{\theta}\Delta X_d}_{\text{Technology effect}} \\ & + \underbrace{\mathbf{e}^t\Delta\boldsymbol{\theta}X_d^t + \frac{1}{2}\left(\Delta\mathbf{e}\Delta\boldsymbol{\theta}X_d^t + \mathbf{e}^t\Delta\boldsymbol{\theta}\Delta X_d\right) + \frac{1}{3}\Delta\mathbf{e}\Delta\boldsymbol{\theta}\Delta X_d}_{\text{Industrial composition effect}} \\ & + \underbrace{\mathbf{e}^t\boldsymbol{\theta}^t\Delta X_d + \frac{1}{2}\left(\Delta\mathbf{e}\boldsymbol{\theta}^t\Delta X_d^t + \mathbf{e}^t\Delta\boldsymbol{\theta}\Delta X_d\right) + \frac{1}{3}\Delta\mathbf{e}\Delta\boldsymbol{\theta}\Delta X_d}_{\text{Economic scale effect}} \end{aligned} \tag{4}$$

3. Results

The results of year-to-year changes in territorial CO_2 emissions in 40 countries over the 15 years from 1995 to 2009 are described using the decomposition method formulated in the previous section. The per capita incomes defined by the World Bank for the 40 countries were used as standards (World Bank, 2013) to classify the countries into three groups: the high-income nation group with per-inhabitant incomes ≥$12616, the middle-income nation group with per-inhabitant incomes ≥$4086 and <$12616, and the low-income nation group with per-inhabitant incomes <$4086.

From the results, we found that the average industrial composition effect of high-income countries during 1995 to 2009 was -60 Mt CO_2, whereas that of mid-income countries including China was 81 Mt CO_2. The average import composition effects for intermediate products and for final products in high- income countries were 3 Mt CO_2 during the study period respectively. Our results show that even if the change in CO_2 emissions associated with imported products is considered, domestic structural change of high-income group has not contributed to increasing CO_2 emissions. However, when we think about the net effect which is the total of the average industrial composition effect and the average import composition effect of high-income group, the net reduction in emissions accompanying the structural changes in the high-income group during the study period amounted to about 9% of the entire world's territorial CO_2 emissions in 1995; thus, they were a non-negligible factor in reductions.

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Pedagogical Training for Environmental Education Based on Life Cycle Thinking for Engineers

Hatsuna Tadaka,*[1] Shinya Matsumoto,[1] Reiko Tomaru,[2] and Chiake Fukasawa[2]

[1]*Yokohama National University, Japan*; [2]*Sanden Kankyo Mirai Zaidan, Japan*
*Corresponding author: tadaka-hatsuna-dj@ynu.jp

1. Introduction

Various environmental issues, such as global warming, have attracted worldwide attention and come to be viewed as matters of urgency. Our mass-consumption lifestyle is one major cause of the drastic changes in our environment in recent decades, and the move from a mass-consumption lifestyle to a low carbon lifestyle is needed for future sustainability of the environment. In Japan, local governments and volunteers have been taking action to effect environmentally beneficial changes in our lifestyles through a wide range of policies and measures employed by the government. Environmental education (EE) is recognized as an effective means to aid us to move to a low carbon lifestyle. Therefore, many EE activities have been implemented in Japanese schools and local communities.

However, there has been no major change in the mass-consumption lifestyle of the Japanese as a result of this activity. One change needed to alter this trend will be to spread awareness of the concept of life cycle and its relation to our own living environments and lives. It is necessary for people to understand the potential environmental load of their own daily lives from a bird's eye view in order to consider what lifestyle changes are needed. This recognition has motivated teachers and scientists involved in LCA research activities to develop a program and teaching materials for EE based on life cycle thinking (LCT) [1-3]. One of the authors developed an EE program based on LCT of a mobile phone and implemented it in schools in Japan [4-6]. Through this activity, we found that it was very important to increase the number of instructors in LCT-based EE programs. We also found that it was important to increase communication among stakeholders in the environment, particularly with respect to the influence of our living activities on the environment. In this work, therefore, we attempted to develop a new training program for engineers in order to deliver our EE program on a mobile phone in schools and local communities.

2. Development of a new training program

Our EE program of a mobile phone uses three important industrial products, plastics, semi-conductors and batteries, as a teaching subject for learning a product life cycle [6]. Students learn about the fundamentals and life cycle of these products and then think about their sustainable use through group working.

Three young engineers who work in the development section of a Japanese automotive parts supplier were selected to be students in the new program. The three products discussed in the mobile phone program are essential to their work, from development to production. This suggests that they should be able to understand and convey the fundamentals and life cycle of these products and the reality of their position in Japanese industry. Learning content and messages will be more persuasive if they are tailored to students' understanding by considering their own individual experience. There will therefore also be differences in awareness between students and working engineers in this regard that should be considered for effective EE.

The new training program had four parts: a homework assignment on plastics, semiconductors, and/or batteries, taking lectures of the mobile phone program with instruction materials, pedagogical skills practice, and an actual lecture delivered by the student in a school. The engineers first read several designated books on at least one of the three products. Then they experienced the mobile phone program and its instruction methods. After their teaching skills were checked and improved, each of them delivered a lecture at a school.

One of the instruction materials for this new training program is depicted in Figure 1. Materials were designed to reflect several areas of focus: 1) the aim and scope of education, including an educational objective; 2) typical instruction methods, such as interactive questioning and education using the Blackboard content-sharing system; and 3) special attention to other important items.

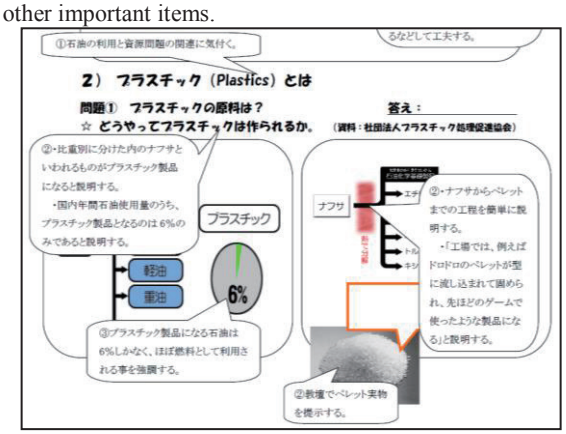


Figure 1. A part of the teaching materials

3. The implementation of the training program

We carried out the new training program with the three engineers in two days in June 2012. Then, in October of the same year, each of them conducted continuous two 50-minute classes on environmental matters at a Tokyo metropolitan senior high school. After the class, a questionnaire survey was conducted among the students and also the engineers. The results indicated that the class had been the students' first opportunity to become aware of the relationships among their daily lives, environmental issues, and industrial activities. We also obtained positive responses from the engineers, who had experienced communications that were unachievable in their company.

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Eliminating mottainai product features for our sustainable society

Masatsugu Kitamura,* Hidetaka Hayashi

EcoDesign Promotion Network(NPO), Tokyo, Japan
*Corresponding author: m.kitamura@ecodenet.com

1.Introduction

This is a study report on elimination of components of products to reduce and to find limit of resource consumption toward sustainable society. Eliminating any unwanted or out of use functions in mass products, that is eliminating mottainai shapes, is the most concerned scheme for this objective, prior to the 3R schemes. And it is useful to describe such elimination oriented market of mass products in our Sustainable Society in near future. All the nodes on industrial supply chain are in combination directly to the objective that fulfills people's desires while sustaining resources by means of restriction of resource consumption.

It is important for the industry to reach rapidly to our Sustainable Society while respecting updated analysis on global warming and also for conquering resource shortages. And also to find strong high potential engine node in the industry, to make cooperation among nodes on industrial supply chain ,

2. Views from Consumer

To promote the scheme there are cases of optimism that people's good sense of mottainai shows strong effect to drastic changing of mass products such as lamps of Incandescent to Compact Fluorescent and cars of Fuel only to Hybrid [1]. And consumers also show their good eco-citizenship to reduce electricity and food when confronting big accident as in Fukushima. While housekeepers may think first their budget when to purchase necessities in their homes, but they have shown further.

3.Views from Industry

People could get their expected functions with ease but together with of no use functions carried both by hardware and software. Because recent mass producing industry, designs were done directly to consumer's desires which are allowing resource consumption with ease. Resource Performance Ratio [2] will show low figures when there are no-need functions included.

It is required a common interface for each customer in order easy to select and mount a set of devices to be used and to dismount out of use devices. And industrial supply chain is required to act reciprocally with backtrack facility s Reciprocal Industrial Resource Supply Chain (RIRS-chain) to treat devices for each customer without applying to recycle system [3].

4.Views from society

So structuring Resource Community is shown logically and also mentally effective to the sustainability, during both supplying and using mass products.

Smart power system comprises solution of greatly reducing electric power generating capacity in contrived community having limited system of power supply. Smart power system of each home will be a member of community power cloud system that can eliminate redundancy of batteries in homes.

A study of music source on the web case, the score characteristics of access of each source shows decaying pattern along with its preferred rate, and also data volume of each source clearly restricted within updated digital format. Then whole amount of traffic and storage will be shrank into small cloud.

5. Limiting resource consumption

Consumers' desire seem to require resources infinitely but most needs of products show saturation along with their popularization followed by their replacement needs, so it is useful to define selected minimal profile for most preferred functions particularly in saturated state after market rising phase . Then the resource consumption will be minimized.

6. Promotion of EcoDesign Industry

A scheme of division and integration for common use functions and custom oriented functions with a new electro and mechanical interface, built in a package, welcome to be standardized, rather than as PC peripherals via cable interfaces. Prioritization of functions from Resource Performance Ratio (RPR) view, enables selection of a set of common use functions showing high RPR. .

RIRS-chain serves to transfer resources which are given specific potential value of a layer such as material, parts or assembly along with value added integration with Reciprocal Manufacturing Robots, avoiding loss of total added values in a Printed Circuit board (PC-board) by recycling for a small partial damage.

7.Summary - invention and innovation

To act on mind of avoiding mottainai lifestyle is necessary for us to sustain society with reusable reasonable lightweight products which will limit resource consumption. And to live on inventions mproving mottainai method of production will lead innovation upon our sustainable society.

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Environmental Performance of Biodiesel Productions Using Waste Cooking Oil

Shogo Eguchi†*, Shunsuke Okamoto† and Shigemi Kagawa†

†Faculty of Economics, Kyushu University, 6-19-1 Hakozaki, Higashi-ku, Fukuoka, 812-8581 Japan

*Corresponding author: shogoeguchi43@gmail.com

1. Introduction

Biodiesel is one of the biomass fuels for diesel engine produced from vegetable or animal fat-based oil. Biodiesel has the following four advantages: carbon neutrality, potential for sustainable production, positive contribution to the energy self-sufficiency rate, and prevention of air pollution (Matsumura, 2006). The Japanese government is attempting to increase the percentage of freight vehicles using biodiesel among all freight vehicles in Japan to 80% by 2050 (Ministry of the Environment, 2009) and usage of biodiesel for aircraft fuel is also being investigated. Thus, we expect biodiesel demand to grow rapidly in the future. However, most biodiesel plants in Japan have difficulty making a profit and need to depend on subsidies from their local governments. Therefore, it is necessary to raise the efficiency of their plant activities.

This study considers life-cycle CO_2 emissions associated with biodiesel production and employs the DEA framework considering two goods (biodiesel and glycerin as a by-product of the biodiesel) and one bad (CO_2). From the results estimated using the time series database on monthly biodiesel production during August 2010 to March 2013, we demonstrate how a particular biodiesel plant can achieve efficient production while reducing life-cycle CO_2 emissions. In addition, we also show how much the biodiesel plant can reduce the production cost of biodiesel by improving its productive efficiency.

2. Methodology

We employed DEA with variable returns to scale to analyze environmental and productive efficiency (Tone, 1993). The DEA framework without considering life-cycle CO_2 emissions can be formulated as follows:

$$\begin{aligned} &\min\ \theta \\ &\text{s.t.}\quad \theta\mathbf{x}_z - \mathbf{X}\boldsymbol{\lambda} - \mathbf{s}_z^x = \mathbf{0} \\ &\qquad -\mathbf{y}_z + \mathbf{Y}\boldsymbol{\lambda} - \mathbf{s}_z^y = \mathbf{0} \\ &\qquad s_{zi}^x \left(i = 1,2,\ldots,m\right) \geq 0 \\ &\qquad s_{zl}^y \left(i = 1,2,\ldots,n\right) \geq 0 \\ &\qquad \lambda_j \left(j = 1,2,\ldots,l\right) \geq 0 \end{aligned} \tag{1}$$

where $\mathbf{x}_z = \left(x_{z,i}\right)$ is the input vector representing the input of material i (i =1, 2,…,m) in month z (target month) and $\mathbf{y}_z = \left(y_{z,k}\right)$ is the output vector representing the output of product k (k=1, 2,…,n) in month z. $\mathbf{X} = \left(x_{ij}\right)$ and $\mathbf{Y} = \left(y_{kj}\right)$ denote the input matrix representing the input amount of material i in month j (j =1, 2, …, l) and the output matrix representing the output amount of product k in month j, respectively. $\boldsymbol{\lambda} = \left(\lambda_j\right)$ is the endogenously determined activity weight of month j. $\mathbf{s}_z^x$ and $\mathbf{s}_z^y$ are the slack vectors of material inputs and product outputs, respectively (e.g., Tone, 1993). In this study, the numbers of materials, products, and months are $m = 5$, $n = 2$, and $l = 32$, respectively.

We also formulated the DEA framework considering life-cycle CO_2 emissions by adding constraints (2) and (3) to the above linear programming problem (1).

$$b_z - \mathbf{b}\boldsymbol{\lambda} - s_z^b = 0 \tag{2}$$

$$s_z^b \geq 0 \tag{3}$$

where b_z is the amount of life-cycle CO_2 emissions associated with biodiesel production in the month z and $\mathbf{b}$=(b_j) is the emission vector representing the amount of life-cycle CO_2 emissions in the month j. s_z^b denotes the slack on life-cycle CO_2 emissions. Solving the DEA problem considering life-cycle CO_2 emissions provides efficiency scores under the environmental externality, $\hat{\theta}$.

Furthermore, we defined the following efficiency scores τ and $\hat{\tau}$ considering the endogenously determined slacks on the material inputs, product outputs, and life-cycle CO_2 emissions (Tsutsui, 2001).

$$\tau = \theta - \frac{\bar{\mathbf{x}}_z \mathbf{s}_z^x + \bar{\mathbf{y}}_z \mathbf{s}_z^y}{m+n} \tag{4}$$

$$\hat{\tau} = \hat{\theta} - \frac{\bar{\mathbf{x}}_z \mathbf{s}_z^x + \bar{\mathbf{y}}_z \mathbf{s}_z^y + \bar{b}_z s_z^b}{m+n+1} \tag{5}$$

where

$$\bar{\mathbf{x}}_z = \left(\frac{1}{x_{1z}} \quad \frac{1}{x_{2z}} \quad \cdots \quad \frac{1}{x_{mz}}\right)$$

$$\bar{\mathbf{y}}_z = \left(\frac{1}{y_{1z}} \quad \frac{1}{y_{2z}} \quad \cdots \quad \frac{1}{y_{nz}}\right)$$

$$\bar{b}_z = \frac{1}{b_z}$$

Then we define the environmental performance indicator (*EPI*) as follows (Tsutsui, 2001):

$$EPI = \hat{\tau}/\tau \tag{6}$$

EPI is greater than 1 if and only the target activity increases productive efficiency under the environmental pressure.

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Life cycle CO_2 emission of wind energy at optimum locations in the world

Kotaro Kawajiri*[1]

[1]*National Institute of Advanced Industrial Science and Technology, Japan*;
*Corresponding author: kotaro-kawajiri@aist.go.jp

1. Introduction

Renewable energies are expected as the important energy sources because the risks of global warming and resource exhaustion, improvement of efficiency and their costs. However, the one of problems of them is the energy generation highly changes by its location. Therefore, it is important to evaluate the geological energy potential for the renewables to reduce the cost and environmental impacts per kWh. Especially, the variance of potential would become large from global perspective.

The potential of photovoltaic (PV) energy in the world is clarified in the foregoing study [1]. In addition, the potential of reducing the environmental impacts per kW nominal power of PV by changing its global supply chain is also investigated [2].

On the other hand, wind energy is also promising renewable energy. However, there are few studies investigating the global wind energy potential. Archer et al clarified the wind energy potential in the world using the actual measurement data [3]. Liu et al clarified the global wind energy potential using the GEOS-5 data in 2006 [4].

The objective of this study is to investigate the wind energy potential in the world using the NASA weather data from 2000 to 2010. Also, the method to estimate the wind energy potential using the data is proposed. Finally, the results are compared with those by the foregoing studies.

2. Method

The CO_2 emissions per kWh of wind energy c_w and CO_2 payback time *CPT* at each location in the world are the objective variables of this study. The analytical method and assumptions are shown as follows.

Firstly, the annual wind energy potential E [MWh/MW] at each location is estimated using the NASA weather database [5] and the method of foregoing study [3]. According to their work, we assumed the capacity of wind power plant is 1.5 MW and its hub height is 80m according [3]. The life time t_L is 20 years, which is usually employed in the foregoing studies.

Since the estimation of embodied CO2 emissions of wind turbine is not the scope of this study, we employed the CO_2 emission of wind power plant C_m [kg] from the foregoing studies. Reviewing the LCA studies of wind turbine, the CO2 emissions of wind turbine vary because of the size of plant and its site condition (on shore or off shore) [6-8]. Here, we adopted nearly 400 t CO_2 emissions per MW are assumed for the 1.5 MW wind power plant [8].

The CO_2 emissions per kWh in the grid c_e are estimated using AIST-LCA ver.5 and IEA data [9-11].

The CO_2 emissions per kWh of wind energy and the CO_2 payback time is estimated as the following equation.

$$c_w = \frac{C_m}{Et_L} \tag{1}$$

$$CPT = \frac{C_m}{c_e E} \tag{2}$$

3. Result

The wind energy potential in the world is estimated using the analytical method by foregoing studies and NASA database as shown in the method section. The variance of wind energy potential in the world is quite large. There are large potentials in the central region in US, the central and south regions in the southern America, the Midwest in China, and some regions in Europe.

On the other hand, the suitable locations to reduce the CO_2 emissions are different from those to increase the wind energy because the CO_2 emissions per kWh in the grid also changes by the country. Considering the CO_2 emissions per kWh in the grid, the suitable locations are Mongolia, Midwest China, Kazakhstan, Australia, and so on because of their large CO_2 emissions per kWh in the grid. The countries with large CO_2 emissions per kWh depend on the coal fired power plant.

The CO_2 payback time is a few months in the locations with large potential of wind energy and large CO_2 emissions per kWh in the grid. Compared with the results in the foregoing study [2], the CO_2 payback time of wind energy is relatively smaller than that of PV at the optimum locations for the both renewables.

4. Conclusion

In this study, we investigated the wind energy potential at each location in the world using the analytical method of the foregoing study and the NASA weather database. Also, we estimated the CO_2 emissions per kWh and CO_2 payback time considering the embodied CO_2 emissions of wind turbine and CO_2 emissions per kWh in the grid. We found that the suitable locations to reduce CO_2 emissions by wind energy are different from those to generate wind energy itself because of the CO_2 emissions per kWh in the grid. Therefore, it is important to consider the CO_2 emissions per kWh in the grid to reduce the CO_2 emissions by wind energy. Finally, we found that the CO2 payback time of wind energy is relatively smaller than that of PV at the most suitable locations for the both renewables.

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Life Cycle Environmental Impacts of Electricity from Renewable Resources in Turkey

Burcin Atilgan[1*] and Adisa Azapagic[1]

[1]*The University of Manchester, UK*
*Corresponding author: burcin.atilgan@postgrad.manchester.ac.uk

1. Introduction

Turkey is a developing country with a rapidly growing economy and population. The electricity demand in Turkey has been growing rapidly, reaching 211,208 GWh in 2010, almost seven-fold higher than in the mid-80s. The high share of fossil fuels in Turkey's electricity mix (73.6%) together with the increasing demand has led to a steady increase in greenhouse gas (GHG) emissions from the sector, growing by 115% between 1990 and 2010 [2]. It is, therefore, important that Turkey identifies and implements sustainable energy technologies suitable for the country, if climate change and other environmental impacts are to be curbed.

In an attempt to effect this, the government has been trying to increase the share of renewables which in 2010 contributed 26.4% to the total electricity generation, with hydropower being the major renewable source (24.5%) [1]. However, their potential to help Turkey reduce its GHG emissions and other impacts is currently unknown. Therefore, this is the subject of this paper.

2. Methodology

The LCA has been carried out following the ISO 14040/14044 guidelines [3]. GaBi v.6 [4] has been used for LCA modelling and estimation of the impacts.

The goal of the study is to estimate the life cycle environmental impacts of electricity generation from renewable sources in Turkey, using 2010 as the base year. Two functional units are considered:

i) generation of 1 kWh of electricity by reservoir, run-of-river, wind and geothermal power plants; and

ii) annual generation of 55,379 GWh of electricity from these power plants in 2010.

The scope of the study is from cradle to grave, comprising electricity generation as well as plant construction and decommissioning (Figure 1).

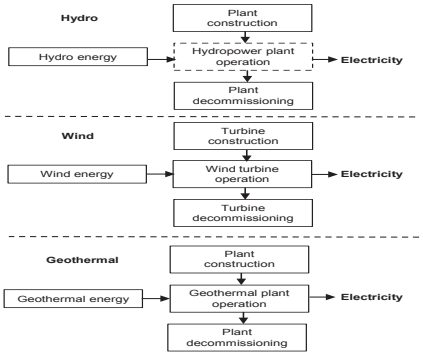


Figure 1. The life cycle stages of renewable electricity

There are 55 reservoir hydropower, 205 run-of-river hydropower, 39 wind and 6 geothermal power plants in Turkey all of which are considered in this study.

3. Results and discussion

The environmental impacts have been estimated following the CML 2001 impact assessment method [5]. The following eleven impacts are considered: abiotic depletion potential (ADP elements and fossil), acidification potential (AP), eutrophication potential (EP), fresh water aquatic ecotoxicity potential (FAETP), global warming potential (GWP), human toxicity potential (HTP), marine aquatic ecotoxicity potential (MAETP), ozone layer depletion potential (ODP), photochemical ozone creation potential (POCP) and terrestrial ecotoxicity potential (TETP).

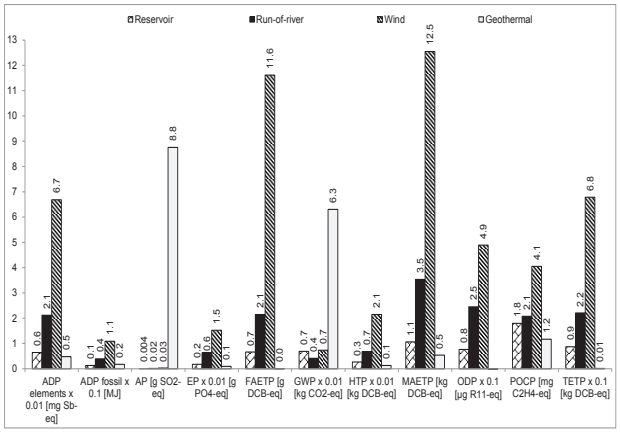


Figure 2. Environmental impacts from renewable electricity sources in Turkey, expressed per kWh

The results indicate that electricity from onshore wind is the worst option overall, with nine out of 11 impacts higher than for hydroelectricity options and geothermal. This is due to the impacts from the materials used to manufacture wind turbines. However, its GWP is 89% and 43% lower than for geothermal power and run-of-river hydropower, respectively. The GWP is similar for reservoir and wind, estimated at 7 g CO_2-eq./kWh. The AP of geothermal power is around 293 times higher than for wind power.

As the results of this study suggest, construction of the power plant is the main contributor to the impacts. Recycling of materials at the end of their useful time instead of landfilling reduces the environmental impacts by up to 40%.

The annual GWP is estimated at 404 kt CO_2-eq., of which reservoir power contributes 76.8%, geothermal 10.4%, run-of-river 7.5% and wind 5.3%.

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Water-based life cycle assessment of power generation and supply in Thailand

Tomohiro Okadera,*[1] and Shabbir H. Gheewala[2, 3]

[1]*National Institute for Environmental Studies, Japan*; [2]*King Mongkut's University of Technology Thonburi, Thailand*; [3]*Ministry of Education, Thailand*
*Corresponding author: okadera@nies.go.jp

1. Introduction

Energy demand of Thailand is rapidly increasing because of industrialization, urbanization and increasing number of tourists [1]. Especially power consumption, where the annual growth rate was 10% for 2010 [2], significantly increases making sustainable power supply one of the most important policies for the residents, industries and tourists. The Thai government promotes development of renewable energy systems such as solar, biomass and hydro power systems and importation from foreign power suppliers as well as the existing power generation plants [3]. With increasing energy consumption, domestic power generation and importation has also increased; especially the imported electricity for 2010 was 89% more than the previous year [2].

Power generation requires a lot of water, so in this study we attempt to evaluate water for power generation and supply in Thailand using a life cycle perspective.

2. Methodology

First we identify a life cycle inventory of the power generation and supply systems in Thailand for 2010 based on energy statistics [2, 4, 5]. This indicated that 574 million GJ of electricity is produced by thermal, hydro and other power plants with 1,495 million GJ of fuels such as natural gas, coal and its products, petroleum products, hydro, renewable energy and waste, geothermal, solar, wind, black liquor and residual gas. In addition, 26 million GJ of electricity is imported from Laos and Malaysia whereas 5 million GJ is exported to Laos, Cambodia and Malaysia.

Next we set water consumption parameters (WCPs) of power generation based on fuel oil, lignite, coal, natural gas, diesel, hydro, solid biomass, biogas, solar, wind, geothermal and others, and fuel production such as coal, natural gas, petroleum products, solid biomass and biogas [6-9]. Then we calculate the life-cycle water consumption by a bottom-up approach, namely multiplying fuel input, power generation, imported and exported electricity by WCPs.

Furthermore, we calculate stress-weighted water footprint, which takes water stress characterization by nation into account [10, 11], for evaluating the environmental impact to water ecosystems. Thailand trades electricity with Laos, Malaysia and Cambodia, whose water stress indices 0.0252, 0.0434 and 0.0893 respectively while that of Thailand is 0.534 [11].

3. Results and discussion

The results show that 415 million m^3 of water is directly consumed at the power plants while 229 million water m^3 is indirectly consumed for the fuel production.

Additionally, 140 million m^3 of water is virtually imported for power supply in Thailand whereas 4 million water m^3.is exported for foreign power supply. Thus the water footprint to supply electricity (sum of direct water consumption of domestic power plants and net virtual water imports) is estimated as 551 million m^3. However, the stress-weighted water footprint is only 222 m^3 because water stress indices of Laos and Malaysia which are the foreign power suppliers are significantly lower than Thailand, which itself has a medium water stress index.

Table 1. Water footprints of the power generation in Thailand

Methods	Net import	Direct water consumption	Water footprint
Standard	136.4	415.1	551.5
Stress-weighted	1.3	221.7	223.0

With taking account of water stress, the share of net import (2%) gets smaller than that of the standard method (24%).

4. Conclusion

This study evaluates the pressure to water ecosystems by power generation and supply in Thailand. We found that more water corresponding to 55% of the direct consumed water is indirectly required for the power generation. 24% of water is virtually imported for the power supply, but the environmental impact is not so much from a water stress perspective.

Acknowledgments

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The Concept of Efficiency in the Context of Sustainable Energy Consumption: Theoretical Considerations and Legacy

Harald E. Otto

Polytechnic University of Marche, Italy
h.e.otto@univpm.it

1. Introduction

Work on energy analysis and energy consumption research began in the 1970s in response to the energy crisis. Initial research concentrated mainly on improvement of the technical properties of equipment, and, to some extent, on behavior aimed at increasing energy efficiency. In both areas, efforts were directed towards the creation of change using energy efficiency as a leading principle. Now, over the past decade, sustainability and climate change have become increasingly important both locally and globally, and have influenced the decision making and activities of all communities and of humanity as a whole as we work towards a future which offers increased harmony between human activities and the systems of the biosphere.

The requirement for research into energy efficiency has made it necessary to broaden the approaches that were defined by the traditional boundaries of disciplinary concepts and models. Multi-disciplinary and interdisciplinary concepts and approaches are necessary not only to help us to develop better technology but also to enable us to understand how energy is used. Thus we can envision means of change for the better within a socio-technological and economic context.

2. Notion and conceptualization

Efficiency is a context-dependent notion. In the technical or engineering sense, efficiency is defined as the ratio of output to input, thus quantifying yield achieved compared to resources used. This is different from the concept of effectiveness, which relates to the capability of producing a desired result or outcome (cf. [1,2]). It describes the degree to which outcomes of programs or strategies match previously set objectives. Of particular interest to program and strategy assessment is the concept of cost-effectiveness, which relates the input of a program or strategy to outcomes achieved. Hence, effectiveness is focused on the achievement of desired outcomes as such, while cost-effectiveness considers the resources required and actually spent in achieving given objectives.

From an historical viewpoint, efficiency developed from a philosophical concept in early modern periods to a concept used to express specific forms of rationality. Efficiency evolved into an important technological value supporting the construction of modern industrial societies and it has become increasingly important to post-industrial societies and economies, especially in relation to our efforts to reduce waste and to manage resources sustainably [3,4]. As a particular technical assessment, its legacy is linked to the experience of industrialization, while being bound to measurements of performance in systems and processes considering the thermodynamics of energy. Hence, efficiency is not just an intellectual concept nor an instrumental value attached to goals, but a value attached to systems and processes entailing the apportioning of means to ends. Here, efficiency can be seen as a measure of surmounting and controlling the means for achieving such ends, i.e. facilitating the use of the least or desired amount of resources to achieve a predetermined outcome.

3. Scope and outline

However, due to its defining properties and the variety of ways in which it can be used, efficiency is not limited to applications within contemporary engineering and technology. It rather represents a construction which is designed to help control and manage systems and processes, but which also provides for an intellectual understanding that can be made practically effective. Hence, efficiency is likely to become increasingly instrumental in the translation and implementation of visions and efforts worldwide (cf. [5]). It has the potential to transform current unsustainable human behavior and developments by reducing the steadily increasing per capita input in consumption to levels that make human endeavor sustainable again in respect to our planet's ecosystems. In this first part of a two-part paper, several important issues connected with efficiency are examined in relation to its historical background and scope. The focus will be on the concept of efficiency and its use, the metaphors developed and used, the methods of measurement, and the conditions and context within which it is pursued. This will provide a basis to facilitate analysis of the current technical, social, and economic implications of the concept of efficiency, and of any shortcomings in the application context of sustainable energy consumption. Such analysis will then be presented in the second part of this paper in [6].

4. Conclusion

Since the concept of efficiency is context-dependent, there exists no general efficiency formula as such, because the techniques for interpreting and measuring efficiency depend on the model that is also the benchmark. Efforts to design ways of optimizing the output-input relationships of processes have to contend not only with a virtually unlimited number of parameters, but also with the fact that those parameters are subject to technological conditions. Moreover, they are also socially determined and influenced by economic pressures.

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Life Cycle Energy and Environmental Assessment of Bio-CNG Utilization from Cassava Starch Wastewater Treatment Plants in Thailand

Seksan Papong,[1] Paritta Rotwiroon,[2] Thawach Chatchupong,[2] Pomthong Malakul[1,3,*]

[1]*National Metal and Materials Technology Center, Thailand;* [2]*PTT Research and Technology Institute, Thailand;*
[3]*The Petroleum and Petrochemical College, Chulalongkorn University, Bangkok, Thailand*
*Corresponding author: Pomthong.m@chula.ac.th

1. Introduction

In Thailand, cassava starch extraction processes require a large volume of water and these in turn produce a large amount of wastewater as 20 m^3 of water is required per ton of starch being produced. The cassava processing plants usually generate two types of wastewater. The first type is generated from washing and peeling cassava roots in the rotary drum. The second is generated from draining the starch sedimentation tank which has high COD and BOD [1]. The purpose of this study was to assess life cycle energy and environmental performance of biogas from cassava starch wastewater treatment plant as a transportation fuel.

2. Methodology

The analysis of this paper was done based on the guidelines for LCA according to ISO 14040 series [2]. LCA modeling was complied by using SimaPro v7.3 software (Pre Consultants b.v.) with the CML 2 baseline 2000 method. The functional units for this study were set to be 1 MJ of biomethane gas (CBG or bio-CNG) and 1 km of vehicle driven. Figure 1 shows the system boundary of the whole life cycle (from Well-to-Wheel) of biogas in this study which covers six stages: digestion, purification and upgrading, compression, distribution, refueling, and combustion.

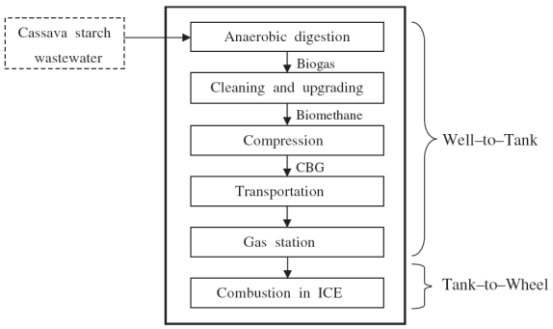


Figure 1. System boundary of this study.

The feedstock for biogas production in this study was primarily the wastewater from cassava starch production. The technologies for biogas production considered in this analysis were anaerobic digestion based on UASB system and three different biogas upgrading technologies including water scrubbing (WS), pressure swing absorption (PSA), and membrane separation (MS). For vehicle operation, only the exhaust emissions from the vehicle based on compressed natural gas were studied. Most data were collected at actual sites in Thailand.

3. Results and discussion

3.1 Net energy ratio (NER)

As shown in Figure 2, the NER of the CBG systems based on WS, PSA, and MS was 4.81, 4.26, and 4.73, respectively. The energy use in the biogas upgrading stage was the highest (42.0-48.4%) followed by anaerobic digestion (20.8-23.2%).

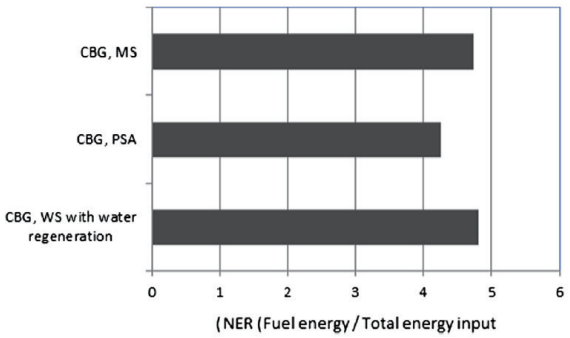


Figure 2. NER of CBG systems.

3.2. Global warming potential (GWP)

Figure 3 shows that the overall GWP from feedstock to combustion ranged from 175 to 194 g CO_2 equivalent per 1 km car driven, depending on the upgrading technology. When comparing three biogas upgrading technologies, WS had the least GHG emission.

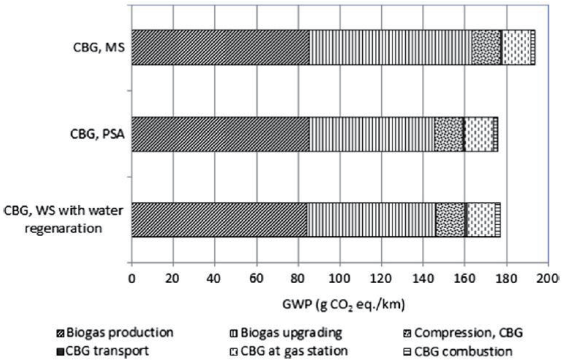


Figure 3. GWP indicator of CBG WTW phase.

4. Conclusions

From the life cycle energy analysis, NER values for cassava starch wastewater were 4.81, 4.26 and 4.73 for WS, PSA and MS, respectively. The results of the life cycle GHG emissions show that the major environmental impacts resulted mainly from CH_4 loss in the anaerobic digestion and biogas upgrading stage.

Acknowledgments

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The Concept of Efficiency in the Context of Sustainable Energy Consumption: Current Practice and Shortcomings

Harald E. Otto

Polytechnic University of Marche, Italy
h.e.otto@univpm.it

1. Introduction

Efficiency, a context-dependent notion and important technological value, was instrumental in supporting the construction of modern industrial societies. It has contributed to the successful development of new sources of power, to technologies for converting energy into useful work, to mass production, to scientific management, and to modern business enterprises. Those productivity-improving technologies and work processes, combined with efforts to foster economic growth, have led to a steadily increasing per capita input into the consumption of resources so that we have now reached levels that make human endeavor unsustainable in respect to our planet's ecosystems. Efforts worldwide within sustainable development place high expectations on efficiency due to its successful legacy and its capacity to represent a construction which is designed not only to help control and manage systems and processes, but also to provide for an intellectual understanding that can be made practically effective.

2. Scope and outline

Unfortunately, in the energy context, the value and role of efficiency remain less than modest in current efforts to bring about a behavior change towards cost-effective and environmental-conscious energy consumption and to accelerate the adoption of efficient energy services along with the production of clean renewable energy. Compelling evidence of this situation is provided by numerous mostly disciplinary studies and reports on what have been identified as energy market imperfections, innovation market barriers, consumer behavior failures, information campaign failures and knowledge problems (cf. [1,2]). The last, considering current efforts to develop information and knowledge-oriented technologies, economies, and social constructs, not only deserve, but rather require, more serious attention and thorough analysis than is currently the case. In this second part of a two-part paper, an interdisciplinary study on energy efficiency is offered. This study relates to investment in producing energy services and behavior change-induced energy conservation. It takes a life-cycle approach with a focus on informational strategies and knowledge generation, as well as on organization. The theoretical foundation presented in the first part of the paper [3] is employed to analyze current technical, social, and economic implications and shortcomings.

3. Curent models and approaches

In traditional models and approaches, technology and behavior are somewhat separated when they are being related to energy-efficient machinery / equipment, and conservation of energy, with the latter primarily seen as actions of management, with curtailment aimed at reducing either energy usage or costs in general. Such a scenario is not structured to gain insight on how members of society, whether they be individuals, households or organizations, perceive energy, plan and actually purchase energy and energy-producing equipment, or how they perceive energy use per se. By sub-dividing the socio-technical and economic contexts, it is also impossible to account for external parameters, such as indirect energy use, geographic location, and size of dwellings, which impact both the process of energy consumption or power generation and actual outcomes achieved. Models and approaches that define and study energy efficiency employing economic concepts related to costs, benefits, and economic agents are usually chosen due to their analytical simplicity and usefulness in addressing empirical problems. In particular, adjusted models taking into account bounded rationality of people and market imperfections helped to conceptualize so-called *market barrier models*. Although these approaches are capable of partially integrating some aspects of the technical, social, and economic dimensions, they are still quite limited when it comes to answering questions related to understanding the perception, purchase and use of energy (see also discussion in [4]).

4. Summary and concluding remarks

The study provides some insight into the structural and conceptual limits and shortcomings of models and approaches in the fields of energy analysis and energy consumption research in respect to information provision strategies and programs. In particular, attention has been given to newly emerging phenomena and structures related to currently evolving information societies and to the rise of knowledge economies in industrial nations and how this relates to the subject of the study. Results obtained offer pointers on how to better integrate and connect disciplinary knowledge and the findings of empirical studies, which remain still rather fragmented, and how to formulate new concepts and approaches that help to answer questions regarding the understanding of energy use and consumption within a socio-technical and economic context. These are preconditions that must be attained in order to enable the design of better and more effective energy efficiency measures and interventions. They will also contribute to the advancement of knowledge and to technical as well as social innovation within the larger scope of sustainable development.

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Evaluating the Greenhouse Gas Emissions and the Life Cycle Cost of Thermoelectric Generators for Passenger Automobiles

Yusuke Kishita,*[1] Yuji Ohishi,[1] Michinori Uwasu,[1] Masashi Kuroda,[1] Hiroyuki Takeda,[1] and Keishiro Hara[1]

[1]*Osaka University, Japan*
*Corresponding author: kishita@ceids.osaka-u.ac.jp

1. Introduction

With the aim to realize a low-carbon society, a thermoelectric generator (TEG) is a potential energy harvesting technology by generating electricity from waste heat. One of the strengths of TEGs is to retrieve electric energy from waste heat whose temperature is as low as 200-300 degrees Celsius. Yet, the conversion efficiency of the current thermoelectric materials remains low at the level of 5-10%, which makes it difficult to diffuse TEGs in society. Much effort is thus being devoted to improving the conversion efficiency by inventing new thermoelectric materials. However, few studies have been conducted to clarify to what extent TEGs can contribute to realizing a low-carbon society.

In order to clarify required performances of TEGs to diffuse them in the future, this paper assesses the life cycle CO_2 emissions ($LCCO_2$) and life cycle cost (LCC) of TEGs based on several lifecycle scenarios. A case study of bismuth telluride (BiTe) TEGS for passenger automobiles is illustrated, where the region of interest is Suita City, Osaka, Japan.

2. A method for life cycle evaluation of TEGs for passenger automobiles

We evaluate lifecycle scenarios of TEGs from the viewpoints of $LCCO_2$ and LCC by modeling each scenario as a combination of processes. We define five types of processes, that is, (i) material production, (ii) product assembly, (iii) transportation, (iv) use, and (v) end-of-life. Notably, in the use process, we evaluate the reductions of cost and CO_2 emissions because of gasoline savings as the effect of using TEGs. Detailed formulae of the processes are described in our preceding study [1]. In each of lifecycle scenarios, specific conditions surrounding individual processes are assumed, such as usage conditions (*e.g.*, when people use TEGs) and the performances of TEGs (e.g., conversion efficiency).

3. Case study

We carried out a case study of installing TEGs in passenger automobiles in Suita City, Osaka, Japan. In the case study, we focused on BiTe TEGs since they are suitable for the exhaust gas of passenger automobiles, whose temperature is around 300 degrees Celsius. The evaluation boundary was set from the material extraction to the landfill of TEGs. We assumed that TEGs are used along with the life span of passenger automobiles (*i.e.*, 12 years) and then landfilled.

We assumed two lifecycle scenarios according to the conversion efficiency of TEGs – (A) Baseline Scenario and (B) Technology Innovation Scenario. The conversion efficiency in Scenario (A) was set at 2013 is 7.2% by assuming the current level [2], whereas that in Scenario (B) was set at 17.7% based on the technology roadmap in 2030 [3].

For evaluating the two scenarios, we collected as much inventory data relevant to BiTe TEGs as possible through literature reviews and interviews. Also, we conducted a questionnaire survey in collaboration with Suita City in order to obtain detailed data on passenger automobiles in Suita City, including the distribution of annual driving distance.

Figure 1 shows the mean $LCCO_2$ and LCC of TEGs per automobile. The mean $LCCO_2$ in Scenarios A and B are -161 $kgCO_2$ and -713 $kgCO_2$, respectively. It is also shown that the TEG price needs to decrease by 90% to make the LCC zero.

As described in Figure 2, the gas savings in Scenarios (A) and (B) amount to 1.9-2.3%/year and 5.4-5.5%/year of the gas consumption of an automobile. If all the gasoline vehicles in Suita City are equipped with TEGs, the annual gasoline savings in the city reach 934kL/year (Scenario A) or 2,440kL/year (Scenario B). As the result, the CO_2 reduction amounts to 0.07% (Scenario A) - 0.30% (Scenario B) compared to the whole CO_2 emissions of the City (1,499 thousand tCO_2).

4. Summary

This paper assessed the life cycle CO_2 emissions ($LCCO_2$) and life cycle cost (LCC) of TEGs for passenger automobiles. Future work includes further sensitivity analysis to clarify critical factors to the $LCCO_2$ and LCC of TEGs.

Acknowledgments

We are grateful to Suita City of Osaka Prefecture, Japan, for providing necessary dataset to carry out this research.

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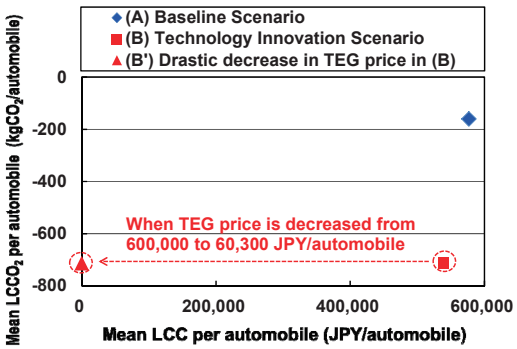


Figure 1. Mean $LCCO_2$ and LCC of TEGs per automobile

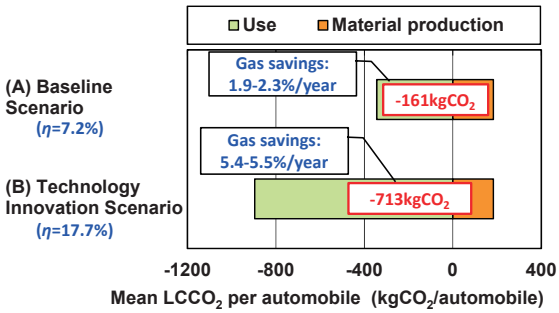


Figure 2. Breakdown of $LCCO_2$ by scenario

An proposal of the eco-efficiency of the Fuel Cell co-generation System of "Ene-Farm" in consideration of the CO_2 emission and metal resources depletion

Yusuke Jinno,*[1] Kenji Koido,[1] and Kiyoshi Dowaki[1]

[1]*Tokyo University of Science, Japan*
*7414615@ed.tus.ac.jp

1. Introduction

Recently, the household fuel cell cogeneration system known as "End-Farm" has been promoted in Japan. However, on the technological advantages including the authorized environmental effects seem to be not so many examples yet. In the Japanese manufacturer group, as a first step, they began to establish the inventory analysis based on the conventional LCA methodology and propose the eco-efficiency in consideration of the life cycle CO_2 (LC-CO_2) emission and metal resources depletion. That is, they try to confirm the significance of Ene-Farm due to the environmental appropriateness. Based on this activity, we propose the improved eco-efficiency on the advantage of technology from sustainable aspect. For the indicated indexes, we discussed about the uncertainties in emissions database and/or the validity of indexes.

2. Analysis Condition

In this study, we targeted Ene-Farm of the co-generation system on basis of Polymer electrolyte fuel cells (PEFC). We basically utilized the report at Mizuho Information & Research Institute, Inc as the reference specification date [1]. We defined the system boundary including the range from mining process to product one. Note that we ignored the eco-burden of fabricating process, which is smaller in comparison to the total influence. The direct intensities, which are corresponding to the energy consumption for operating this system, were out of range. Because the factor of energy consumption is various, and our purpose is to find out the advantages of the product.

3.1 Definition of the Improved Eco-efficiency

In this study, we conducted an inventory analysis on energy intensity and CO_2 emission in use of the Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables(3EID). In general, the validity of all inputs would be required in this methodology. However, on the highly confidential system like PEFC, we cannot collect all inputs so as to analyze the environmental indexes. Thus, we need to examine to somewhat extent this variability effect on the result. Because the factor of energy consumption is various, and our purpose is to find out the advantages. Also, we have to consider the communication index so that the end-users judge the eco-burden and the performance to some extent. Here, for the purpose, we defined the following environmental efficiency which was provided by the product performance and the eco-burden of LC-CO_2 emission or metal resource depletion. With respect to the environmental efficiency of LC-CO_2 emission, we considered the deviation on the specific data on the items which are categorized in IO-table. We argued the following two scenarios: (1) weight saving of iron material (Scenario 1), and platinum consumption of one tenth in comparison to the conventional unit (Scenario 2).

Finally, we evaluated the value due to the consumption change of platinum and iron. Here, on the unit price of Ene-Farm, we refferd to the date of NEDO. Also, we defined the value of Ene-Farm from the viewpoint of metal resources consumption as follows:

$$RVj_\alpha = \frac{PEne_\alpha}{AUj \times Pj_\alpha} \quad (1)$$

Where, α, RVj_α, $PEne_\alpha$, AUj, and Pj_α are the target periods (2015～2030), the resource value of j-material (P: platinum, F: iron) [-],the unit price of Ene-Farm in α-year [yen/unit], and the price value of j-material [g/unit], respectively. Based on our investigation, we assumed that the price values in 2014 were 5,010 yen/g of platinum and 320,000 yen/t of iron, and that the reserves (Dj) were 7.1×10^4 t of platinum and 7.9×10^{10} t of iron. At the present, the annual consumptions were 445 t-platinum/yr and 858×10^6 t-iron/yr, respectively. If the each resource value corresponding to platinum or iron consumption by introducing Ene-Farm in the future is defined as Cj_α, Pj_α is shown as the following equision.

$$Pj_\alpha = Pj_{2014}/\left(1-\frac{445(\alpha-2014)+\sum_\alpha Cj_\alpha}{Dj}\right) \quad 2015\leq\alpha\leq2030 \quad (2)$$

4. Results

The result of eco-efficiency shows in Fig.1. As a result, on the eco-efficiency on CO_2 emission basis, 4.22×10^{-2} to 4.81×10^{-2} MWh/kg-CO_2eq/kW in scenario 1 and 4.52×10^{-2} to 4.88×10^{-2} MWh/kg-CO_2eq/kW in scenario 2 were obtained, and on that metal resource depletion, 31.3 MWh/kg-Sb/kW in scenario 1 and 27.3 MWh/kg-Sb/kW in scenario 2 were estimated, respectively. We would be able to find the differences on basis of each scenario in spite of somewhat deviation.

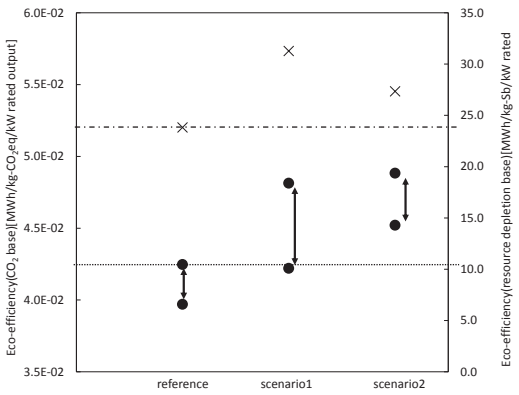


Figure1. Eco-efficiency

On the result of resource value, for instance, in the platinum case, the value would be approximately 1.93 times against that in 2015. Based on the scenario 2, the deference would be 10.0 point in comparison to the conventional one.

5. Conclusions

We defined the eco-efficiencies on CO_2 emission and metal resource depletion and we analyzed the influences of Ene-farm promotion on basis of some scenarios. Through our research, the index of eco-efficiency, which we proposed, would become extremely important.

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Cost, CO_2 Emission and Energy Consumption of Bioethanol Production from a Lignocellulosic Energy Crop, *Erianthus sp.* by SRB-CaCCO process

Takahiro Orikasa*[1], Ken Tokuyasu[2], Masakazu Ike[2], Rui Zhao[2], Mitsuru Gau[3], Shoji Koide[1], and Takeo Shiina[4]

[1]*Iwate University, Japan*; [2]*National Food Research Institute, NARO, Japan*;
[3]*Kyushu Okinawa Agricultural Research Center, NARO, Japan*; [4]*Chiba University, Japan*
*Corresponding author: orikasa@iwate-u.ac.jp

1. Introduction

The interest in bioethanol as an alternative to fossil fuel for transportation has been increasing, and lignocellulosic biomass, such as agricultural waste, woody biomass, and lignocellulosic energy crops (such as *Erianthus* and *Miscanthus*), is expected to be the new second-generation bioethanol resource [1]. The SRB-CaCCO (Simultaneous Recovery of By-products and Calcium Capturing by Carbonation) process was recently reported as an integrated process for phenolic acid recovery as valuables in addition to fuel ethanol (bioethanol) production from herbaceous feedstock [2]. In order to promote an action for the construction of commercial bioethanol plant by SRB-CaCCO process, the costs, CO_2 emissions, and energy ratios for bioethanol production should be evaluated. However, these have not yet been reported. In this study, cost, CO_2 emission and energy consumption of bioethanol production from *Erianthus sp.* were analyzed.

2. Methods

The process of bioethanol production from *Erianthus* (*Erianthus arundinaceus*) by SRB-CaCCO process was evaluated in terms of the total cost, CO_2 emission, and energy ratio. The system boundary included collection of biomass, distribution of biomass and ethanol production process. The LCI analyses have been done based on three scenarios (base case, innovative case, and futuristic case) established for the process evaluation (Table 1).

The total CO_2 emissions were calculated by multiplying the coefficients of CO_2 emissions for fossil fuel, electricity and (if any) utilities (including the bioethanol plant construction process) by the respective values of consumption from each of these sources and then summing the results. The coefficients of the CO_2 emissions for fossil fuel, electricity and utilities (including direct energy use and indirect energy use) [3] and for bioethanol plant construction [4] were obtained from the literature. The total CO_2 emissions and energy consumption were allocated to produced bioethanol and by-products (*p*-coumaric acid, ferulic acid and silica) by price value basis.

3. Result and discussion

The total cost of bioethanol production by SRB-CaCCO process was estimated to be 84-128 Yens/ L-ethanol (Fig.1). A gain on sale of by-product, such as *p*-coumaric acid and ferulic acid, had an effect for reducing the total cost of bioethanol production. The CO_2 emission and energy consumption were estimated to be 1.12-1.71 kg-CO_2/ L-ethanol and 12.2-18.9MJ/ L-ethanol, respectively. The lower expected energy consumption of by-product production process in SRB-CaCCO could result in reduction in both the CO_2 emission and the energy consumption. These results suggested that the SRB-CaCCO process could be an environmentally-friendly technique for producing bioethanol from lignocellulosic biomass.

Acknowledgments

This work was supported by a grant from the Ministry of Agriculture, Forestry and Fisheries of Japan (Rural Biofuel Research Project; 310, 311).

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Table 1 Parameters of bioethanol production conditions

	Base	Innovative	Futuristic
Pretreatment			
Electricity of milling [kWh/kg-BM]	0.039	0.039	0.039
Heating time [h]	1	1	1
Heating temperature [°C]	120	100	95
Boiler efficiency [%]	80	80	80
Heat loss[%]	20	20	20
Solid content of pretreated sample [%]	20	22.6	22.6
Biomass input [t/day]	215	186	180
Lime concentration [%]	10	10	10
Saccharification and fermentation			
Enzyme protain loading [mg/g-cellulose]	15	15	2.5
Protain production efficiency [kg-protein/kg-C]	0.22	0.22	0.24
Enzime production rate [g-protein/L/hr]	0.15	0.15	0.3
Enzime production time [h]	168	168	168
Fermentation time [h]	78	78	60
Distillation and purification			
Ethanol concentration [%]	5	5.5	5.5
Ethanol yield [L/kg-dry]	0.212	0.213	0.252
Methane fermentation			
Amount of waste liquid after distillation [t/day]	200	200	200
By-products			
Materials		*p* CA, FA, Silica	
Recovery of *p* CA [g/kg-BM]	9.7	9.7	9.7
Recovery of FA [g/kg-BM]	2.8	2.8	2.8
Ratio of Silica [%]	17.3	17.3	17.3
Electricity [kWh/kg-BM]	1.64	1.64	1.64

**p* CA means *p*-coumaric acid. FA means ferulic acid.

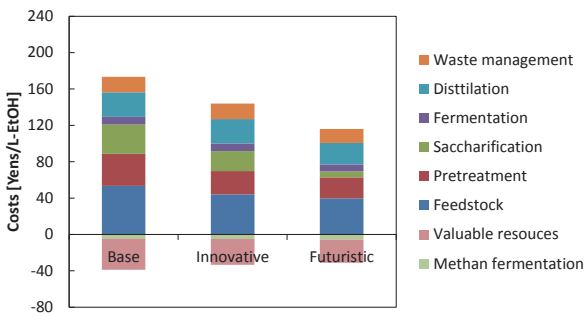


Fig.1 Breakdown of the total costs of the production of bioethanol from rice straw

Evaluation of Power Interchange Potential and Supply-demand Balance of Distributed Generation in Kinki

Daisuke Fukuhara,*[1] Naoki Yoshikawa, [1] Koji Amano, [1] and Koji Shimada[1]

[1] *Ritsumeikan University, Japan*
*Corresponding author: rv006078@ed.ritsumei.ac.jp

1. Introduction

In order to reduce the risk that depends on only the large-scale centralized generation, power supply by distributed generation is attracting attention. However, the stability of the supply-demand balance has become an issue because power generation amount of renewable energy and power demand have variation by district and time. When introducing a mass renewable energy, to stabilize supply-demand balance, the charge-discharge of the battery and power interchange are necessary to alleviate the variation with district and time.

There are research using Geographic Information System (GIS), to evaluate the potential of new energy [1, 2], and there are also studies of smart grid [3]. However, there is not much research to evaluate the supply and demand balance and power interchange potential using GIS.

This study evaluated the reduction of dependence on large-scale centralized power generation and the stability of system for charging-discharging power and power interchange of surplus power generated by distributed generation in Kinki region, Japan. We have estimated power generation potential and demand of power by time period in each district by using GIS. In addition, we evaluated the effect of the power interchange with supply-demand balance in consideration of variation with time or district.

2. Methods

In this study, in order to estimate the supply and demand balance of power that targets the Kinki region, from weather observations [4] and statistical data [5], we estimated the available supply of natural renewable energy and power demand by using the GIS. By using the estimation results of the supply-demand balance, this study evaluated the local area and Kinki whole power self-sufficiency rate, power supply configuration ratio, the amount of power interchange, the cumulative amount of storage, and supply and efficiency.

3. Results

As shown in Figure 1, this study revealed difference of common supply-demand balance through the year between the mountainous area and urban area, and it became clear the power storage and power interchange of efficacy for power supply exceeds the demand power in the middle and summer season. As shown in Figure 2, because the excess power by distributed generation is large, it is possible to effectively utilize the surplus electricity by the power interchange and the power storage in interim period. However, power storage and power interchange was less efficacious because power demand does not exceed supply throughout the day in the winter.

4. Conclusion

This study revealed that it can afford to supply power to the residential sector as much surplus power is generated during the day in the interim and summer period and that the more supply is required from the grid power in the early morning and evening.

This study also revealed that it can be increase more alternative power amount to the distributed generation from grid power to storage to prepare for power shortage of night and early morning from surplus power during the day or, to interchange to urban areas where electric power is insufficient from the mountains in the same time.

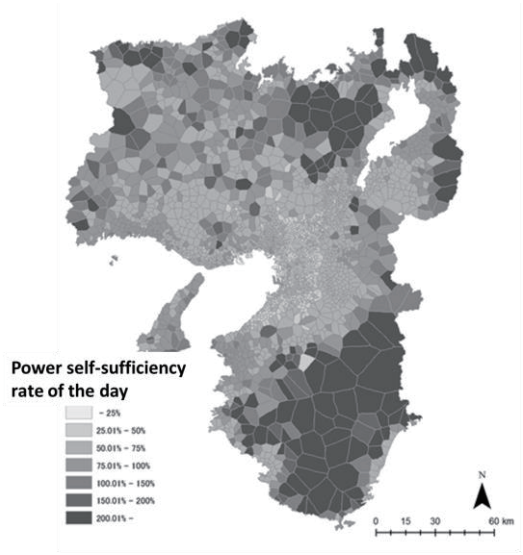


Figure 1. Power self-sufficiency rate of the day (May)

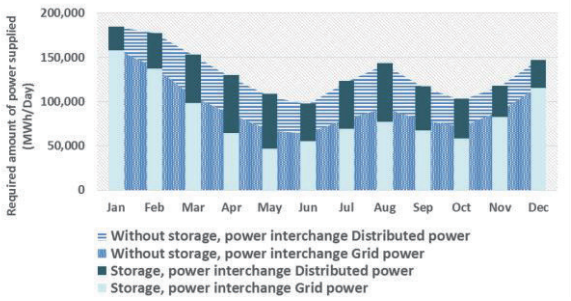


Figure 2. Evaluation of power supply efficiency

Acknowledgments

We would like to acknowledge Nippon Life Insurance Foundation for financial support.

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A Framework to Assess Impacts of Grid Mix Changes in Japan Using Input-Output Tables

Shunichi Hienuki,*[1] Yuki Kudoh,[1,2] and Hiroki Hondo[1]

[1] *Yokohama National University, Japan*; [2] *National Institute of Advanced Industrial Science and Technology, Japan*
*Corresponding author: hienuki-shunichi-sh@ynu.jp

1. Introduction

In the aftermath of the Great East Japan Earthquake that occurred in March 2011, the entire energy demand and supply system in Japan is facing its turning point. The current Strategic Energy Plan [1] does not specify the exact power mix in the future and some factors remains uncertain such as the contribution of nuclear and renewables.

Since the impact associated with future grid mix is not limited to the environment but should affect to socio-economic aspects, a comprehensive approach that could assess the potential impacts should help decision makers select the best choices from the grid mix options. One of the effective tools that are used for this subject is the input-output (IO) table. Using an IO table for future analysis is limited because the industrial structure is fixed to the IO table benchmark year and it is thus not possible to reflect any potential inter-sector transaction changes that may arise from technological progress. However, it is valuable in estimating the future potential impacts that might arise from the current industrial structure and technology level.

This study aims at establishing a framework for evaluating the environmental and socio-economic impacts by power generation technology using the IO table. A case study is conducted using the framework on the potential impacts of Japan's future grid mix scenarios.

2. Socio-Economic and Environmental Impacts Estimation

Employment generation as socio-economic impact and GHG emissions as environmental impact is evaluated by using a hybrid of bottom-up and IO approaches for life cycle inventory analysis (Equations (1)–(2)).

$$L = L_d + \hat{l} \cdot (I - A)^{-1} \cdot f \quad (1)$$

$$G = G_d + \hat{g} \cdot (I - A)^{-1} \cdot f \quad (2)$$

Where, L is the direct and indirect employment, G is the direct and indirect GHG emissions, L_d is the direct employment, G_d is the direct GHG emissions, $\hat{l}$ is the diagonal matrix of employment coefficient, $\hat{g}$ is the diagonal matrix of GHG emissions, I is the unit matrix, A is the input coefficient matrix, f is the final demand, $\hat{l}$ is the number of employees per unit of production, and $\hat{g}$ is the embodied GHG emissions per unit of production. The Japanese 2005 IO table and GHG emissions are used for the calculation [2, 3].

In order to reflect the quality of employment generated in terms of continuous and temporary jobs to the socio-economic impact estimates, the framework considers the differences in lead-times and durable years by power generation technology.

3. Case Study Assumptions and Scenarios

The target power generation technologies are nuclear, three renewables (geothermal, wind and photovoltaic), fossil fuels (coal, oil and LNG) and large-scale hydro. Four life cycle stages of manufacturing and construction, operation and maintenance, safe storage (for nuclear only) and decommissioning are considered for the estimation.

Figure 1 shows the grid mix in 2012 and its future scenarios in 2030 applied to in this case study. The total electricity supply is assumed to decrease by approximately 10% in 2030 from 2012.

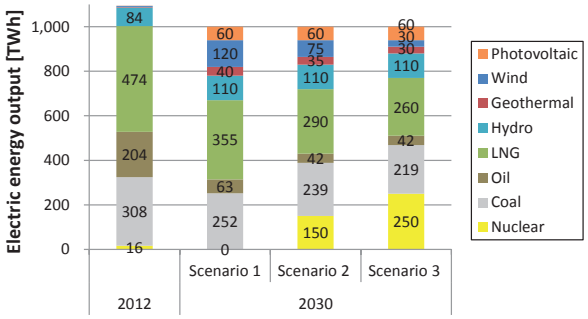


Figure 1. Grid mix scenarios

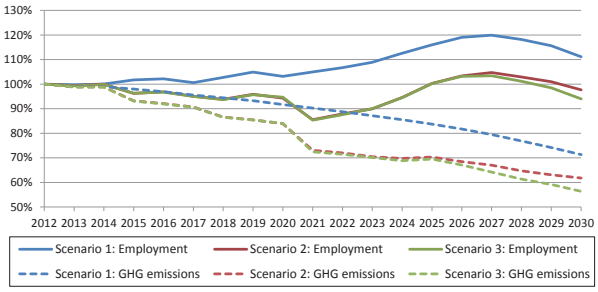


Figure 2. Employment and GHG emissions transitions

The amount of power generation from three renewables towards the future is estimated using logistic equations. Since the scenarios assume preferential electricity supply from nuclear and three renewables, fossil fuel powers play roles to fill the gaps between total electricity demand and supply from nuclear and three renewables. Replacements of three renewables and fossil fuel powers are considered according to their durable years, whereas large-scale hydro only considers operation stage due to its difficulty for their newly-constructions in the current Japanese situation.

4. Case Study Results

Figure 2 shows employment and GHG emissions transitions from 2012 until 2030. The employment generation changes by +11%, -2% and -6% respectively for each scenario in 2030 compared with 1.3 million person years in 2012. All the scenarios show the maximum in 2027 (+20, +5 and +3%) but will gradually balance out because of a decrease in electricity demand. On the other hand, continuous GHG reduction is observed in each scenario.

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Analysis of environmental loads and benefits of a bio-coke production factory: a case study in Osaka

[1)] Yukari Fuchigami, [1)] Keishiro Hara, [2)] Takeo Kita, [1)] Michinori Uwasu, [1,2)] Shuji Kurimoto

1) *Center for Environmental Innovation Design for Sustainability, Osaka University, Japan*
2) *Osaka Prefecture Forest Owners Association*

*Corresponding author: fuchigami@ceids.osaka-u.ac.jp

1. Introduction

In Japan, due to a decrease in the demand for timber and the availability of inexpensive foreign lumber, domestic timber prices have been low. Currently, the domestic forestry industry could not keep operation to sustain itself without subsidies from the central and local governments. These subsidies are insufficient due to the financial constraints and the budget for basic management practices, such as pruning and thinning, is limited. As a result, the forest industry tends to ignore environmental aspects while focusing primarily on the profitability of operations. Moreover, though some practices, such as bio-coke production, have been promoted from the viewpoint of carbon-neutral biomass utilization, actual environmental benefits of such practices have been hardly understood from life cycle perspectives. Against this background, it is necessary to first understand potential environmental loads and benefits in a set of operation processes and to develop sustainable forest management practices that are rational, efficient, and environmentally friendly.

2. Research objectives and methods

In this study, we evaluated the environmental loads associated with bio-coke production processes from woody biomass, particularly focusing on energy consumption and CO_2 emissions. We conducted a case study at Takatsuki Biomass factory of Osaka Prefecture Forest Owners Association. Based on interviews in the factory and field surveys, we obtained data on electricity and fuel consumptions in the manufacturing process along with data on the amount of products based on these data from June 2012 to February 2014. These bio-cokes are used as an alternative fuel for coke in an enterprise. So, we also estimated reductions of CO_2 emission by the alternative use.

We represented bio-coke production flow of Takatsuki Biomass factory in Figure 1. System boundary of this presentation is from raw material production process to using process. The disposal and recycling processes aren't included in the boundary, nor are the waste water treatment of product

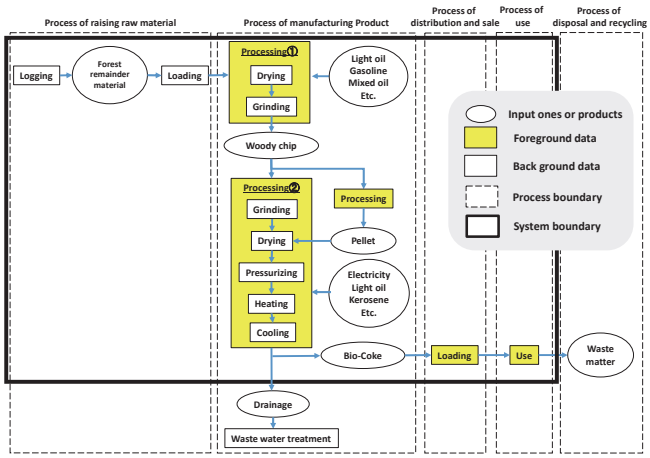


Figure. 1 Life cycle flow of bio-coke

manufacturing process. In addition, we use the background data for the process for procurement of raw materials [1].

3. Result

The amount of CO_2 emissions in the production and transportation of bio-coke was 1.28t-CO_2. Figure 2 shows the classification of CO_2 emissions in each step. It reveals that the majority of the emission is due to the manufacturing process. The largest emission source in manufacturing process was electricity consumption.

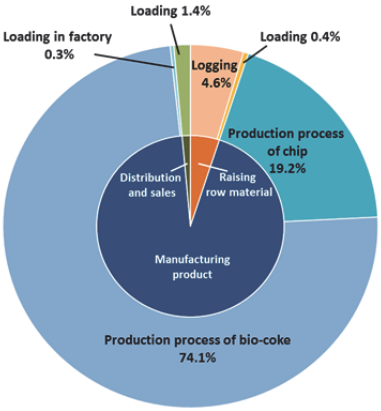


Figure.2 Classification of CO_2 emissions in the bio-coke production

Comparing the amount of heat between bio-coke and coke, 1.7t bio-cokes is required to substitute for 1t coke. CO_2 emissions from use of cokes minus CO_2 emissions of the production and transport bio-coke, it was 0.62t-CO_2 / t. This is the capable amount of reducing CO_2 by an alternative use of bio-coke.

4. Conclusion

Even taking into account the environmental impact during production and transport, bio-coke was concluded to be the ecological fuel. We argued that it is reasonable to anticipate environmental benefit, though more and continuing utilization is necessary by such company. In future study, we aim to propose a comprehensive model of sustainable forest management by looking into other aspects such as cost performances.

Acknowledgments

We are grateful to Osaka Prefecture Forest Owners Association for their help.

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Input-output analysis of introducing smart grid systems in Japan

Satoshi Nakano[1] and Ayu Washizu*[2]

[1]*The Japan Institute for Labour Policy and Training, Japan*; [2]*Waseda University, Japan*
*Corresponding author: washizu@waseda.jp

1. Introduction

Since the Great East Japan Earthquake, attention in Japan has been focused on the construction of an energy system that is more dependent on renewable energies. Construction of new smart grid systems is indispensable to the introduction of renewable energies. Renewable energies are small and distributed, and both photovoltaics (PV) and wind power generation are variable. Consequently, mass introduction of renewable energies can destabilize power flow. The 2006 European blackout is thought to have been partially caused by the broad introduction of wind power, which shows how difficult the introduction of renewable energies can be (Yokoyama [1]). Smart grid technologies are capable of rapidly detecting, analyzing and responding to various perturbations in the network by integrating advanced control methods and equipment (Hidayatullah et al. [2]).

In fact, some engineers are offering alternative smart grid configurations. Because the grid is one of the most basic pieces of infrastructure in a society, the decision-making should be based on social economic considerations. This is the motivation behind our study.

2. Alternative engineering scenarios

The Central Research Institute of Electric Power Industry (CRIEPI) report [3] looked at the effect of the mass introduction of PV and wind power, and the assumptions made can be seen in Table 1. It is assumed that new, efficient thermal and pumped hydro power plants will be constructed to stabilize power systems. Proper power control operation of thermal and pumped hydro power plants can play a positive role in electrical power storage. Case 8b assumed that renewable energy capacity would be the same as Case 8, but energy generated by renewable sources in Case 8b is larger than in Case 8. Introduction of smart grids makes this possible. By comparing these cases, we can analyze the comprehensive effect of introducing smart grids. In comparison, METI's report [4] looked at the effect of introducing 28,000 MW of PV and constructing a large number of batteries. It is assumed that power system stabilization will require the large-scale introduction of batteries (See Table 2). Two kinds of batteries were considered. Scenarios 4 and 5 have almost the same conditions, but the latter assumed that interface control units would be introduced. Interface control units are the most basic elements of smart grid systems.

Table 1. Assumptions made in CRIEPI's report (May 2013)

	Capacity of photovoltaics + wind power MW	Percentage of total capacity*	Generation of photovoltaics + wind power GWh	Percentage of total Generation*
Case 1	3,568	4.12%	4,522	1.26%
Case 5	34,524	30.62%	37,897	10.16%
Case 8	60,418	44.51%	54,214	14.25%
Case 8b	60,418	44.76%	73,790	20.19%

*Total amount in east Japan

3.Results

As the existing Japanese input-output table doesn't include renewable energy and smart grid activities, we constructed an extended input-output table for the analysis of next generation energy systems. Using this table, we calculated economic and environmental effects from constructing and operating the facilities considered in the studies which provided the data in Table 1 and Table 2. (Nakano and Washizu [5]). The results can be seen in Table 3 and 4.

Table 2. Assumptions made in the METI report (April 2010)

	Battery	PV power control	Smart grid
Scenario 1	NaS (Largest)	No	
Scenario 1'	Li-ion (Largest)	No	
Scenario 2	NaS (Medium)	Medium	
Scenario 3	NaS (Larger)	Small	
Scenario 4	NaS (Small)	Large	
Scenario 5	NaS (Small)	Large	Interface control unit

(NaS: Sodium-sulfur battery , Li-ion: Lithium-ion battery)

Table 3. Annual induced amount per GWh
(from construction and operation of new power plants)

Service life of facilities = 20 years

		output (million JPY)	labor (person)	Energy consumpiton (GJ)	CO_2 emission (t-CO_2)
thermal and pumped hydro	Case 1	32.9	1.2	8,288	481
	Case 5	33.7	1.2	8,772	561
	Case 8	37.6	1.4	10,313	805
	Case 8b	47.7	1.8	13,681	1,212
Photovoltaics and wind power	Case 1				
	Case 5	77.4	2.3	1,355	52
	Case 8	87.6	2.7	1,432	61
	Case 8b	72.7	2.1	1,311	47
Total	Case 1	32.9	1.2	8,288	481
	Case 5	60.8	1.9	4,176	246
	Case 8	80.5	2.5	2,693	167
	Case 8b	71.1	2.1	2,094	121

Table 4. Annual induced amount per GWh
(from construction and operation of new PV)

	Output (million JPY)	Labor (person)	Energy consumpiton (GJ)	CO_2 emission (t-CO_2)
Scenario 1	241.43	9.01	4,163	223.5
Scenario 1'	265.72	11.23	4,213	251.4
Scenario 2	114.06	2.86	1,681	80.3
Scenario 3	147.26	4.47	2,324	117.6
Scenario 4	100.79	2.22	1,421	65.4
Scenario 5	99.53	2.17	1,387	63.8

4. Discussions

Comparing the results of case 8 to case 8b in Table 3, and scenario 4 to scenario 5 in Table 4, we can see that the introduction of smart grid systems has economic and environmental merit. Furthermore, comparing the results of Table 3 to Table 4, we see the advantage of introducing not only PV but also wind power, and that power systems can be stabilized through power control operation in thermal power plants, and by operation of pumped hydro plants.

Acknowledgments

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Benefits of biogas projects from local and global perspectives

Aya HEIHO,* Hiroki HONDO, and Yue MORIIZUMI

Yokohama National University, Japan
*Corresponding author: heiho-aya-gm@ynu.jp

1. Introduction

Many biomass projects based on local initiatives have been recently planned or implemented in Japan. However, few studies have been conducted to evaluate their environmental and socio-economic performance from a life cycle perspective. The objective of the present study is to propose a method to assess sustainable development benefits of biomass projects focusing on where benefits accrue.

2. Method

The method proposed consists of the following three steps: (i) definition of system boundary and functional unit, and selection of indicators, (ii) inventory analysis, (iii) evaluation of the benefits of a local biomass project.

First, the two project systems that describe the situations "before" and "after" implementing a project are defined. A functional unit is set for the two project systems to provide the same amount of goods and services for a year. The present study chooses greenhouse gas (GHG) emissions, fossil fuel consumption and employment as indicators.

Second, the values of indicators for each project system (E_{before} and E_{after}) are estimated using a hybrid method that combines both merits of process and input-output analysis from a life cycle perspective. Since the present study identifies where the benefits of a project accrue, E_{before} or E_{after} are calculated by region according to the following equation (1):

$$E_{before}\ or\ E_{after} = E^{Spot} + E^{Inside} + E^{Outside} \quad (1)$$

The present study divides Japan into three regions, namely, the project spot (i.e. the place where a biomass project is actually done), inside of the local area, and outside of the local area to calculate the values of indicators for the three regions (E^{Spot}, E^{Inside}, and $E^{Outside}$). For the calculation, the present study uses national and regional input-output tables together with primary data from a local government and companies and secondary data from literature.

Finally, the benefits of the project (E) are assessed by comparing E_{before} and E_{after} as shown in equation (2):

$$E = E_{after} - E_{before} \quad (2)$$

3. Case study

The method proposed is applied to assess the benefits of a small-scale biogas project in Hokkaido, Japan. Figure 1 shows the project system before implementing the project. In the before system, livestock waste from milk cows is used for making compost on each farm. The compost is used as a fertilizer for feed crops. Electricity is supplied from conventional power plants in the local electric power company. Figure 2 indicates the project system after implementing the project. In the after system, power and heat are generated with biogas that is produced from livestock waste. Digested slurry that generates in the biogas generation process is delivered to farms as a fertilizer.

Table 1. Environmental and socio-economic consequences of a local biogas project

	GHG emissions [t-CO_2eq./year]	Fossil-fuel consumption [GJ/year]	Employment [man*days/year]
Project spot	▲ 15,496	856	1,268
Inside Hokkaido	▲ 282	▲ 1,916	1,770
Outside Hokkaido	155	1,608	729
Total	▲ 15,623	548	3,766

4. Results

Table 1 shows the changes in GHG emissions, fossil fuel consumption and employment resulting from the project implementation. A black triangle indicates decrease.

The bioenergy utilization is effective for the GHG reduction. In particular, the GHG reduction in the project spot is considerable, because CH_4 and N_2O are substantially reduced due to the absence of the compost making process in the after system.

On the other hand, fossil fuel consumption increases by implementing the biogas project. The breakdown by region reveals that although it decreases inside Hokkaido, it increases in the project spot and outside Hokkaido. Biogas power generation reduces the use of fossil fuels for conventional power generation inside Hokkaido. Conversely, diesel consumption increases in the project spot because of the transportation of livestock waste and digested slurry. Outside Hokkaido, indirect fossil fuel consumption increases associated with the production of materials, equipment, fuels etc.

Employment increases in all the three regions. In the project spot, new employment related to livestock waste collection, plant operation and digested slurry delivery is created. Inside and outside Hokkaido, indirect employment increases due to the demand of manufacturing, maintenance and repair of equipment of the biogas plant.

Acknowledgments

We thank Shikaoi town environmental conservation center for providing valuable data. This work was partly funded by Environment Research and Technology Development Fund of the Ministry of the Environment, Japan (Grant No. 2-1302).

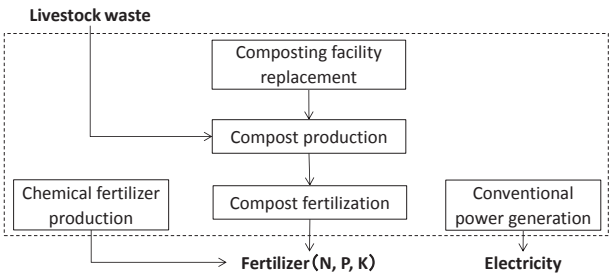


Figure 1. Before system

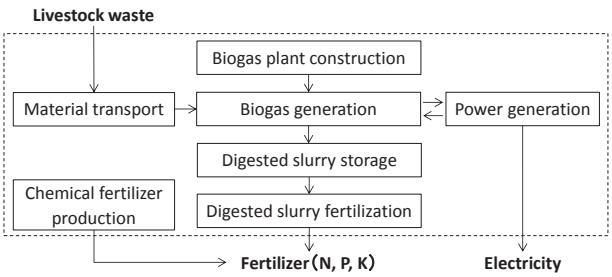


Figure 2. After system

Carbon footprint labelling certification of railway operating service in Korea

Jae-Young Lee*[1], Woo-Sung Jung[1], Cheul-Kyu Lee[1] and Hee-Man Kim[2]

[1]*Korea Railroad Research Institute (KRRI), Republic of Korea*; [2]*Korea Railroad cooperation (KORAIL), Republic of Korea*
*Corresponding author: iyoung@krri.re.kr

1. Introduction

In Korea, the carbon footprint labelling certification system for a product and service has been introduced from 2009. The aim of this study was to certify the carbon footprint labelling of railway operating service. Figure 1 shows national railway line in Korea. In this study, the targets of railway operating service for the carbon footprint labelling certification were selected as KTX (Korea Train eXpress) from Seoul to Busan as a long-distance travel and Nooriro (electric multiple unit) from Seoul to Sinchang as a short-distance travel.

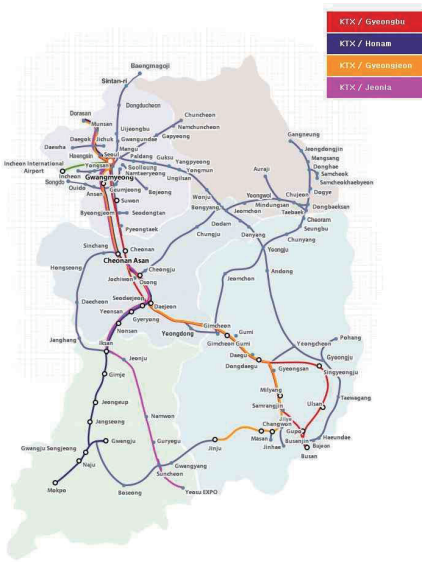


Figure 1. National railway line in Korea

2. Methodology

The calculation criteria of carbon footprint in this study was one-way per one passenger for the travel route of railway operating service. The system boundaries were from the pre-manufacture to the manufacture phase including the maintenance and the operating service of railcar except for the use and the waste phase. The CO_2 emission of pre-manufacture phase for KTX and Nooriro service was calculated to multiply the carbon footprint labelling coefficient by the amount of the exchange components at the railcar inspection and water use [1]. At the manufacture phase, the CO_2 emission was predicted using the amount of electrical energy consumed during the operation of KTX and Nooriro at the selected travel route [2]. Finally, the carbon footprint of railway operating service was confirmed by Korea Environmental Industry & Technology Institute (KEITI).

3. Results and Discussions

Table 1 summarizes the amount of carbon emission with the life-cycle of KTX and Nooriro service. Figure 2 describes the contribution ratio of carbon emission with the life-cycle of KTX and Nooriro service and Figure 3 shows the carbon footprint labelling certified by KEITI for KTX and Nooriro service.

As a result, the carbon footprint of KTX service from Seoul to Busan was 10.21kg CO_2/passenger-line and Nooriro service from Seoul to Sinchang was 2.47kg CO_2/passenger-line. Most of carbon footprints were resulted from the manufacture phase containing 97% of KTX service and 99.6% of Nooriro service.

Table 1. The amount of carbon emission with the life-cycle of KTX and Nooriro service

Target (Unit : kgCO_2)	Pre-manufacture	Manufacture	Use	Waste	Total
KTX (Seoul-Busan)	0.17	10.04	-	-	10.21
Nooriro (Seoul-Sinchang)	0.01	2.46	-	-	2.47

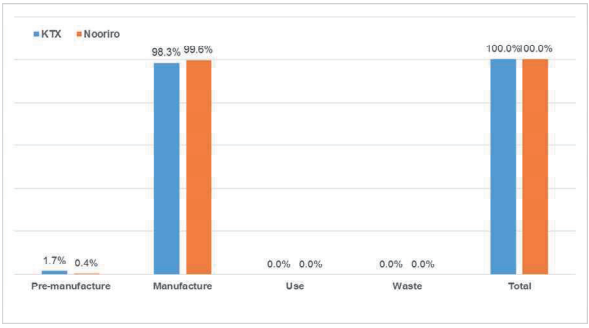


Figure 2. Contribution ratio of carbon emission with the life-cycle of KTX and Nooriro service



(a) (b)

Figure 3. Cabon footprint labelling for (a) KTX and (b) Nooriro service

4. Conclusions

The carbon footprint labelling for two railway operating service has been applied to inform the advantage of railway as a low carbon emission source compared with other transport modes in Korea.

Acknowledgments

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A Review of the Life Cycle Assessment of Nearly Zero-Energy Residential Buildings

Markus Weißenberger,*[1] Werner Jensch,[1] and Werner Lang[2]

[1]*Munich University of Applied Sciences, Germany*; [2]*Technical University Munich, Germany*
*Corresponding author: markus.weissenberger@hm.edu

1. Introduction

Given that the field of life cycle assessment (LCA) of buildings is vast, the aim of this paper is to clarify this area by analyzing LCA case studies of nearly zero-energy residential buildings. As final energy demand during the operation phase has fallen constantly over time, the impact of production and disposal increases in terms of the total life cycle. In addition to the European Union guidelines (2010/31/EU), it is required that only nearly zero-energy buildings can be built after 2020. These buildings will have a very low operational energy demand and a very high total energy performance. Therefore, it is essential to analyze the life cycle of buildings [1].

This article focuses on a meta-analysis of peer-reviewed papers in order to identify the state-of-the-art of basic parameters and reference values from LCAs of nearly zero-energy residential buildings.

2. LCA of building services engineering

The final findings highlight that despite the wide range of standards (i.e., ISO 14040, ISO 14044, EN 15978) some elements within some standards are simplified or even neglected (Table 1). If the production of the HVAC (heating, ventilation, air-conditioning) system is considered, usually only the main components are assessed. As Table 1 indicates, only heating is evaluated in all case studies; all other use phase categories are only occasionally considered.

Table 1. Consideration of building services engineering (+ included; - disregard; o nonspecific; n/a not applicable)

No.	Prod.	Use				
		Heat-ing	Hot water	Ventil.	Cool-ing	Electr.
[2]	+	+	+	+	+	+
[3]	o	+	+	+	n/a	+
[4]	+	+	o	+	+	+
[5]	+	+	+	+	+	+
[6]	-	+	+	o	+	-
[7]	-	+	+	+	n/a	+
[8]	+	+	+	o	+	-
[9]	+	+	+	+	n/a	+
[10]	+	+	o	o	n/a	o
[11]	-	+	-	o	+	-
[12]	+	+	+	+	+	+
[13]	+	+	+	+	+	+

3. Energy and environmental impacts

Different inputs and outputs are described in the 12 case studies [2-13]. The input of energy consumption is mentioned in all studies. Furthermore, the most applied measurement of environmental impact (75%) is the Global Warming Potential (GWP). Acidification Potential (AP) as well as Eutrophication Potential (EP) are applied by 58%. ½ of the case studies used Photochemical Ozone Creation Potential (POCP) and 42% Ozone Depletion Potential (ODP); the other environmental impacts are insignificant. Moreover, all case studies assess the production and use phase of buildings; however, the end-of-life is inconsistent and not considered in 25%. As Figure 1 shows, by reducing the operational energy, embodied energy increases, but the primary energy over the whole life cycle decreases.

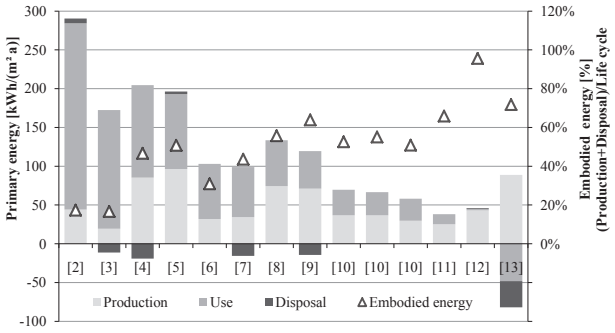


Figure 1. Primary and embodied energy over the life cycle

4. Discussion

There are no case studies which could be compared one-to-one. Every case study applies different system boundaries (e.g., the maintenance is sometimes either neglected or included in the production or use phase). However, compared to conventional buildings the embodied energy shifts from 10-20% [14] and 2-38% [15], respectively, to 17-96% (average 51%). That means 8-100kWh/(m^2 a) is the reference value of embodied energy in nearly zero-energy residential buildings. Due to that, the maintenance (also embodied energy) is mostly included in the use phase, the value is conservative.

5. Conclusion

The results indicate the need to research the substructures (e.g., the HVAC system) to enhance a standardized, practical approach that includes firm and definite general requirements in order to assess the life cycle of nearly zero-energy buildings.

Acknowledgments

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An Aggregative Assessment of Environmental Impacts on Reservoir Catchments Imposed by Public Construction Projects – A Case Study on Feitsui Reservoir

Yu-An Lin and Yuh-Ming Lee*

National Taipei University, Taiwan
*Corresponding author: yml@mail.ntpu.edu.tw

1. Introduction

Taiwan belongs to subtropical climate, and the average annual rainfall is almost to 2500 mm, but due to the non-uniformly distributed precipitation and the steep-sloped rivers, reservoirs has been widely constructed manage the water supplies in Taiwan.[1] However, it's still many problems about the water resource management and distribution.

Reservoirs are the major water supply facilities in Taiwan, and keeping good status of reservoirs operation is has been the great object for Taiwan.

2. Methodology

Environmental impact assessment (EIA) can be defined as the systematic identification and evaluation of the potential impacts (effects) of proposed programs or legislative actions, relative to the physical–chemical, biological, cultural, and socioeconomic components of the environment. [2]

Taiwan government promulgated the environmental impact assessment in 1994. The purpose of the assessment is to ensure that decision-makers consider environmental impacts before deciding whether to proceed with new projects. To achieve the goal of environmental protection and sustainable development, those who don't follow the assessment won't allow implementing the development activity.

3. Case Description

Feitsui Reservoir, with Xindian River as primary flow and Beishi River as secondary flow, serves as the greatest reservoir and is the primary resource of drinking water for Taipei metropolitan area. The functions of Feitsui Reservoir which is multiple targets operational are water supplying, electricity generation and flood prevention.

In order to shorten the time of communication between Taipei and Yilan as well as solve the surrounding traffic congestion problem, Ministry of Transportation and Communications R.O.C. proposed a project called "Taipei-Yilan Straight Railway Project" that includes three routes in 2013. According to the environmental protection law, the project requires to hold an environmental impact assessment in advance. Yet, part of the planning routes which pass through Feitsui Reservoir catchments, could cause different extent of effects to the water source protection areas and other environmentally sensitive areas. [3]

4. Assessment Results and Discussion

To understand more about the extent of effect by the development actions of Feitsui Reservoir catchments, this study used BASINS/HSPF model and reviewed the impact of the flow, sedimentation volume and water quality pollutants of the catchments that are affected by the construction.

Better Assessment Science Integrating Point and Nonpoint Sources (BASINS) is a geographic information system based tool developed by USEPA's Office of Water. It's a multipurpose environmental analysis system designed to bring together data on water quality and quantity, land uses, point source loadings, and other related spatial data with supporting nonpoint and water quality model at a quicker and more effective pace. It can help regional, state, and local agencies evaluate more efficiently water-bodies and watershed that are not meeting water quality standards.

WinHSPF is designed to interact with the BASINS utilities and data sets to facilitate the extraction of appropriate information and the preparation of model input files. The input files can be modified and adapted to site−specific conditions through the use of WinHSPF and supporting information provided by the BASINS utilities and reporting functions, as well as locally derived data sources. [4-5]

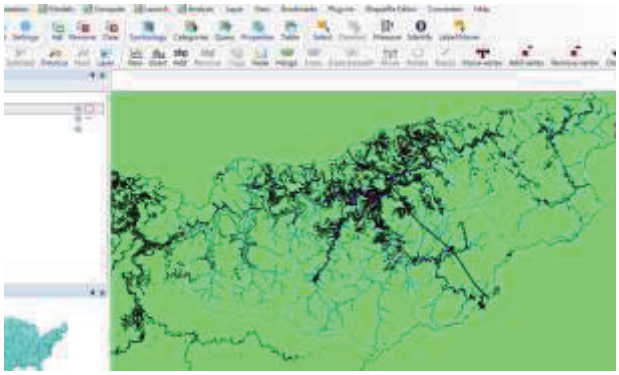


Figure 1. Screen image of analysis in BASINS

5. Summary and Conclusion

Because of the environmental influence which is by traffic constructions development activities through collecting, compiling the monitoring information about the quality of water, water quantity, and sedimentation volume through the changing of time, by analyzing and judging the direct and potential impact factors of influential possibility to Feitsui Reservoir catchments. At the same time, we also assessed the environmental hazards comprehensively by using concept mapping with the viewpoint is from the "receptor" (the affected).

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Environmental impacts of portland cement manufacturing and developed process with alternative technologies in Thailand

Unchalee Suwanmanee,[1] Suthida Authayanun,[1] Worayut Saibuatrongand,[2]
Viganda Varabuntoonvit[2] and Thumrongrut Mungcharoen, *[2]

[1]*Department of Chemical Engineering, Faculty of Engineering, Srinakharinwirot University, Nakhon-nayok 26120 Thailand*
[2]*Department of Chemical Engineering, Faculty of Engineering, Kasetsart University*, *Bangkok 10900 Thailand,*
*Corresponding author: fengtrm@ku.ac.th

1. Introduction

Global strategic management 2007 reported that the average annual of cement production and consumption has been continuous increasing from 2,283 million tons per year in 2005 to 2,836 million tons per year in 2010 or about 4.7% globally [1]. Office of natural resources and environmental policy and planning reported that Thai industry sector generated greenhouse gas (GHG) emissions accounted for 16.4 million tons CO_2 equivalent or 7.2 percent of the total GHG emissions in 2000. Majority of GHG emissions in the Thai economy was dominant from Thai cement industry of 12.7 million tons CO_2 equivalent or 79.3 percent of the total GHG emissions in Thai industry sector. In this study was analyzed and evaluated two environmental impacts, energy (EI) and carbon (CI), of cement industry over the period from 2012 by using Life Cycle Assessment (LCA) technique. The second objective of this work was to evaluate and assess the hypothesis for the improvements in cement production.

2.1 Goal and scope of the study

The goals of this study are to assess the EI and CI from cradle to production gate of cement production. The scope of the study includes the extraction of limestone and shale from mining process, crushing, raw meal preparation, clinker production, cement grinding, and transportation of intermediate product as shown in Figure 1. The functional unit was set as 1 tons of portland cement.

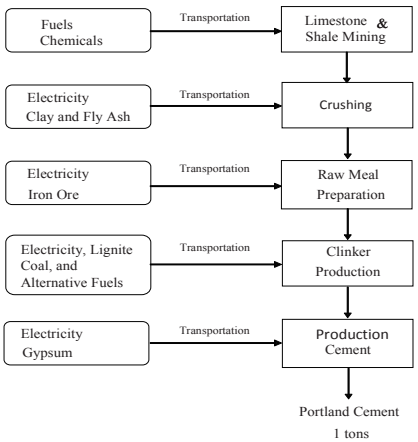


Figure 1. System boundary of portland cement production.

3. Results and Discussion

3.1 Life Cycle Impact Assessment or LCIA (part i)

It is found that the EI and CI of cement production were 3.26 GJ per ton cement and 0.74 ton CO_2 equivalent per ton cement respectively as shown in Figure 2. The largest contribution was from fossil fuels (coal and lignite) used for the limestone calcination in clinker production of 2.75 GJ per ton cement or 88 percent of total EI and 0.70 ton CO_2 equivalent per ton cement 95 percent of total CI.

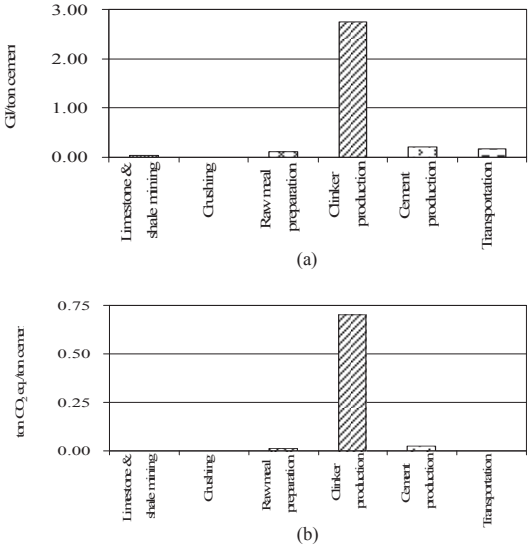


Figure 2. a) EI and b) CI of portland cement production.

3.2 Life Cycle Impact Assessment or LCIA (part ii)

The second objective is to improve cement production which is described as follows: (i) replacing high carbon fuels by using low carbon fuels; (ii) increasing the alternative fuels to fossil fuels ratio (replacing high carbon fuels by using alternative fuels); (iii) increasing the pozzolan to cement ratio (blended cements). It was found that using low carbon fuels can reduce the CI by 16.96 percent of total CI. Using alternative fuels and increasing the pozzolan to cement ratio, the total EI were reduced by 17.65 and 10.06 percent of total EI, respectively and the total CI are reduced by 3.77 and 5.21 percent of total CI, respectively.

4. Conclusion

It was found that the EI and CI of cement production were 3.26 GJ per ton cement and 0.74 ton CO_2 equivalent per ton cement respectively. Using low carbon fuels can reduce the CI by 16.96 percent of total CI. Using alternative fuels and increasing the pozzolan to cement ratio, the total EI were reduced by 17.65 and 10.06 percent of total EI, respectively and the total CI were reduced by 3.77 and 5.21 percent of total CI, respectively.

Acknowledgments

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Eco-benefit analysis of multifunctional building products

Michael JÄGER,*[1] Johannes GANTNER,[1] Sarah HOMOLKA,[2] and Hannes KRIEG[1]

[1]*University of Stuttgart, Chair for Building Physics (LBP), Dept. Life Cycle Engineering (GaBi), Germany,*
[2]*Fraunhofer Institute for Building Physics IBP, Germany*
*Corresponding author: michael.jaeger@lbp.uni-stuttgart.de

1. Introduction

One of the most important political goals of the European Union is the energy turnaround. For the construction sector especially the energy efficiency of the buildings has to be increased significantly. The implementation of the Energy Performance of Buildings Directive (EBPD) is an important initiative that shall lead to energy efficient and in parallel to more air tight buildings [1]. In this context especially building products have to play a major role. Building products such as wall panels usually provide a multitude of different (building physical) functions. Hence in current environmental and economic analysis usually only the main function is addressed. In a multifunctional context this is a methodological challenge. When several products are compared via Life Cycle Assessment a single, but complex functional unit or functional equivalent has to be defined. With regards to the comparability and applicability this definition cannot be easily done due to the fact that building are complex systems with a multitude of needed, different functions one product can contribute.

2. The European research project ECO-SEE

The European project ECO-SEE (with funding from the EU) aims to improve the indoor environmental quality of energy efficient buildings. In the project different innovative eco-building materials are developed, that shall improve not only the energy consumption, but also improve further building physical properties. Both an LCA and an LCC study are conducted for these products to identify both more environmentally friendly and cost-efficient solutions. [2]

3. Multifunctional building products

In this context a method has been developed that addresses the multifunctional building physical properties in order to define comparable scenarios. The functions shall improve the energy efficiency of the building on the one side (e.g. insulation effect) and improve the indoor environmental quality (e.g. air borne chemicals, particulates, microbiological pollutants and allergens) on the other side.

Therefore modular, dynamic reference scenarios are compiled to cope with different functions that are provided by several products. Instead of analyzing only a main function so called functional bundles are defined. The required functions can be provided by a single product (e.g. innovative eco-building material) or by a bundle of different products.

4. Eco-benefit approach

The described approach introduces an eco-benefit method to identify the most advantageous solution in order to provide a functional bundle. In addition to an LCA the method includes an innovative LCC-approach. Generally Life cycle costing analysis is a method to estimate the total costs that occur during the whole lifetime of a product. [3]

A “forward LCC”-analysis is used to calculate the life cycle costs of the examined products in a first step. This bottom-up approach shall answer the question regarding actual costs of the product. In a second step a “backwards LCC” based on currently available products/ product bundles in order to estimate the competitiveness of the innovative product and identify optimization potential.

5. Target Costing approach

As different functions are defined, a target costing approach is used to identify those cost elements which have the major influence on the end products and on the final price. The basis for determining the target costs is the intended or expected price for the final product, which is the building product in the context of the presented method.

6. Conjoint analysis

Cost optimization also derives from the willingness to pay (WTP) of the customer. As the customers WTP mainly depends on the functions that a product provides, in a further step the conjoint analysis [4] is used to identify the most important attributes from an end-user perspective. The conjoint analysis is a method in the area of market research with the aim to predict achievable market prices. The method is often used for marketing or product management issues and is based on stated buying preferences of possible customers.

Within the eco-benefit approach both environmental and economic advantageous solutions can be identified.

7. Conclusion and Outlook

All in all the method enables the user to improve the products from an economic perspective, but as consistency to LCA is ensured, also from an environmental perspective. Furthermore the maximum final price of the product is identified from an end-user perspective.

The method is a decision-support instrument to develop more sustainable products. Its application is shown on the basis of building products that are developed in an ongoing European research project.

Acknowledgments

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Development of a combined LCA and LCC tool for refurbishment measures of districts

Rafael Horn,*[1] Johannes Gantner,[2] and Michael Baumann[2]

[1]*Fraunhofer IBP, Germany*; [2]*University of Stuttgart, Germany*; [3]
*Corresponding author: rafael.horn@ibp.fraunhofer.de

1. Introduction

The refurbishment of the building stock in terms of energy supply and efficiency is a significant part of the German turnaround in energy policy, as the building sector accounts for 40% of Germany's total energy demand. Thus the required refurbishment ratio of at least 2% is not yet achieved. The main reasons are high investment costs and uncertainties in both economic and environmental benefits. Moreover, synergy effects of decentralised energy supply and their saving potentials are usually not considered.

3. Software Tool

In this context an analysis tool is developed to reduce the efforts for comparative environmental and economic analysis of refurbishment measures for existing districts. The tool aims at enabling comparisons of different refurbishment scenarios with minimal user effort wherefore the user input data is completed by typological data and generic databases. It is not aiming at detailed modelling but giving guidance to decision-makers in situations of potential refurbishments. Thus a contribution to the acceleration of the refurbishment ratio and to the sustainable development in the building sector is possible.

4. Approach

The model is realised within a two-stage methodology, in which the buildings are assessed initially before they are regarded in district context. Each of the stages contains an LCA-module based on the recommendations of the EeBGuide [1] and an LCC-module, which is implemented based on [2] and [3]. For the whole model only energy-saving refurbishment measures that differ between the scenarios are considered due to its focus on comparative analysis. At building level, the scenarios "conventional refurbishment", "future-oriented refurbishment" (low-energy building standard) and "partial refurbishment" are compared to the reference scenario, that only takes conservation measures into account. With regard to several system configurations and boundary conditions the best scenario for each building can be identified. All buildings are combined on district level (see figure 1), where they are analysed summatively.

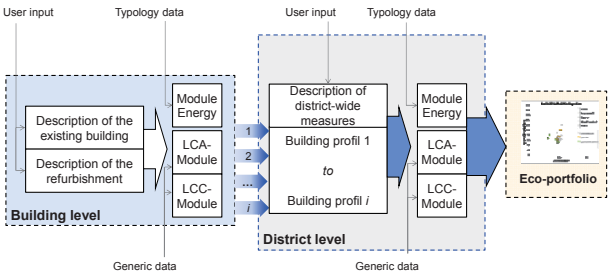


Figure 1. Connection building and district level

The criteria and methodology developed on building level can also be used on district level as well. Further optimisation potentials can be identified by taking into account several measures on district level like district heating systems including cogeneration or integration of renewable energy systems. To aggregate the results to be conveyed at a glance an eco-portfolio (see figure 2) is developed including direct comparison of ecological and economic efficiency of the chosen scenarios.

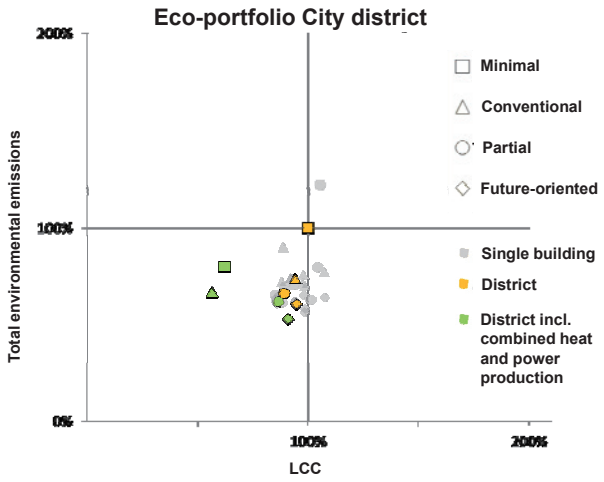


Figure 2. Example Eco-portfolio of a city district

Thus the best district refurbishment concept from the user's point of view can be generated. Due to the generic database the model holds potentially significant uncertainties. These were analysed quantitatively on both building and district level. On building level a high consistency has been proven by comparing the results to several available tools with similar methodology. For validation on district level a comparison with an already conducted district refurbishment has been carried out. Again, a high correlation between the outcome of the developed model and the measured data could be stated. In contrast to current approaches the model takes a complete life cycle approach into account and is not restricted to CO2 emissions within the use phase.

4. Conclusion

In summary, the LCA and LCC tool for districts enables architects and urban planners already in early design stages to assess the different economic and ecologic impacts of different refurbishment strategies and optimize those.

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Macro Analysis of Life Cycle CO_2 from Urban Passenger Transport Systems in Asian Developing Countries

Kei ITO*[1], Naoki SHIBAHARA[2], Hirokazu KATO[3], Koh KANAI[3]

[1]*Nagoya City Hall,* [2]*Japan Environmental Management Association for Industry,* [3]*Nagoya University, Japan*
*Corresponding author: k.ito@urban.env.nagoya-u.ac.jp

1. Introduction

This research estimates a macro-estimate of the CO_2 emissions from urban passenger transport systems in Asian developing countries using the life cycle assessment framework. The transport mode with the lowest CO_2 emissions were determined for each city by reflecting in the estimates for each transport mode the energy efficiency of each country, whose electric power source configuration and combination of fuels differ greatly. In addition, estimates were carried out taking into consideration future trends in energy and emission technology in each country, and the differences in CO_2 emissions among urban transport system development scenarios were evaluated.

2. Method of Estimating Life Cycle CO_2 for Passenger Transport Modes

The assessed mode is BRT, LRT, and railway, for which development is proceeding in Asian developing countries (Table 1). In order to evaluate the quantity of emissions in accordance with transport demand, the evaluation index "life cycle CO_2 emissions per passenger-km transported (transport demand)" was used. CO_2 emissions were estimated for each of the activities of vehicle operation, infrastructure construction, maintenance and repair, and vehicle manufacture, by multiplying the vehicle distance traveled, the route length, and the number of vehicles manufactured by their respective CO_2 emission factors. The life cycle of the transport system was set to 60 years. Local differences in energy efficiency and future changes were reflected in the factors.

It is considered that the actual railway and bus operators determine the level of service for the aspects of both transport capacity (number of vehicle trips × capacity of each vehicle) and number of trips. This relationship between transport intensity and transport capacity was approximated as an exponential function, and the transport capacity was set in accordance with the transport intensity. The number of journeys is calculated by dividing the transport capacity by the vehicle capacity.

Table 1 Transport mode

	BRT ※1	LRT ※2	Rail ※2
Capacity [passengers/vehicle]	85※3	85	130
Vehicles in a train [vehicles/train]	1	1	Variable
Energy consumption efficiency	0.65 [l/km]	2.5 [kWh/km]	2.0 [kWh/km]

*1:Set based on articulated bus
*2:Set based on values for tramcars for LRT and values for urban railway for rail systems, by reference to the Railway Statistical yearbook.
*3:The safe capacity (128 passengers) based on the Road Trucking Vehicle Act, converted to the capacity of rail commuter vehicles in accordance with JIS E 7103.

3. Setting emission factors

This research analyses the differences in emission factors for electricity generation coefficients, infrastructure construction, and vehicle manufacture, whose characteristics are different among countries. The LCA software MiLCA[1)] was used for setting the factors for each area, and the values for each country in the inventory database IDEA contained in MiLCA were used for the electricity generation coefficients. For each emission factor of infrastructure construction, maintenance and repair, and vehicle manufacture, the estimation values for Japan[2)] were corrected using the ratios of CO_2 emission in each country for rail track construction, and vehicle manufacture obtained from MiLCA.

Future changes in energy efficiency are anticipated in the operational stage, where the effect of technological advances is easily reflected. In Japan it has been reported that an improvement in fuel consumption of bus vehicle is approximately 10% by 2020. In this research an improvement in fuel consumption of 2% every 10 years as vehicles are renewed was set, envisaging a final improvement in fuel consumption of 10%. For energy efficiency in the energy generation stage, an improvement of 30% in 20 years is envisaged for fossil-fired power generation only, where major improvements are anticipated.

4. Results and Discussion

Fig. 1 shows the relationship between transport intensity and life cycle CO_2 per passenger for China and Vietnam, which have the largest difference in electricity generation coefficient. It can be seen that as the transport intensity increases the emissions per person decrease, and the transport mode with the smallest emissions changes. In China, even if BRT is introduced on a route with high transport demand, its emissions are lowest. On the other hand, in Vietnam where the electricity generation coefficient is less, it can be seen that the transport mode with the smallest emissions changes from LRT to railway at a transport intensity of about 10,000 [passengers/day].

From the above, it is important to consider the differences in electricity generation coefficient, etc., among countries when evaluating the introduction of an urban transport system from the point of view of low carbon properties.

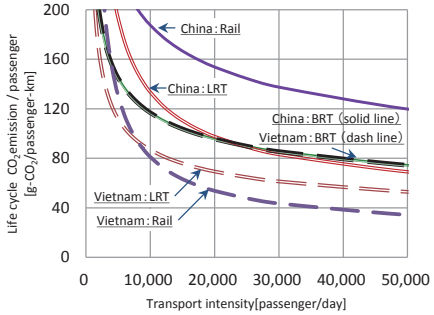


Fig. 1 Sectional transport demand intensity and life cycle CO_2 per passenger-km

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Estimation Method of the Change in Life Cycle CO_2 from Mass Transit System Applying Micro-scopic Traffic Flow Simulation

Naoki Shibahara*[1], Ryoko Morimoto, Nozomi Kudo[2] and Hirokazu Kato[3]

[1]*Japan Environmental Management Association for Industry*;
[2]*National Traffic Safety and Environment Laboratory, Japan*; [3]*Nagoya University, Japan*
*shibahara@jemai.or.jp

1. Introduction

The purpose of this research is to develop a method of estimating the total life cycle CO_2 emissions from a mass transit system by taking account of vehicle traveling, infrastructure construction and production of vehicles in order to comprehensively evaluate the change in CO_2 emissions associated with system introduction. In particular, congestion of roads due to crossings, traffic signals and the driving behavior of vehicles with mixed traffic of light rail transit (LRT) were analyzed by micro-simulation of traffic flow.

2. Method of Estimating CO_2 Emissions

As a case study, the life cycle CO_2 emissions were estimated for a project to replace a part of the conventional bus route (14.5km) with a new LRT 5km section. The conventional bus, LRT system and automobiles in the area were included in this evaluation.

The method of "rough LCA", which was generally used to find the emission factors, on the standard structure supposition[1], was used to estimate CO_2 emissions from vehicle manufacturing, infrastructure construction and maintenance stages.

An urban traffic simulator developed by the National Traffic Safety and Environment Laboratory was used to obtain the CO_2 emissions by the operations of route buses, automobiles, and the LRT. For automobiles, this simulator was able to reproduce running modes such as accelerating, decelerating, and stopping (idling) to obtain positional data for each vehicle every 0.5 second with calculations of CO_2 emissions.

3. Results

The estimated results of life cycle CO_2 emissions indicated that it was necessary to shift transportation demand from automobiles to LRT in order to reduce the CO_2 with introducing LRT. Sensitivity analyses were carried out for the changes in CO_2, which were due to changes automobile operations, when there was a change in demand. This research focuses on the road conditions, to determine how the sensitivity to transportation demand shift differs in the direction towards the central station, where there was congestion, and the direction away from the central station, where there was no congestion.

The hourly CO_2 emissions were estimated for a case in which 10 to 50% automobiles traveling on the road alongside the LRT shifted to the LRT.

Figure 1 showed the analysis results in the direction towards the central station. If 20% of the automobile transportation demand was shifted to the LRT, the CO_2 emission reduction was greater than the dotted line which showed the reduction of CO_2 emissions in proportion to demand shift line. It is considered that this was because of congestion at the crossroads contributing predominantly to deterioration of the vehicle driving environment.

On the other hand, in the analysis results for the direction away from the central station in the same area (See Figure 2), the reduction in the CO_2 emissions was less than that of the direction towards the central station. This was because of no congestion in the direction away from the central station originally. Therefore, even though the traffic volume was reduced by this shift, there was no great change in vehicle behavior. In addition, the road traffic is also greatly affected the sensitivity analysis results for this transportation demand shift.

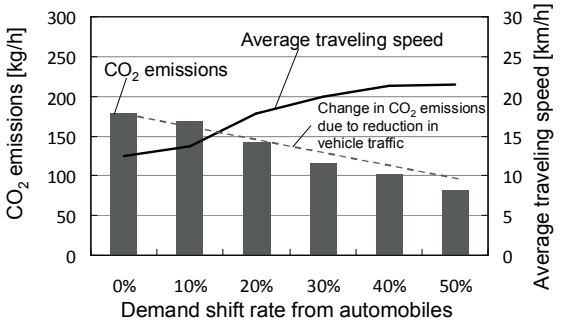


Figure 1. Sensitivity analysis of demand shift from automobiles (towards central station)

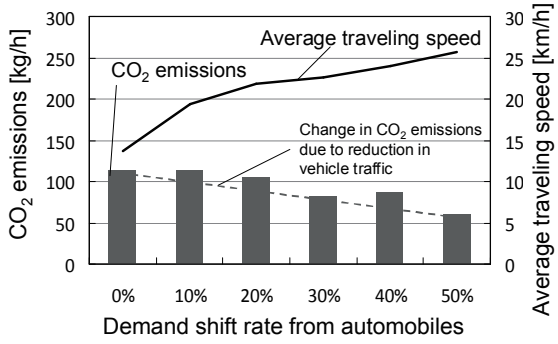


Figure 2. Sensitivity analysis of demand shift from automobiles (away from central station)

4. Conclusion

As a result of micro-scopic traffic flow simulation, it was found out that the changes of driving behavior were possible to reflect the CO_2 estimates. Therefore, it was possible to evaluate, environmental aspects of measures in more detail, such as the introduction of public transport priority signals or elimination of congestion by improvement of crossroads, which change the local driving environment.

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Net CO_2 emissions by the change of consumption in consequential LCA

Kotaro Kawajiri,*[1] Masaharu Motoshita[1,2], Tomohiko Ihara[3], Hiroki Hatayama[1], and Kiyotaka Tahara[1]

[1]*National Institute of Advanced Industrial Science and Technology, Japan*; [2]*UniversityTechnische Universität Berlin, Germany*; [3]*The University of Tokyo, Japan*
*Corresponding author: kotaro-kawajiri@aist.go.jp

1. Introduction

Sustainable consumption is one of the main issues in an environmental science. While nearly 20% of CO_2 emissions come from the residential section in Japan, the other CO_2 emissions from the other sectors would be also attributed to the consumer behavior because the final objectives of the activities of the other sectors are the benefits of consumers. Therefore, the effects of consumer behavior on the CO_2 emissions in Japan would be large.

The effect of consumer behavior would be the matter at the usage stage. The most of foregoing studies employ the simple assumptions for the consumer behavior, such as a consumer buys a new product, use and waste it, and any other change happens in his/her life. However, if they buy the product, the substitution or complement of consumption would happen.

There are few studies investigating such a consequential effect by consumer behavior in LCA field. Dowaki et al [1] investigated the rebound effect by the policy in Japanese transportation sector. Tiesen et al [2] investigated the rebound effect caused by buying a luxurious product. However, there are a few studies investigating the analytical framework to estimate the environmental impacts of such a consequential consumer behavior.

The objective of this study is to propose the comprehensive analytical framework to estimate the environmental impact of substitutional/complemental consumption by the change of consumption pattern for all items of their daily lives.

2. Method

This study employs the second largest classification with 63 items of daily expenditure in a national survey by the Statistics Bureau and the Director-General for Policy Planning of Japan (2005) [3]. The number of classification is 63. The CO_2 intensity of each item c_i is estimated using the 3EID database [4] and methods proposed by the previous study [5].

The analytical method is composed of the following three calculation steps.

Firstly, the total expenditure of each respondent is normalized by the average total expenditure of all respondents.

Secondly, the correlation coefficient m_{ij} is obtained by the single regression analysis between the item i and the item j. The correlation coefficients are summarized into the matrix M. Here, the sum of each row of matrix M is zero due to the constraint that the total expenditure does not change by the change of consumption pattern.

Finally, the net CO_2 emissions c_{net} by changing the spending considering the change of consumption pattern by substitution and complement is estimated by multiplying the matrix M and the CO_2 intensities c as,

$$c_{net} = c^T M$$

3. Result

The 63 x 63 matrix M is obtained by the method in the previous section. The values of matrix are negative and positive; where the negative value means the substitutional relationship and the positive value means the complemental relationship.

Highlighting the cells relating to a food in the matrix, food materials are in the complemental relationship each other. For example, increase in the spending for the meat leads to increase in the spending for the rice. On the other hand, the consumption of food material and some items, such as dining out, boarding, and rent for house, are in the substitutional relationship.

The net CO_2 emissions per Yen of the following three items, (1) oil and seasoning, (2) milk, egg, and daily products, (3) and waterworks, are larger than those of electricity. A large amount of the net CO_2 emissions of those items is caused by the complemental spending for electricity. The increase in spending for the former two items would be due to the increase in energy consumption by cooking devices and refrigerator. The increase in spending for waterworks would be due to the energy consumption to heat water. Therefore, it seems reasonable that those items have large net CO_2 emissions. These results imply the importance of the effects of substitution and complement on the total CO_2 emissions for such items, which have small CO_2 intensity but large net CO_2 emissions.

4. Conclusion

In this study, we proposed the analytical framework using matrix to estimate the net CO_2 emissions of consumption considering the change of consumption pattern by substitution and complement.

The matrix shows the substitutional and complemental relationship between the each consumption. The following prominent characteristics were found in the matrix. The food materials are in complemental relationship each other. The food materials and some items, such as dining out, boarding, and rent for house, are in substitutional relationship

Some items, such as oil and seasoning, milk, egg, and daily products, and waterworks, have the large net CO_2 emissions. These large emissions come from the complemental consumption of electricity.

This study sheds light on the large hidden impacts of consumption by substitution and complement, which have not been clarified so far. The proposed analytical framework would be useful to investigate such a hidden impact of consequential consumer behavior.

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Modeling Consumer's Choice and its GHG Implication under Simultaneous Consideration of Available Income and Time

Koji Takase*[1] and Yasushi Kondo [2]

[1]*Shizuoka University, Japan*; [2]*Waseda University, Japan, Japan*
*Corresponding author: jktakas@ipc.shizuoka.ac.jp

1. Introduction

Consumers face the time constraint in addition to the monetary budget in their daily life. Accordingly, consumer's choice for a particular purpose greatly influences other activities through those constraints. For example, driving a private car is generally less time consuming, more expensive and less environmentally-friendly than public transportation. If consumers shift their transportation modes aiming for reducing environmental loads, their action will cause a time shortage and a budget surplus. The difference in the total time and budget must be compensated by adjusting other activities, such as reducing home laundry and making them done by professional cleaners instead. These adjustments might end up with more environmental loads as a whole, which is a source of the rebound effects. In this manner, some choices, which are regarded as environmentally-friendly under a particular situation, constitute only a portion of consumers' lifestyle. Therefore, a holistic approach is indispensable to evaluate the total environmental loads associated with consumer's choices.

With this background, we propose a new method for evaluating environmental loads induced by consumption patterns which meet both time and budget constraints. In other words, our method provides a systematic way to deal with the time and income rebound effects simultaneously. Although the time rebound effect has been considered in Jalas [1, 2] and Druckman et al. [3], the income rebound effect is not explicitly taken into account in their analysis.

2. Model

In our model, consumers are assumed to choose their operation levels of the consumption "technologies" (CT). A CT is expressed as a set of products and time that are necessary to achieve some purpose as in Becker [4]. For example, the CT "home laundry" needs several inputs such as a washing machine, detergent, utility charges and time for washing and drying to produce output (laundry activity). Likewise, the CT "laundry service" needs cleaning charges, time for stopping in cleaning shops, and time for pick-up. As mentioned above, there are a few mode of transportation which are regarded as CTs for transportation activity. Because there are many activities and modes in our daily life, consumer have to allocate there resources (income and time) among those CTs.

With the basic idea of the CTs, we can write down the household consumption vector $\mathbf{y}$ as the linear form.

$$\mathbf{y} = \mathbf{Bz} + \mathbf{y_0} \quad (1)$$

In equation (1), the vector $\mathbf{z}$ represents operation levels of CTs. The matrix $\mathbf{B}$ is the converter matrix that connects CTs and products. The vector $\mathbf{y_0}$ is the fixed consumption, such as a fridge and clothes that cannot be sorted to a particular CT.

In addition, budget and time constraints are employed to our consumer model,

$$\mathbf{py} = \mathrm{M} \quad (2)$$

$$\mathbf{b_t z} = \mathrm{T} \quad (3)$$

where $\mathbf{p}$, M and T represent price vector, income and total time, respectively. The vector $\mathbf{b_t}$ represents time required for CTs. Note that variety of CTs is described by the fixed matrix $\mathbf{B}$ and the fixed vector $\mathbf{b_t}$ in equations (1) and (3).

With this consumer model and an environmentally extended input-output model such as Nansai, et al. [5, 6], we evaluate the GHG emission induced directly and indirectly by consumers,

$$\{ \mathbf{d}\ (\mathbf{I-A})^{-1} + \mathbf{c}\ \}\mathbf{y} \quad (4)$$

where $\mathbf{d}$ and $\mathbf{c}$ represent the direct GHG emission by industry and consumer, respectively, while $\mathbf{A}$ represents the input coefficient matrix.

To find the optimal operation levels of CTs (the vector $\mathbf{z}$), we have constructed a linear program (LP) to minimize the GHG emission (4) subject to the monetary budget (2) and the time constraint (3). An optimal solution to the LP can be regarded as a social outlook for an environmentally-friendly lifestyle.

3. Empirical example and concluding remarks

In our empirical example of Japanese household, we have classified products and time into 37 CTs. There are some alternative CTs for laundry, leisure, eating and travel activities. Therefore, consumers can choose their optimal operation levels of those alternatives. In addition to the time and budget constraints, other technical restrictions have been introduced. The total laundry weight, the total food intake and the total travel distance are fixed; operation levels of some activities (sleep, personal care, work, etc.) are fixed; upper and lower bounds are set for the change rate of each CT to avoid unrealistic solutions.

To sum up, this paper provides a holistic framework to evaluate consumer's choice in terms of the GHG emission. The basic concept of CTs is illustrated. The income and time rebound effects are incorporated into our model because budget and time are used up through those constraints.

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Determinants of Environment-conscious Behavior in Eating Habits

Tomohiko Ihara*[1], Wakana Zaima[1], and Hideaki Kurishima[2]

[1]*The University of Tokyo*; [2]*Shibaura Institute of Technology*
*Corresponding author: ihara-t@k.u-tokyo.ac.jp

1. Introduction

Resolution of today's environmental issues requires not only the implementation of large-scale environment-conscious policies by governments and corporations but also the consumers' daily practice of environment-conscious behaviors. Eating habits are related to various environmental issues and chosen by consumers' decisions. This study aims to clarify what factor affects consumers' decisions in environment-conscious behaviors in eating habits and what personal attribution is related to their decisions in order to extract the elements encouraging environment-conscious behaviors.

2. Method

Previous studies on determinants of environment-conscious behaviors have been conducted based on Factor association model (FAM) [1], Collective protection motivation model (CPMM) [2], or Psychological processes model [3]. The study adopted FAM and CPMM because these two models have relatively high explanation effects.

The survey results are analyzed based on FAM and CPMM using path analysis by a free statistical computing software R. First, their explanation effects are compared. After the comparison, the relationship between personal attributes, the type of environment-conscious behaviors, and the degree of practice of environment-conscious behaviors are evaluated using the model which had higher explanation effects.

3. Data

A survey via the Internet is conducted for 500 Japanese adults in their 20s or 30s living urban areas (Tokyo or the cities which have more than 300,000 residents) (100 male students, 96 female students, 150 male no student adults, and 154 female no student adults). The questionnaire includes the degrees of consciousness of four environmental issues (drought, global warming, waste, and water pollution) and practice of 28 environment-conscious behaviors related eating habits.

4. Comparison between FAM and CPMM

Akaike's information criteria (AIC) was adopted for goodness of fit of the models. FAM had lower AICs in all the behaviors (see Figure 1). FAM was adopted for the following analysis.

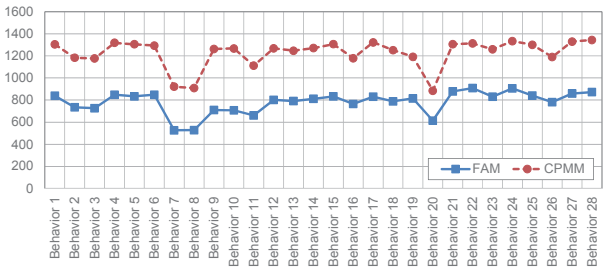


Figure 1. Comparison of AIC between FAM and CPMM

5. Difference of determinants by personal attributes

The model was constructed for each subject group. The models showed that the perceived seriousness of environmental problems had the largest path to the general goal intention of a pro-environmental lifestyle and the feasibility evaluation had the largest path to the behavior intention of environment-in conscious behavior all the subject groups.

6. Difference of practices by personal attributes

The survey results were compared by the personal attributes.

Female subjects have significantly larger values in the general goal intention, the perceived seriousness of environmental problems, the ascription of responsibility for environmental problems, and the belief in the effectiveness of a pro-environmental lifestyle. No student subjects do not have any significantly larger values compared to student subjects.

Subjects who do grocery shopping or cook frequently has significantly larger values in the general goal intention, the perceived seriousness of environmental problems, the ascription of responsibility for environmental problems, and the belief in the effectiveness of a pro-environmental lifestyle.

7. Behavior intention and practice

Practice of the specific environment-conscious behaviors were also surveyed at the same time in the study. Regression analysis between behavior intention and practice showed that the coefficients of determination were 0.196 to 0.507 and all the relationships were significant ($p < 0.05$). It is considered that the behavior intentions affect the behavior practices certainly but other factors for the behavior practices would exist.

8. Conclusion

The previous studies have showed that FAM and CPMM had similar explanation effects. However, this study showed that FAM has larger explanation effects.

Our analysis found that the perceived seriousness of environmental problems and the feasibility evaluation give the largest impacts on the intention. Therefore, appeal on seriousness of environment problems and institution/education on environment-conscious behaviors can be effective for encouraging practice of environment-conscious behaviors.

Sex, occupation, the degree of grocery shopping, and the degree of cooking also affected the consciousness of environmental issues and the practice of environment-conscious behaviors. Promoting grocery shopping and cooking may encourage the practice of environment-conscious behaviors.

Acknowledgments

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Product differentiation and eco-behavior by using carbon footprint

Kenju Akai,*[1] Haruaki Tamura,[1] and Nariaki Nishino[1]

[1]*The University of Tokyo, Japan*
*Corresponding author: akai@css.t.u-tokyo.ac.jp

1. Introduction

It is required that each citizen tries to reduce Green House Gases (GHGs) to mitigate the impact of global warming. However, each person tends to set a high value on convenience and economical reasonableness, disregarding eco-friendliness. This tendency is generally called social dilemma [1].

To remove this social dilemma, carbon footprint is thought to be attractive. Carbon footprint is a kind of eco-label, which is to be attached to each product. Since the carbon footprint shows the total emission of CO2 in whole process of production, it enables to grasp how much CO2 is emitted in each action of process of production.

The aim of this study is to analyze the effect of the spread of carbon footprint and influence of the carbon tax to the social dilemma. To this end, this study constructs the game-theoretic models for trading goods with carbon footprint between producers and consumers, and then analyzes their actions in the laboratory experiment by employing real human subjects.

2. Model description

This study considers the situation in which producers decide whether to produce eco-friendly products or not and consumers whether to purchase them or not. The eco-friendly products have three levels of the CO2 emissions, highest amounts, defined as φ_a, middle amounts, φ_b, and lowest amounts, φ_c. The costs of these products are $c_a > c_b > c_c$. The producers choose one of these three products.

The environmental damages are assumed to be calculated as some relation to the cumulative CO2 emissions caused by the products. Some amounts of CO2 emissions are sunk naturally in the long life. All products are sold in the market until Period *T*. The cumulative CO2 at period $t \in T$ is defined as $\bar{\varphi}_t$. Thus, the damage function $f(\bar{\varphi}_t)$ from the emissions is defined as follows:

$$f(\bar{\varphi}_t) = \frac{\gamma}{n(1+\exp(-\alpha\varphi_t+\beta))} \quad (1)$$

where

$$\bar{\varphi}_t = \sum_t (\sum_i M_i^t \varphi_i - s), \quad i = a, b, c \quad (2)$$

Notice that M_i^t is the number of purchasing product at period t. s is the CO2 sinks. $\alpha, \beta,$ and n are the parameters for environmental damages, respectively.

There are k producers. They obtain profits defined as the multiplication of the number of products they sold, m_t^l, and the profits from the one unit of each product, S. The, the profits for producer *l* is defined as follows:

$$\pi^l = m_t^l S, \; l = 1, \ldots, k, \quad (3)$$

There are *j* consumers. They obtain net benefits defined as the difference between benefits from the purchased product and environmental damages. The prices of the three products are defined as p_a, p_b and p_c, respectively. The reservation price of consumers is defined as *r*. The net benefit for consumer *m* is defined as follows:

$$u^m = r - p_i - f(\bar{\varphi}_t), m = 1, \ldots, j, i = a, b, c \quad (4)$$

3. Human subject experiment

This study employs the experimental economics method to analyze the decision making for human subjects. The principle of this method is the induced value theory [2]. This theory suggests providing monetary incentives for subjects as a reward relative to the profit they earn in the laboratory. This method is useful for breaking the hypothetical bias that is defined as the overestimation when subjects have no monetary incentive and hypothetically make their decisions [3].

This study conducts the two treatments. One is the tax treatment in which consumers need to pay tax for the proportion to the amount of CO2 emission of each product they buy. The other one is no-tax treatment which is the benchmark control session. There are two producers and three consumers in each group. We recruit 4 groups. One session includes more than 20 periods. Same subjects join the both treatments. Average payments are about 3,000 yen in 2 hours.

4. Results

The highest eco-friendly product is more frequently produced and purchased in all groups in the tax treatment than that in non-tax treatment. This result suggests that the tax system succeeds in promoting to purchase and produce eco-friendly products. However, there are two groups which produced and purchased the lowest eco-friendly products more frequently in the tax treatment than the no-tax treatment. This result implies that the tax system also has a risk to promote some consumers to become free riders, that is, to purchase less eco-friendly products because damages from the pollution become less. In total, the net amount of CO2 emission in the tax treatment is 30% less than that in the non-tax treatment, which implies that the tax system succeeds in enhancing incentives for consumers and producers to reduce CO2.

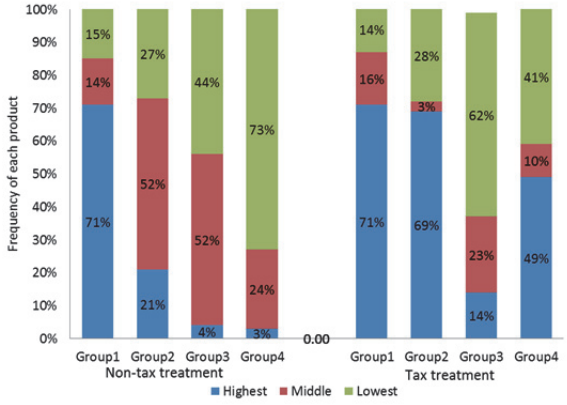


Figure 1. Fraction of eco-products in non-tax vs. tax treatments

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Effect on CO_2 Emissions of Low-Carbon-Technology Considering Residents' Activity Schedule

Chika Ishida,*[1] Hiroyoshi Morita,[2] Yoshimi Kanaoka,[3] and Hirokazu Kato[1]

[1]*Nagoya University, Japan*; [2]*Nippon engineering consultants company, Japan*; [3]*Urban Renaissance Agency, Japan*
*Corresponding author: cishida@urban.env.nagoya-u.ac.jp

1. Introduction

Smart City projects are currently in progress all over the world, owing to concerns over the exhaustion of petroleum resources and global warming. These projects are largely using information and communication technology (ICT)[1]. Some major trial examples are 1) decreasing CO_2 emissions of domestic housing, buildings, and transportation; 2) visualization of the energy supply and demand in each district and area-wide energy system (Micro Grid)[2].

The energy consumption and peak characteristics of the domestic energy sector are dependent on the lifestyle of the individual household; this includes the way of life, means of transportation, and location. Moreover, development of ICT instigates telework and shared housing. These kinds of lifestyle changes are predicted to influence energy demand.

This research aims to investigate low-carbon sectors from two perspectives; the introduction of low-carbon technology and space construction. A model was constructed, which can calculate the energy demand and CO_2 emissions from the activity schedule of each household. Furthermore, the influences of new lifestyles on the reduction of CO_2 emissions are analyzed.

2. Composition of CO_2 emission model

The model for estimating CO_2 emission is shown in Figure 1. Firstly, household composition is set up and a schedule is created for each member with SCHEDULE v2.0 using statistical research[3]. Secondly, the energy demand of light, electrical appliances, air-conditioning, hot-water supply, and transport is calculated. Thirdly, energy consumption is calculated depending on the assumed energy system. Finally, the CO_2 emissions from domestic sources in the entire area are estimated based on the household composition and land use.

In this study, the energy system, which is assumed to be introduced in the future, has four types. One is that the energy of each house and building is controlled individually. The other is that area energy is operated cooperatively, accommodated, and controlled. The systems are divided as decentralized, semi-centralized, and centralized.

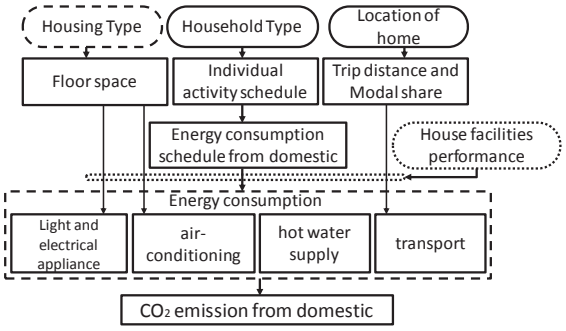


Figure 1. CO_2 emission estimate model

3. Case study in the Nagoya metropolitan area

Evaluation of the introduction of each energy system to three areas (inner, suburbs, outer) in the Nagoya metropolitan area is conducted. The changes set for household composition coincided with the problems in each area. The changes introduced shared housing in inner areas, relocation from a detached house to an apartment in the suburbs, and telework was proposed in outer areas.

CO_2 emissions are reduced compared to the current situation by changing household composition. Introducing the energy system lowers area-wide CO_2 emissions in the order of decentralized, semi-decentralized, and centralized.

In the inner area, a reduction rate of 24% is observed, in the current system, by introducing shared housing. Additional reductions are expected by introducing the energy system.

In the suburbs, a reduction rate of 4% in the current situation is achieved by house relocation. Furthermore, CO_2 emissions per capita become negative when area-wide energy is introduced. This is because the amount of power generation from housing is balanced with commercial and business energy consumption.

In the outer area, CO_2 emissions are slightly reduced, in the current system, by introducing telework. However, when the energy system is introduced, the emissions increase. This is because the energy used to power a car is generated by photovoltaics. The CO_2 emissions are not influenced by shorter trips, while CO_2 emissions from houses increase because time-at-home is increased through telework.

4. Conclusion

In this study, a CO_2 emission model, which is influenced by area characteristics, space composition, and activity schedules, is constructed. The different effects of introducing low-carbon technology are analyzed based on land use, household composition, and activity schedules.

This study reveals the following: 1) The effect of introducing area-wide energy is greater in the suburbs because load leveling is achieved. 2) In the case of introducing telework, CO_2 emission is lower in the current energy system. However, if the public transport share increases and the CO_2 emission basic unit of electric vehicles decreases, then CO_2 emissions from housing could increase.

Acknowledgments

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Evaluation of relationship between agricultural workers and agricultural residues: A case study of Hyogo prefecture

Tomohiro Tabata,*[1] and Yukako Sakon,[1]
[1]*Kobe University, Japan*
*Corresponding author: tabata@people.kobe-u.ac.jp

1. Introduction

Technical, economic, and social issues for energy utilization of agricultural residues exist even though such utilization of such residues is quite important from the viewpoint of global warming. However, stable supply of agricultural residues might be difficult in the future because there are few younger agricultural workers in Japan and aging ones have increased. In this study, we develop a model to estimate production of agricultural residues taking into account population of agricultural workers and cultivated acreage.

2. Methods

This model consists of five modules, aiming to (1) estimate sales of agricultural products using a regression model, (2) convert each agricultural residue from sales of each agricultural product, (3) estimate CO_2 reduction effect if the agricultural residue is utilized for heat and electricity, (4) estimate future outlook of population of agricultural workers, and (5) estimate future agricultural residues.

First, an agricultural census in Japan from FY2000 to FY2010 [1] is utilized to construct the regression model (FY means fiscal year. FY2000, which ends in March 2001). Sales of agricultural products are extracted as the explained variable; and 18 variables, such as agricultural workers and cultivated acreage, are extracted as explanatory variables from this census. Second, residue to product ratio of each agricultural product is examined via a literature survey and interview. Third, heat and electricity made from agricultural residues are assumed to substitute for heating oil and system power of major power companies. Fourth, future outlook of population of agricultural workers is estimated using the cohort-change rate method. Finally, future outlook of agricultural residue is estimated by multiplying agricultural residue and the future outlook of the population of agricultural workers.

This model is applied to Hyogo prefecture as a case study. The future outlook of production of agricultural residues from FY2010 to FY2030 is estimated.

3. Results and Discussion

The following regression formula is introduced.

$$\underset{(10.08)}{S} = \underset{(10.08)}{60.85L_M} + \underset{(3.09)}{10.33L_F} - \underset{(-4.31)}{0.46A_A} + \underset{(15.67)}{123.24A_L} - \underset{(-1.37)}{7{,}084} \quad (1)$$

where, S are sales of agricultural products, L_M are male agricultural workers, L_F are female agricultural workers, A_A is cultivated acreage for rice, vegetables, and fruits (are), and A_L: is cultivated acreage for feed grains and crops (are).

There are about 150,000 agricultural workers in FY2010 [1]. Based on the cohort-change rate method, the result in FY2030 is reduced to approximately 63,000 people (Figure 1). According to the results of agricultural workers, production of agricultural residues is 7.8 million tonnes in FY2010 (Figure 2). On the other hand, the result in FY2030 is reduced to 3.5 million tonnes. Energy of agricultural residues in FY2010 corresponded to 595 GJ and the result in FY2030 is reduced to 278 GJ. These values take into account utilization of agricultural residues, such as compost. If all agricultural residues are utilized as energy, 5,928 GJ can be utilized in FY2010. The CO_2 reduction effect is also 1.9 million tonnes in FY2010, and the result in FY2030 is reduced to 0.8 million tonnes. If the population of agricultural workers aged 14–44 years is raised quinquennial until 20%, then for our outlook between FY2010 and FY2030, production of agricultural residues may increase 2.1 million tonnes in FY2030.

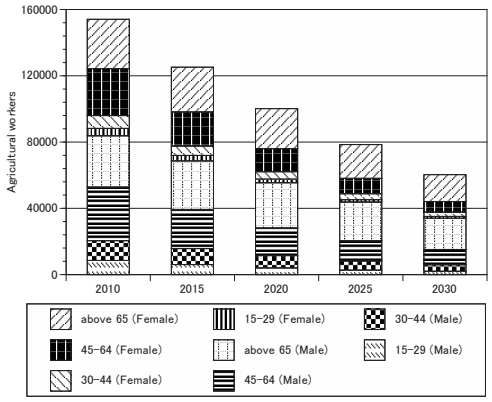


Figure 1. Future outlook of agricultural workers

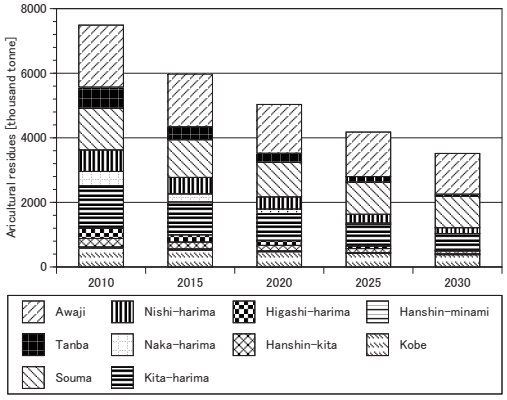


Figure 2. Future production of agricultural residues

4. Conclusion

Although local governments estimate the renewable energy potential of agricultural residues for their future biomass utilization plans, they do not consider the decline of agricultural works. The model we developed is able to interrogate and assess their plans taking into account actual farming.

Acknowledgments

This research was partly supported by the Sumitomo Foundation. The residue to product ratio of vegetables and fruits for each agricultural product was provided from Chiba Prefectural Agriculture and Forestry Research Center.

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Land constraints associated with future food and biofuel demands

Kento Tamura,*[1] Naoki Yoshikawa,[1] Koji Amano,[1] and Seiji Hashimoto[1]

[1]*Ritsumeikan University, Japan*
*Corresponding author: rv0013ir@ed.ritsumei.ac.jp

1. Introduction

Demand for food has been increasing while biofuels have attracted attention as carbon-neutral energy resources. Increased demand for these agricultural products is expected to affect some planetary boundaries such as global land use, biodiversity loss, freshwater use, nitrogen and phosphorus flows, and climate change. An estimate shows 62 countries will not be self-sufficient in the future because of their land constraints [1]. Furthermore, cropland requirements are estimated to be a maximum of 2,669 million ha by 2100 [2]. Therefore, assessing land constraints associated with both food and biofuel demands are important. Nevertheless, such land constraints have not been well examined. This study estimated the following: (1) demand for crops for food and biofuels under new IPCC scenarios (SSPs) and (2) required agricultural land. We then briefly discuss gaps and potential to satisfy the necessary areas devoted to crop production.

2. Method and data

This study examined 187 countries and regions all over the world. Shared Socioeconomic Pathways (SSPs) developed by the Intergovernmental Panel on Climate Change (IPCC) were used to get future population and GDP data of 2010–2100. We estimated the demand for food of 96 items in Food Balance Sheets of Food and Agriculture Organization (FAO) of the United Nations using the methods based on [3] and estimated the demand for crops for bioethanol for vehicles using methods based on [4]. Figure 1 presents a flowchart of this study.

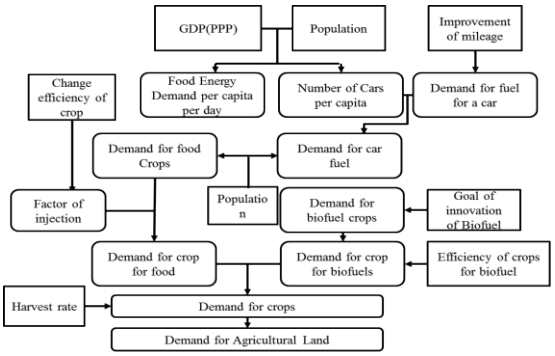


Figure 1. Flowchart of this study

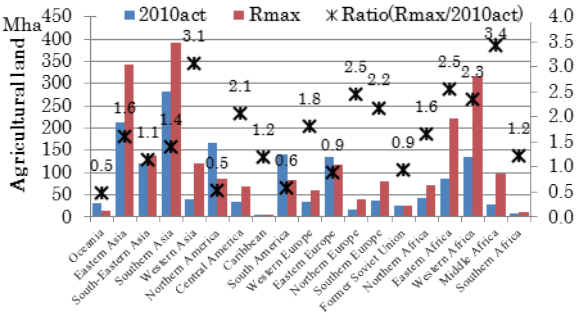


Figure 2. Actual area harvested and estimated agricultural land requirements

3. Results and discussion

As a result, food crop demand might reach 16.3 Gt, or 2.4 times the present level, through 2100. Although most crop requirements are expected to decrease in association with depopulation after 2050, wheat and maize must increase until 2100 because of increased per-capita intake of meat and increased demand for feed. Biofuel crop demand will reach 10.0 Gt, about half of which is sugar cane.

This result also demonstrates that land requirements can reach 1.3 times larger than the present land harvested (1.6 Gha) at most because of expected increases in per-capita GDP and population. Land demand for biofuels was expected to be 10-20% of the total at most under this scenario. Economic growth had greater influence on its increase than that of land for food crops.

In Figure 2, the maximum value of agricultural land demand through 2100 for each region (R_{max}) is shown with the actual area harvested in 2010 (2010act). Most regions must expand agricultural land. Especially in Eastern and Southern Asia and Eastern and Western Africa, they had large difference between 2010act and R_{max}.

Moreover, land demand for biofuel was expected to be 30% of the total at most. Halving meat consumption could reduce about 15% of total land requirement at most.

4. Conclusion

This study estimated the demand for crops for food and biofuel under new IPCC scenarios (SSPs) and required agricultural land. Results shows 1.3 times the present agricultural land might be needed through 2100 because of expected increases in per-capita GDP and population. Most regions must expand agricultural land. Especially, Eastern and Southern Asia and Eastern and Western Africa must greatly expand their land area from present levels. Moreover, halving meat consumption could reduce about 15% of total land requirement at most.

Acknowledgement: This research is supported by the Environment Research and Technology Development Fund (S-11-2) of the Ministry of the Environment, Japan.

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Web-Based system Development for GHG emission from Livestock Sector

Geun-young Lee ,*[1] Sung-mo Yeon[1], and Kun-mo Lee[2]

[1]*WECOS, Korea*; [2] *Ajou University, Korea*
*Corresponding author: gylee1011@wecos.co.kr

1. Introduction

As the global GHG emissions increase, Korea governments have enforced a National/Sectoral GHG Mitigation Target system for GHG emission management in all sectors. Each company including this system has conducted various activities for GHG reductions.

Ministry of Agriculture, Food and Rural Affairs (MAFRA) have studied diverse researches for GHG management in livestock sector. But up to now, there is not almost the GHG emissions management system in national low lever local government. Therefore the need to manage and calculate GHG emission in national level is required increasingly.

2. Research and result

2. 1. Goal and scope definition

2. 1.1. Goal

In Korea, researchers have studied diverse researches for GHG emissions in livestock sector. But there is not almost the GHG emissions management system in national local government. Therefore the goal of this study has developed Web-based system in order to manage GHG emissions in local government for milk cow, Korean beef/beef cattle and pig.

2.1.2. Scope

Geographical scope is 227 local governments and livestock studied are milk cow, Korean beef/beef cattle and pig.

In addition, we separated GHG emissions into 4 steps, namely feedstuff production, enteric fermentation, electricity for farm, manure management

2.2 Activity data

2.2.1 Number of heads

But we need the number of heads of each growth phase for milk cow, Korean beef/beef cattle and pig, there is not relevant data in Korea.

Therefore we calculated the number of heads using local government's statistics annual report and national statistical data.

2.2.2 Feeding

We estimated the amount of the feed fed in the each growth phase utilizing feeding standard of Korean National Institute of Animal Science (NIAS) and relevant association data.

And we classified feedings as 3 categories, namely roughage feed, concentrated feed and TMR. For TMR, we assumed "0" because there is no data in feeding standard and statistical data.

2.2.3 Energy consumption

There is no standard farm's operation data for energy consumption in Korea. Korea Energy Economics Institute (KEEI) has published the national energy consumption data about agriculture sector every 3 years. But that data is not suitable for this study.

Therefore we calculated energy intensity (energy consumption/head) from the GHG emission of farm operation including "Development of carbon tracing system for livestock agriculture" by performed MAFRA.

2.2.4. GHG emission factors

Emission factors provided by Greenhouse Gas Inventory & Research Center of Korea (GIR), Korea Environment Corporation and Ajou university' s farm model are used.

2.3. Result

We developed web-based GHG emission management system which we can use the above-mentioned activity data and emission factors.

Main characteristic of this system is that we are able easily to enter raw data and calculate GHG emissions to local government level.



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Figure 1. The main screen of web-based system

The total of 3 livestock's GHG emissions is 929,377 tCO2 in 2001 and 1,402,192 tCO2 in 2012. The highest GHG emission area is Gyeonggi-do province for milk cow, Gyeongsangbuk-do Province for Korean beef/beef cattle and Gyeonggi-do province for pig.

3. Conclusion

To manage GHG emissions in livestock sector consistently, we need to introduce new national scheme. Also we have to study the research for detailed activity data and emission factors.

Acknowledgment

This research has been development within the frame work of "The method development of calculation and medium for CH4 and N2O emission" and supported by Korean National Institute of Animal Science (NIAS).

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Greenhouse Gas Emission of Rice Production System in the Philippines Based on Life Cycle Inventory Analysis

Elmer G. Bautista[1] and Masanori Saito[2*]

[1]*Philippine Rice Research Institute, Philippines;* [2] *Tohoku University, Japan*
*Corresponding author: msaito@bios.tohoku.ac.jp

1. Introduction

In the Philippines, agriculture was 3% of GDP and employing 35% (12.9 million) of the total labor force [1]. Rice cultivation is 34% of its total agricultural area [2]. The national inventory in agricultural has been 1994 data. It is important to quantify the GHG emission from rice production.

Most rice fields are cultivated twice a year. Methane, the GHGs emitted through anaerobic decomposition of organic matter in the field, is less in rainfed than irrigated rice. With low mechanization status, carabao is still widely used as draft animal for plowing and harrowing. Rice straw burning is most practice (95%) because it is the fastest, economical, and easiest way but cause environmental and health hazards.

Climate change has been the biggest threat to humanity. The Philippines has been severely experiencing natural calamities such as floods, typhoons, and droughts as it is more devastating in the tropics than other climatic zones.

This paper assessed the GHG emissions of rice production based on lifecycle inventory analysis. It is vital to help identify potential mitigation processes.

2. Methods

This study classified rice production into irrigated (2.9M ha) or rainfed (0.13M ha) area with ave. 4.21 and 2.93 t ha^{-1} in 2006-2007, respectively. The system boundary included seedbed preparation, land preparation, transplanting, crop care, harvesting, and threshing. In the Philippines, harvested rice is usually preserved as grain and was milled immediately before consumption.

The GHG emissions from fertilizer, pesticide, fuel and carabao; and methane (CH_4) and nitrous oxide (N_2O) emissions from soil were estimated based on 2006 IPCC guideline. The difference in rice straw management (burning or incorporation) was also accounted. Data and GHG emission factors were gathered from the Philippine surveys of 2006-2007 [1] and references [2]. GWP used were 21 and 310 for CH_4 and N_2O, respectively. The total GHG emission of rice production was calculated using the following formula:

$$GHG_r = \sum(GHG_{rc} + GHG_f + GHG_{cm} + GHG_{fuel} + GHG_{rs} + GHG_p + GHG_{mach})$$

Where: GHG_r = the total GHG emission of rice
GHG_{rc} = the GHG emission during rice cultivation
GHG_f = the GHG emission of fertilizer
GHG_{cm} = the GHG emission of carabao
GHG_{fuel} = the GHG emission of fuel
GHG_{rs} = the GHG emission of rice
GHG_P = the GHG emission of pesticides
GHG_{mach}= the GHG emission of machine

3. Results and Discussions

The total GHG emission of rice production in the Philippines was 13.3 Tg CO_2 eq. yr^{-1}.

Table 3. GHG emission of rice in the Philippines.

	Total kg CO_2 eq. yr^{-1}	kg CO_2 ha^{-1} yr^{-1}
Irrigated area	1.14E+10	3.92E+03
Rainfed area	1.87E+09	1.38E+03
Total	1.33E+10	3.11E+03

Rice yields from irrigated and rainfed areas were 74% & 26% of the total rice production while GHG emission were 11.4 Tg CO_2 eq. yr^{-1} (86%) and 1.87 Tg CO_2 eq. yr^{-1} (14%).

The GHG emission of rice in the Philippines was lower than other temperate countries. Lower GHG emission was due to lower use of fertilizer, agro-chemicals, fuel, and other inputs.

Increasing rice productivity will increase inputs but also increase GHG emission. However, if the increase in yield is comparable with the increase in inputs from fossil sources, the GHG emission per rice grain might be kept at the same level.

Table 2. GHG emission of rice in the Philippines

	kg CO_2 eq. ha^{-1}		kgCO_2eq kg $grain^{-1}$	
	irrigated	rainfed	irrigated	rainfed
CH_4 emission from soil	3,625	1,141	0.861	0.389
CH_4, N_2O from carabao	50	50	0.012	0.017
N_2O from N applied	105	79	0.025	0.027
Fertilizer	99	74	0.024	0.025
Pesticides	5	2	0.01	0.01
Fuel	6	5	0.01	0.02
Threshing	13	13	0.03	0.04
Handtractor	17	17	0.04	0.06
Total	3,922	1,381	0.931	0.471

Several mitigation processes could be adapted such as use of alternate wetting and drying and midseason drainage; replacing carabao with handtractor; and good straw management.

4. Conclusion

The major GHGs emitted were CH_4 and N_2O from soil and fertilizer. Mitigation for these processes should be prioritized. Also, it was noted that GHG emission from rainfed was much smaller than irrigated rice's. The Philippines needs to produce more rice by expansion of irrigation and use of advance rice farming but inevitable increase GHG emission. Therefore, it will be more important to satisfy both increasing rice productivity and mitigating GHG emission.

5. Acknowledgment

The authors are grateful to the JSPS RONPAKU fellowship program. The fellowship was given to E.G.B.

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A proposal of the CF index of rice in consideration of consumer's health condition.

Takashi Oi,*[1] Kenta Shiokawa,[1] Kenji Koido,[1] and Kiyoshi Dowaki[1]

[1]*Tokyo University of Science, Japan*
*7414604@ed.tus.ac.jp

1. Introduction

Recently, the demand of rice is decreasing due to a change of the food culture in Japan. Accordingly, the number of rice farmer has been declined slightly. On the other hand, Japan government announced to join in Trans-Pacific Partnership (TPP) in the future. TPP is a Free Trade Agreement (FTA) with a high-level liberalization goal so as to reduce all trade tariffs to zero. So far, Japanese rice was protected by high tariff rate. However, based on the scheme, the government seems to get a good chance to enlarge the number of rice farmers. That is, the characteristics of eco-friendliness and/or high quality etc. would be remarkable.

In this paper, we focus on the Japanese rice production from the viewpoint of LCA thinking and product quality. This means that the agricultural product can take a good strategy so as to enlarge the market. Also, the product can be exported by making differences on the eco-friendliness and the quality, even if TPP scheme would be promoted.

2. Estimation Conditions

Here, we considered the following two scenarios: (1) the product is the rice exported after the brown rice cultivated in Japan is polished, and (2) that is the rice exported after the brown rice cultivated in Japan is unpolished. Both of products are assumed to be stored in foreign countries before shipment, for instance, Asian countries which would be promising area. We adopted the model country of Indonesia. Thus, we investigated the influences of not only agricultural activity but also transportation and storage.

3. Calculation method

Based on the system boundary, we calculated the $LCCO_2$ emission and DALY. In the calculation of above indexes, the specific energy consumption was due to sub-processes of agricultural activities or transportation. Also, this time, we involved the effect of quality change of product. On the rice cultivation, we executed the site investigation in Yamagata, Japan, that is, we used the bottom-up methodology.

The index on the food security was considered by the measurement data. Using the measurement result of heavy metal content of rice, we calculate DALY per polished rice 1 kg. Here, our estimation was estimated by LIME2. DALY is calculated by the product of chronic damage function and amount of daily intake per kilogram of body weight. Also, chronic damage function is as follows:

$$\text{chronic} = \text{PDI} \times \text{DR} \times \text{DALYs} \quad (1)$$

$$\text{DR} = 0.1/(\text{ED10h} - \text{THr}) \quad (2)$$

$$\text{ED10h} = 1.6 \times \text{NOAEL} = 0.3 \times \text{LOAEL} \quad (3)$$

where, chronic, PDI, DR, DALYs, ED10h, THr and NOAEL are chronic damage function, daily ingestion predictive quantity [mg/kg/day], dose-response factor, DALY of chronic [risk/(mg/kg/day)], 10% of quantity which influences a person, threshold, and no observed adverse effect level, respectively.

Also, we considered quality of rice. Here, the quality is palatability. That is, the quality means the inclusion of heavy metal, protein, amylose, moisture, consistency and stickiness, by which the preference is extermenly affected. Thus, as a frist stape, we focused on the influecne for quality change due to the cold storage. Compared the case of cold storage at 12 deg.C to that of ambient storage at room temperature, we investigated the quality change of target rices with the passage of time of a month and fourth month. Then, the effect was calculated by the following equations of rate of deterioration (See (4)).

$$\text{RD} = \frac{\text{balance of after storage}}{\text{balance of before storage}}, \ \text{balance} = \frac{\text{H}}{-\text{H}} \quad (4)$$

Where, RD, H and –H are rate of deterioration, consistency [kgf] and -H is stickiness [kgf].

4. Estimation Results

First, we discussed the CO_2 emissions and DALYs for the differences of harvesting area and the product of rice. On the CO_2 emission, that was 1.46 kg-CO_2eq/kg of polished rice which was exported from Tokyo, Japan to Jakarta, Indonesia. Varying the harvesting area, for instance, California, US from which the product was delivered to Jakarta, Indonesia, that was 3.21kg-CO_2eq/kg. In this estimation, the specific CO_2 emission of rice would be affected by the cultivation method. Especially, the emission of US was 2.75 kg-CO_2eq/kg [1].

Next, we investigated the health influence due to the toxic substances in rice. Using the chronic damage function of cadmium and arsenic, we obtained 0.0343 DALYs/kg-Cd and 0.149 DALYs/kg-As. Also, from the measurement results, Thus, the DALYs of the following cases: brown rice with storage, polished one with storage, polished one with exportation and brown one with exportation, were 0.00684, 0.00180, 0.00702 and 0.00478 DALYs/kg, respectively.

On the quality change, RD and taste score were shown in Table 1. In general, it is said that brown rice or the rice with cold storage can keep better quality. However, the RD of rice with ordinary storage at room temperature in this study would be better. That is, there would be little influence about the rice of short-term storage without cold storage.

Table1. Change of quality

Kind of rice (day of analysis)	RD	Taste score
Brown rice storage (28. 5.2014)	–	74
Ordinary temperature storage(8.7.2014)	1.09	71
Refrigerated storage (8.7.2014)	1.14	73
Polished rice storage (28. 5.2014)	–	72
Ordinary temperature storage(8.7.2014)	1.14	67
Refrigerated storage (8.7.2014)	1.17	70
Polished rice exportation (28. 5.2014)	–	75
Ordinary temperature storage (8.7.2014)	1.39	74
Refrigerated storage (8.7.2014)	1.23	75
Brown rice exportation (28. 5.2014)	–	76
Ordinary temperature storage(8.7.2014)	1.09	74
Refrigerated storage (8.7.2014)	1.16	75

5. Conclusions

From the above results, probably, there is a good potential to export Japanese rice with better quality to Asian countries, even if the delivery method is the system without any cold storage.

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Influence of management practices on life cycle greenhouse gas emissions from rice production in Yamagata Prefecture, Japan

Katsushi Yokoyama *[1] and Kiyotada Hayashi [2]

[1]*Yamagata Integrated Agricultural Research Center, Japan*; [2]*National Agriculture and Food Research Organization, Japan*
*Corresponding author: yokoyamakats@pref.yamagata.jp

1. Introduction

One of the primary agricultural policy objectives in Yamagata Prefecture is to mitigate greenhouse gas (GHG) emissions from rice production while decreasing rice production costs. These factors are considered be mutually dependent, and therefore their relationship requires clarification for each factor to be effectively promoted. However, knowledge on the relationship between management practices and their environmental impacts is limited.

In this study, life cycle GHG emissions from rice production in Yamagata Prefecture in 1990 and 2011 were estimated. These two years were chosen for comparison because there were less farmers associated with a large-sized business and fewer measures implemented for achieving environmentally friendly rice cultivation practices in 1990 than in 2011.

2. Methodology

GHG emissions in rice production between 1990 and 2001 were compared by conducting life cycle assessment analysis according to the size of each business in Yamagata Prefecture (Figure 1). The data used for the assessment are based on representative farm management records from 1990 and 2011 that were associated with prefectural agricultural extension services, as well as data obtained from the World Census of Agriculture and Forestry in Japan. GHG emissions from rice production were estimated according to a simplified assessment method developed by the National Agriculture and Food Research Organization.

GHG emission estimates were subjected to various assumptions. The assumed size of a business was determined based on five categories: 1 ha, 3 ha, 5 ha, 10 ha, and 30 ha. One type of paddy rice cultivar was considered for 1990, and three types were considered for 2011. Moreover, the estimation considered the paddy rice cultivar cropping ratio, environmentally friendly rice cultivation attestation area, agricultural-work commission ratio, mean pest control area, seedling raising management method, and the preparative method used for crop drying, among other factors.

GHG emissions were divided into direct emissions from paddy fields and indirect emissions resulting from the consumption of energy, materials, and chemicals in the cultivation and harvesting processes. Then, emissions were estimated with respect to carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), and converted into the amount of emission relative to CO_2.

3. Results

As compared with 1990, a decrease in GHG emissions per cropping area and per kilogram of product was observed in 2011. In both 1990 and 2011, there were fewer GHG emissions per cropping area and per kilogram of product when the size of the farm was large (Figure 2).

Environmentally friendly cultivation resulted in a low amount of GHG emissions per cropping area, but high GHG emissions per kilogram of products, as compared with conventional cultivation in 2011. However, in 1990, as compared with conventional cultivation, environmentally friendly cultivation resulted in reduced GHG emissions per kilogram of products (Figure 3).

4. Conclusion

In order to win the battle against the negative effects of global warming for rice production, it is essential to increase the efficiency of production while still enabling expansion of a business. Therefore, it is important to secure yield while practicing environmentally friendly cultivation to improve manufacturing efficiency.

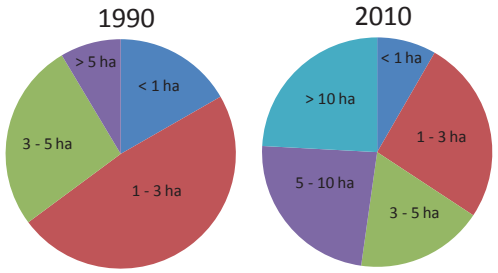


Figure 1. Farm sizes (paddy field) in 1990 and 2010 In Yamagata prefecture, Japan

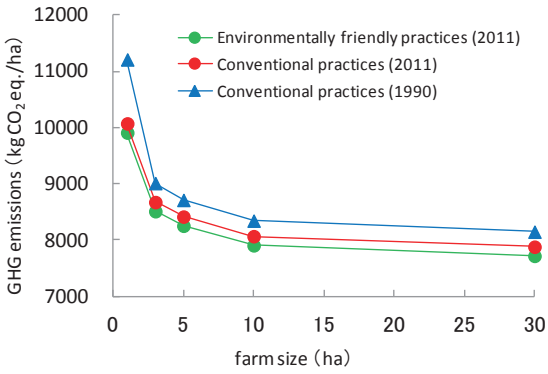


Figure 2. GHG emissions in farms of different size

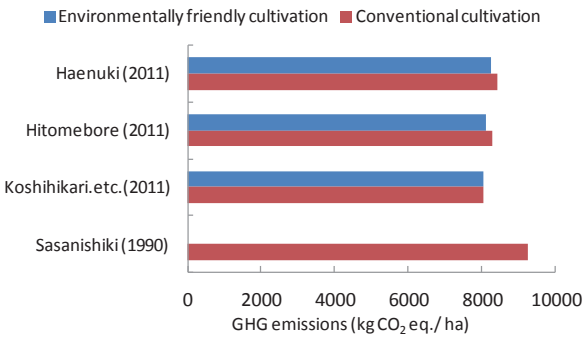


Figure 3. GHG emissions for each farm size and rice cultivar (Haenuki, Hitomebore, Koshihikari, and Sasanisiki: paddy rice cultivar)

Potential reductions in life-cycle greenhouse gas emissions from paddy rice production: assessing the influence of puddling, transplanting density, and irrigation depth

Motoko Shimura,*[1] Hidehiro Takahashi,[1] Chiharu Ito,[2] Makoto Shibuya,[2] Kiyotada Hayashi,[3] and Kenji Matsumori[1]

[1]*NARO Western Region Agricultural Research Center, Japan*; [2]*Akita Prefectural Agricultural Experiment Station, Japan*; [3]*NARO Agricultural Research Center, Japan*
*Corresponding author: shimura@affrc.go.jp

1. Introduction

When water is stored in paddy fields for long periods, the soil becomes reducing and methane (a greenhouse gas; GHG) is produced. In rice cultivation, low-cost and labor-saving methods have been emphasized in the past. Recently, approaches that integrate multiple functions, such as ecosystem preservation and water quality conservation, have been introduced. However, there have been few studies examining the effects that introduction of these technologies has had on generation of GHG. In this study, a life-cycle assessment of these newly applied technologies and approaches was carried out.

2. Study area and Cultivation techniques

We evaluated reclaimed land in Hachirogata in the Akita Prefecture of Japan (Figure 1). Non-puddling cultivation is a technique for planting rice without standing water. A rotary plow is used to plant the rice in finely crushed soil. Turbid water is produced when puddling is used, but not with this method, effectively improving water quality. Furthermore, it is possible to delay irrigation. Thus, the soil is less likely to become reduced and a smaller amount of methane gas is produced. Sparse planting is a technique in which the density of the planting stock is reduced by 30% (21 stock/m^2 to 15 stock/m^2), reducing the material costs of producing seedlings. In deep-water management, because the amount of water stored in the paddy field and the number of days of storage is increased, water purification occurs through denitrification and sedimentation of suspended solids.

3. Results and Discussion

We found that with use of non-puddling technology, methane emissions were reduced to 64% compared to with use of puddling (Figure 2). Furthermore, since turbid water outflow is suppressed, the eutrophication impact had a negative value, as the non-puddling approach improves the aquatic environment.

For sparse planting, the amount of methane emissions was equivalent (97%) with conventional planting (Figure 3).

Furthermore, we evaluated the global warming and eutrophication impact. We used the JLCA database that has been developed using the SimaPro.

As a result, GHG emissions using non-puddling technology was reduced to 69% compared to with puddling. GHG emissions using sparse planting was reduced only a small amount to 93% of that for full planting and the eutrophication impact was nearly the same (Figure 4).

For deep-water management, GHG emissions did not change, but the eutrophication impact also had a negative value due to its water purification effects.

Therefore, non-puddling cultivation is appropriate to suppress GHG emissions. In addition, from a viewpoint of water quality conservation, both deep-water management and non-puddling cultivation are effective.



Figure 1. Study area

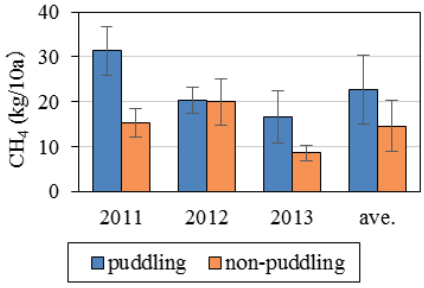


Figure 2. Methane gas emissions of rice paddy field : the influence of puddling

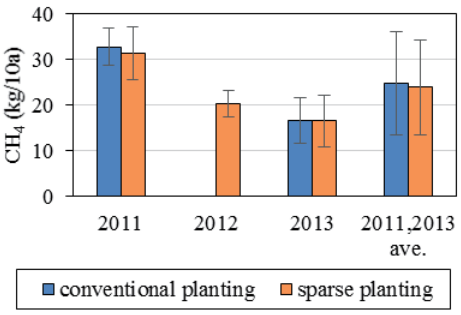


Figure 3. Methane gas emissions of rice paddy field : the influence of transplanting density (21, 15 stock/m^2)

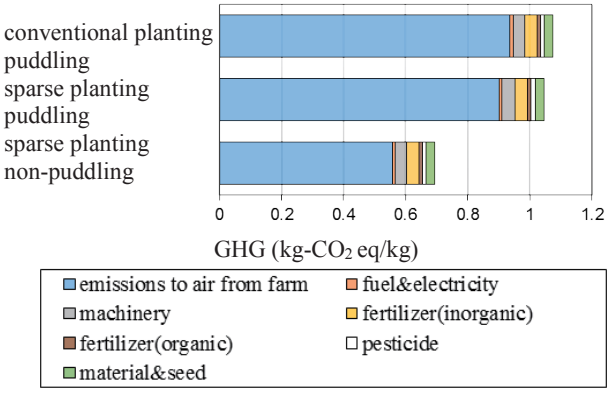


Figure 4. Greenhouse gas emissions of rice paddy field

Life cycle CO_2 emission of konjac production via an overwintering methodology in Gunma, Japan

Kenji Koido,*[1] Yusuke Akaike,[1] Yousuke Isshi,[1] Keisuke Ide,[1] Shou Ushikubo,[1]
Masanori Kou,[1] Kenta Komiya,[1] Katsuya Shimizu,[1] Takumi Minami,[1] and Kiyoshi Dowaki[1]

[1]*Tokyo University of Science, Japan*
*Corresponding author: koido@rs.tus.ac.jp

1. Introduction

Agricultural crops cultivation selling in global chain may require not only consumer's health benefits but also ecological friendliness. Especially, konjac is becoming popular in western countries as a food and nutraceutical products because it is effective for dietary food and relieving intestinal ailments [1,2]. The konjac production will be promoted when it is proved that its health benefits and eco-friendliness are high.

Konjac is a perennial crop, which takes two or three years for production of grown-up corms from planting to harvest and requires frequent transportation by trucks and much fuels for storage [3,4]. About 90% of konjac corm annually produced in Japan is cultivated at Gunma prefecture. To reduce carbon dioxide (CO_2) emission in transportation and drying for storage and diminish excessive work hours, an overwintering methodology is a promising cultivation method in comparison with the conventional one. For conventional methodology, more transportation and drying for storage of the corms are required after the cultivation perennially. The overwintering methodology can omit such a process and drastically reduce CO_2 emission and useful for large-scale cultivation of konjac.

Efficiency in konjac production system is proportional to the productivity and inverse of the input energy. The higher efficiency requires either higher productivity or lower input energy. The latter is reasonable because the former has a limitation in producing konjac with a certain level of nutrient values. In this study, calculation of a case-based CO_2 emission in the overwintering konjac production system is estimated by means of buildup approach to reveal the reduction effect of CO_2 emission for the future promotion of the overwintering cultivation.

2. Scopes and system boundary

The system boundary of konjac production is shown in Fig. 1. The cultivation system comprises field operations, field processes, energy consumption and storage including agrochemicals production, fertiliser production and transportation. Input to the system consists of raw materials and small corm, while output has konjac and CO_2. The functional unit is kilo gram of konjac.

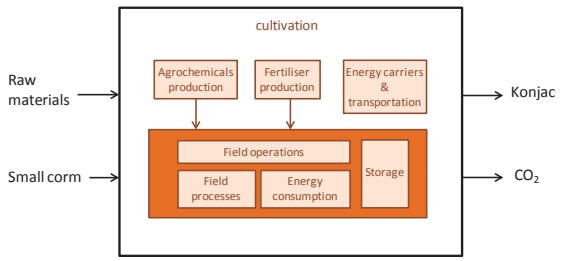


Fig. 1: System boundary of konjac cultivation

3. Inventory analysis

Inventory data for the cultivation was obtained from interviews with a farmer in Gunma, Japan. The konjac is a perennial crop as shown in Fig. 2, and it takes two or three years to produce large-sized corm available for sale in conventional cultivation, where the growing-area ratio for the first-year, second-year and third-year konjac is 3:6:1. On the other hand, all of the konjac grown with the overwintering method are harvested after two years cultivation in overwintering method. For the conventional cultivation, fertiliser fed to the field has the amounts of 140 kg-N/ha, 140 kg-P/ha and 140 kg-K/ha, while those for the overwintering one is 120 kg-N/ha, 120 kg-P/ha and 120 kg-K/ha in first year and 80 kg-N/ha, 80 kg-P/ha and 80 kg-K/ha in second year.

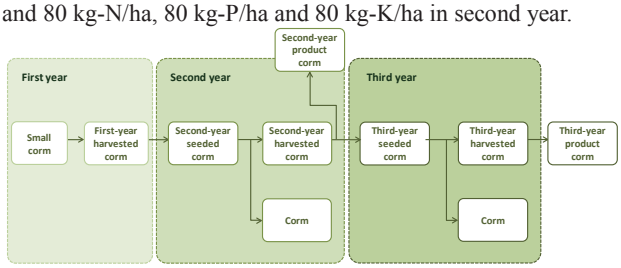


Fig. 2: Cultivation of perennial konjac

4. Results and discussion

CO_2 emission for the conventional cultivation is 112 g-CO_2/kg-konjac, whereas that for overwintering is 57 g-CO_2/kg-konjac, which is half of the conventional CO_2 release. Such small amount of emission was caused by no storage in winter season for the overwintering. Moreover, fertilisation process has large amount of CO_2 emission for both conventional and overwintering cultivations in comparison with other processes as shown in Fig. 3.

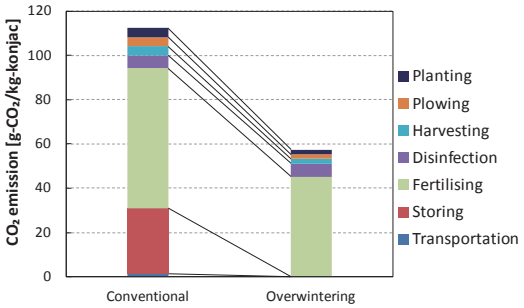


Fig. 3: Comparison of CO_2 emission between conventional and overwintering cultivation of konjac

5. Conclusion

The results showed that the CO_2 emission in overwintering production was 112 g-CO_2/kg, while that in conventional production was 57 g-CO_2/kg. That indicated the high possibility of overwintering konjac corms cultivation to reduce CO_2 emission and excessive work hours for labours.

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Life Cycle Cost Analysis of Willow Production on Small-Scale Fields

Hidetsugu Morimoto*[1], Shigeru Satoh[2], Kimiharu Ishizawa[3] and Takeshi Arai[1]

[1]*Tokyo University of Science, Japan*; [2]*Kyoto Prefectural University, Japan*; [3]*Miyagi University of Education, Japan*
*Corresponding author: m0r1m0t0@rs.tus.ac.jp

1. Introduction

Energy security is one of the most important issues worldwide. In particular, regions like Japan that have a lower rate of self-sufficiency should urgently consider sustainable energy production systems. In this country, the abandoned field area is about 400,000 ha (MAFF, 2012). This issue has been discussed in recent decades. In May 2014, the Japanese government proposed the introduction of coordinated renewable energy production in regional land use in its Act for Renewable Energy Production in Rural Areas.

This paper addresses renewable energy production on small-scale fields, such as the use of abandoned fields for the preservation of agricultural lands. Willow (KKD; Salix spp.) grown as short rotation coppice, cultivation in three different places, has superior woody biomass for use in combination with fossil fuels.

2. Methodology

The analysis area is shown Figure 1. The analysis period is over two growing seasons. Three test fields, in Ibaraki (F1), Kyoto (F2) and Miyagi (F3) prefectures, are in humid subtropical climates, or Cfa according to the Köppen climate classification. The respective field areas are 49.22 a (F1), 25 a (F2) and 46.8 a (F3). Since all infrastructure was already in place, calculation began at the leveling stage.

3. Yields and Production Costs

Table 1 shows results for yields and willow production costs of the three fields. All fields had yields per unit area more than 1.0 dry-t/10 a. Sara et al. (2012) reported yields of 0.3–0.79 dry-t/10 a in commercially advanced Sweden. In our case, yield was the same among all test fields and did not depend on planting density or maintenance times. Weeding two to four times in the first season and about twice in the second season was sufficient.

Costs depended on harvesting. When the cost of the first season was considered the initial cost, the field with the highest operation cost was F2 (Table 1). Although field F1 was maintained (weeding, herbicide and pesticide application) 12–14 times per season, its cost was the highest; however, its operation cost was lowest. The reason is that the harvest cost for F1 was lower than for the other fields. For the test cultivation, it was necessary to consider not harvest cost per field unit but per tree unit, because the density varied among the fields. Costs (JPY/tree) were 7.5 (F1), 79 (F2), and 74 (F3). Maintenance of F3 was the lowest. To keep operation costs low, it was necessary to control the harvest.

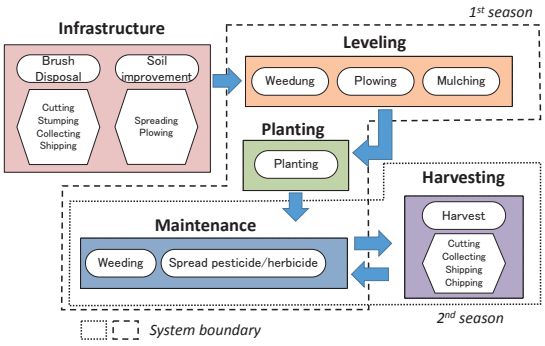


Figure 1. Flow chart of willow production and system boundary for LCC

4. Comparing production costs with other crops

Willow cultivation can be considered one use for abandoned fields. Some willow production costs were lower than those of rice and sugar cane cultivation in Japan. Willow is more costly than extensive production of food crops such as rapeseed and buckwheat, which are cultivated to control increases in unutilized farmland in Japanese rural areas. However, given the Optimal Case (OC), which is the lowest processing (leveling, planting, maintenance and harvesting in Fig. 1) cost among the willow production fields, willow cultivation becomes a feasible use of abandoned fields.

5. Comparing cost unit per unit heat value with other resources

The cost per unit heat value (CHV) of willow is similar to that of fossil fuel energy but lower than that of woody biomass given the OC. The CHV_{OC} was 1.88 JPY/MJ, in which heat value is 18.8 MJ/dry-t (Satoh et al., 2012) and OC operation cost is 35,315 JPY/dry-t. Heat values of woody biomass, kerosene and heavy oil were 0.67, 3.02 and 1.99 JPY/MJ, respectively. The price of natural gas is lowering because of the shale gas revolution, and the CHV of willow is inferior to it. However, considering that gas is finite, willow production might be a superior resource.

6. Conclusion

It is possible to produce willow on small unused and abandoned fields in Japan. The yield is about 1.0 dry-t/10 a, similar to or greater than commercially advanced countries. If the production process cost can be controlled, the CHV of willow would be superior to fossil fuel energy.

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Table 1 Amount and cost of production

		F1	F2	F3
Field Area [a]		50.0	11.6	46.8
Production period		2011. Mar. - 2012. Dec.	2012. Mar. - 2013. Dec.	2012. Apr. - 2013. Dec.
Plant density [tree/10 a]		900	1,379	751
Weight [wet-kg/tree]		5.21	2.27	5.24
Moisture content [%]		43.0	42.2	45.0
Annual average [dry-t/10 a]		1.32	1.34	1.08
Operation Cost [JPY/10 a]		79,251	171,998	93,264
(JPY/dry-t)		(60,039)	(128,357)	(86,356)
Maintenance content				
Weeding	rotary tiling	14 times	5 times	—
	brush cutter	12 times	—	2 times
Herbicide		12 times	7 times	—
Pesticide		2 times	2 times	1 time

Life Cycle Inventory Analysis for Small Scale Trawl Fishery in Sendai Bay

Kazuhito Watanabe*[1] and Kiyotaka Tahara[2]

[1]*Kwsennuma Regional Promotion Office, Japan*; [2]*Advanced Industrial Science and Technology, Japan*
*Corresponding author: watanabe-ka825@pref.miyagi.jp

1. Introduction

Small scale trawl fishery is done around the coastal areas of Japan. This is one of the large amounts of fish catching fishery as well as purse seine fishery and offshore trawl fishery in Japan. As to the application of LCA for fisheries, the discussion of functional units is remained. In order to construct the fisheries and marine products LCI data corresponding to catch variability, we need dynamic analysis associated with the amount of fishing effort and catches to comprehend the dispersion of data as a reality. Therefore, in this study, we performed LCI analysis for small scale trawl fishery in Sendai-bay using multi-year data, and clarified the impact for the result by the difference of annual fishing catch. In addition, we considered the suitable indicator for fisheries and marine products.

2. Method

System boundary: the inputs are each item of fishing gears, fishing boat, and fuel oil. The outputs, on the other hand, are landings and environmental burden. The manufacturing processes of fishing gears, fishing boat, and fuel oil are considered in addition to an immediate operation of the fishery in this system. However, the abandonment stage of the fishing equipment was excluded from the investigation.

Data collection: Data were basically gathered by an interview with the WATARI Fisheries Cooperative Association. The researchers also gathered data through the questionnaires given to the fishermen.

Inventory analysis: In this research, the researchers took up CO_2 as an index of the environmental burden in the point of global warming prevention. CO_2 emission functional unit of each item are calculated by AIST-LCAver5. In addition, the researchers summed up the amount of CO_2 emission by taking the sum total of CO_2 of each item emission in fishery system. Each of the landings (weight) and the amount of money was requested in conversion into the CO_2 emission functional unit. Moreover, the researchers calculated the differences of each fishing boat and monthly changes of CO_2 emissions.

3. Results and Discussion

Table 1 shows the amount of CO_2 emission of the small scale trawl fishery and calculation results of the CO_2 emissions as functional unit. The total amount of CO_2 emission by the small scale trawl fishery (11 boats) was 1,009t per year. Expressed in ton, the value becomes 4.7t. Moreover, expressed in million JPY, the value becomes 8.2t. Moreover, the ratio of the CO_2 emission in the small scale trawl fishery is calculated. The influence by the fishing boat and the fishing gear was small ratios (totally 3%) while the emission by the fuel consumption was 97% of the whole, and occupied big ratios. Therefore, in order to reduce the CO_2 emissions of small scale trawl fishery, the policy for reducing direct fuel consumption must be devised. Thus circumstanced, the use of fishing gear which expanded mesh of fishing net was suggested one of the ways to reduce CO_2 emission. However, the trade-off between fish landings and CO_2 emissions needs to be considered.

Table 1 CO_2 emission caused by small scale trawl fishery

Fishing method	Cumulative CO_2 emission [t-CO_2]	/ fish catches [t-CO_2/t-products]	/ fish catches [t-CO_2/million yen]
Small Scale Trawl Fishery [11 boats total]	1,009	4.7	8.2

The difference in the CO_2 emissions of each fishing boat was computed (Figure 1). The CO_2 emissions of each fishing boat are in the ranges from 6.6 to 12.1t-CO_2/million yen respectively, and the difference of 1.8 times was observed between maximum value and minimum value. These results indicated that the difference of information as to fishery formation in ocean and/or the know-how based on the fishermen's experiences besides trim parts (engine ability, GPS and fishing gear, etc.). Secondly, monthly changes of CO_2 emissions were investigated (Figure 2). The lowest value was 6.5t-CO_2/million yen in the August. On the other hand, the highest value was 10.1 t-CO_2/million in May and October. The difference of 1.5 times was observed between maximum month and minimum month. When the fish in season was obtained at the time of its season, it was indicated that CO_2 emissions also tend to become low.

These results were also compared with I-O table analysis results (2005 edition). It was 9.1 t-CO_2/million yen as average value of the whole sea surface fishery. Since the value of the small scale trawl fishery was 8.2 t-CO_2/million yen, it turned out to be lower value than that of average value based on I-O analysis.

LCI analysis was performed for the small scale trawl fishery in this study. As a result, CO_2 emission was cleared. Moreover, changes of CO_2 emission from small scale trawl fishery was shown in the view point of individual boats and monthly. Continued case study is required to develop fishery LCI database in the future.

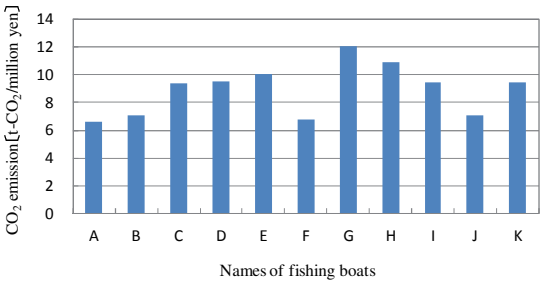


Figure 1 CO_2 emissions of each fishing boat

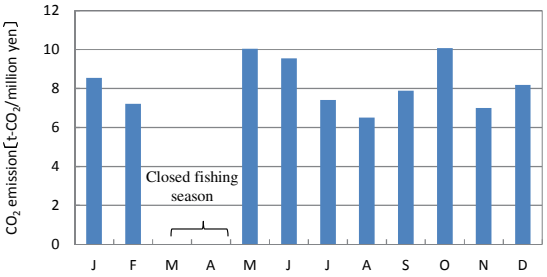


Figure 2 Monthly changes of CO_2 emissions

Improving the Environmental efficiency of woody biomass utilization: Focusing on the manufacturing of High Value-added Products in Maniwa, Japan

Dami MOON*[1], Naomi KITAGAWA[1], Masayuki SAGISAKA[1], and Yutaka GENCHI[1]

[1]*National Institute of Advanced Industrial Science and Technology, Japan*
*Corresponding author: dami.moon@aist.go.jp

1. Introduction

Generally, woody biomass is often used to produce bio-energy for converting electricity, heat, or biofuel. Meanwhile, Okayama prefecture is suggesting the possibility of material production from woody biomass in order to enhance the value of woody biomass as a resource. Maniwa city, which is located in western part of Japan, has built integrated woody biomass station (IWBS) for a purpose to produce woody products, such as wood chips, barks, and chip dust, to promote logging residues utilization which are collected from forests in rural district. Furthermore, Okayama prefecture, a large administrative unit of Maniwa, is to support the planning for producing high value-added (HVA) products using logging residues and mill residues in Maniwa, called Master batch of Cellulose Nanofiber (CNF-MB), and High standard chip dust (HSD) as a possible alternative to plastic composites.

This study quantified the effects of financial benefits and Greehouse Gas (GHG) emissions and its efficiency by the production of HVA products in Maniwa. Overall, the purpose of this study was to find a better understanding the environmental and economic effect of business model for manufacturing high value-added products.

2. Methodology

There are 6 types of woody products that are manufactured or planned in IWBS, Maniwa. 4 products of chip for paper, chip for fuel, bark, and chip dust are currently being produced, and other 2 products of HSD and CNF-MB are planned to produce in the near future. For this study, the process for manufacturing woody products can generally be divided into five stages : harvest, transport to the IWBS, sawmilling, manufacturing, and transport to the consumer. Among these, the process using logging residues go through only 4 stages except for sawmilling stage.

In order to examine the effects of financial benefits and Greehouse Gas (GHG) emissions by introduction of HVA products, two scenarios were proposed : one describes the current situation for producing 4 types of existing woody products (BAU scenario), and the other scenario describes the planning situation in which the production of HVA products such as HSD and CNF-MB are added from the current situation (HVA scenario).

Quantitative information related to supply and demand of woody biomass has been collected through in-depth interview by executives of Maniwa lumber cooperation and the Maniwa city hall during 2011-2013. And specific information about manufacturing of CNF and HSD was obtained by the result of the internal experiment by cooperating with Okayama prefecture. Based on information, financial expenditure, income and benefit could be calculated. Total amount of GHG emissions also could be estimated using the value of amount of woody biomass input of each product and the value of GHG emissions per tonnes of woody biomass as shown in equation (1).

$$GHG_t = \Sigma^n{}_{i=1} (A \times GHGu_i) \quad (1)$$

Here, GHG_t is total amount of GHG emissions(kg-CO_2eq); A is amount of woody biomass input of each products (input-ton/year); i indicates 5 stages of the process (n=1~5). Where, 1: harvest stage, 2: sarmilling stage, 3: transport to the IWBS, 4: manufacturing stage, and 5: transprot to the consumer stage ; $GHGu$ is GHG emissions per unit tonnes of woody biomass.

3. Results

As results, 1,195 JPY/input-ton of benefit can be obtained in HVA scenario, which is increased by up to 100% compared to BAU scenario of -1,195 JPY/input-ton.

In GHG emissions terms, it was estimated that approximately 51 kg-CO_2eq/t of GHG are emitted in HVA scenario, while about 37 kg-CO_2eq/t of GHG are emitted in BAU scenario.

Income-expenditure ratio of 4 types of existing products, chip for paper, chip for fuel, bark, and chip dust, was 0.8, 1.1, 0.6, 0.8 respectively in BAU scenario. Meanwhile, income-expenditure ratio for 4 types of existing products and 2 types of HVA products of HSD and CNF-MB was 0.8, 1.1, 0.6, 0.8, 1.2, 1.2 respectively. And total income-expenditure ratio for all products was changed to 1.2 in HVA scenario from 0.9 in BAU scenario by the effects of the production of HVA products.

The effect of benefit compared to its GHG emissions of each products was calculated, based on the results of financial benefit and GHG emissions. In BAU scenario, benefit for GHG emissions for chip for paper, chip for fuel, bark, and chip dust was -0.03, 0.05, -0.03, -0.01 respectively. Whereas, in HVA scenario, the value for 4 types of existing products and 2 types of HVA products of HSD and CNF-MB was -0.06, 0.02, -0.06, -0.05, 0.02, 0.11 respectively. And the value for total products in HVA scenario was turned to 0.02 from -0.03 in BAU scenario by adding the HVA products.

4. Conclusions

This study examined to clarify the meaning of the production of high value-added (HVA) products which are produced of woody biomass. The results of this study show that adding the production of HVA products can improve the cost efficiency and also be increased the amount of benefit compared to GHG emissions to the region. Through this study, we figured out that production of HVA products can stimulate economic and environmental effective than existing products. The next task will involve in-depth analysis linking substitution effect of woody products that may guide woody biomass to transition to useful resources for material production that promote economically and environmentally sound and less carbon development in rural regions.

Acknowledgement

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Potential for energy saving of dairy farming system dependent upon land utilization

Tatsuo Hishinuma*[1]

[1]*Utsunomiya University, Japan*
*Corresponding author: thishinuma@cc.utsunomiya-u.ac.jp

1. Introduction

Dairy production is an important agricultural sector in Japan, placed second in agricultural production value in 2012. 1.4 million dairy cows produced milk at 18 thousand dairy farmers, in Japan. Energy from fossil fuels is used at several processes of milk production system; forage production, feeding process, milking process, manure handling.

We applied life cycle inventory analysis to dairy farming system dependent upon land utilization, to reveal amount of energy consumption. We discussed potential for energy saving at the total system.

2. Materials and methods

We investigated a dairy farming system at the Utsunomiya University (UU) as in Table 1. The dairy farming system at the UU has 15 hectare roughage production fields. Amount of roughage production was plenty to feed dairy cows, it was a type of dairy farming dependent upon land utilization. The dairy barn has facing out tie stall barn, tunnel ventilation with 6 fans, ridge roof. The manure treatment systems were utilized composting process for solid waste treatment and activated sludge process for liquid waste treatment.

Table 1. Dairy farming at the Utsunomiya University

Parameters	Values
Number of heads (dairy cow)	16 head
Milking times per day	2 times
Milk production per cow	1,300-5,400 kg/yr
Forage production lands	1,526 a
Hay fields	621 a
Corn fields (for corn silage)	505 a
Pasture fields	400 a
Period of pasturage	from Apr to Nov

The objective processes to assess the dairy farming system at the UU were feed production processes (concentrate feed and roughage), livestock management process, and manure treatment processes excludes liquid waste treatment, in this study.

The data of fossil fuels consumption and other materials consumption (fertilizer, pesticide, concentrate feed, medicine, and other chemicals) were collected annual report from the dairy farming system at UU. in 2009. The amounts of electricity consumption on equipment at livestock housing and manure treatment process were measured with an electric power meter (KW1M-H Eco-Power Meter, Panasonic). The functional unit was set to 1 L milk production, 4 % fat-corrected milk. The energy consumption factor of materials were collected LCA software (JEMAI-LCA pro), and articles and reports.

3. Results and discussion

The total amount of energy consumption was 630 GJ/yr, 10.7 MJ/L-milk. The roughage production process (pasture, rapped corn silage and hay) represented 45% of the total energy consumption, which was derived from diesel fuel. The energy consumption from concentrate feed (import grains) production process and electricity consumption from dairy equipment were contributed 23% and 18% of total energy consumption. From the amount of energy consumption at monthly variation, energy consumption during Jul to Nov was large (Figure1).

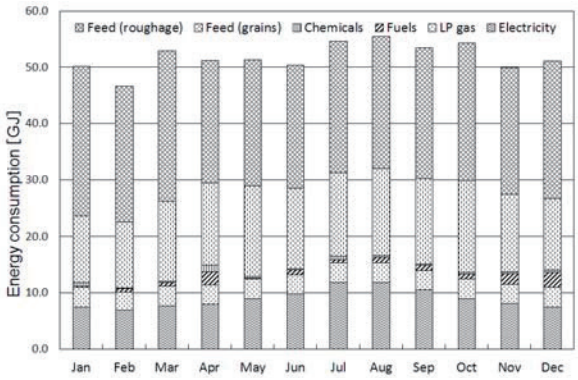


Figure 1. Energy consumption of dairy farm at UU

Energy consumption at a rapping corn silage production process was 8.0-15.0 MJ/TDN-kg, which was large value compared with the energy consumption at a hay production and a pasture management. Total energy consumption of self-sufficient roughage was lower than energy consumption of utilizing imported hay (from Australia).

The large electricity consumption of dairy equipment was due to ventilation fan and pump for pipe line milking system. Especially, electricity consumption of ventilation fan at the livestock management process varied with seasons, because the ventilation fan was run in summer more than in winter, for heat management. On the other hand, electricity consumption from milking pump and barn (lightning, electric fences and other) were flat through the whole years (Figure 2).

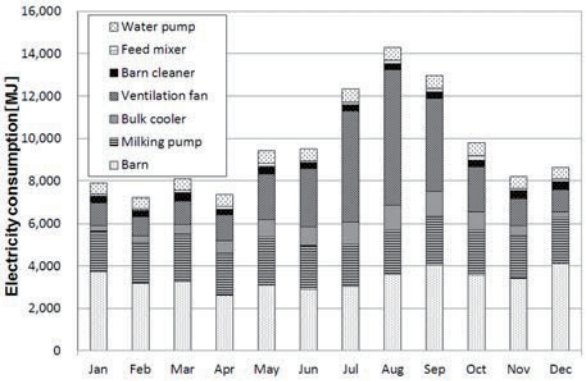


Figure 2. Electricity consumption of dairy farm at UU

4. Conclusion

Energy consumption from the dairy farming system dependent upon land utilization was low, compared with the dairy farming system utilizing imported hay. For energy saving, improvement ventilation system inclding effective heat management in summer is required, from results of LCI analysis at dairy farming system at the UU.

Substance Flow Analysis on Agricultural Nutrients focusing Nitrogen and Phosphorus

Takashi Yamamoto*[1], Masafumi Mizoguchi[1], Kazuyo Matsubae[1], Kenichi Nakajima[2], Keisuke Nansai[2], Tetsuya Nagasaka[1]

[1]*Tohoku University, Japan* [2]*National Institute of Environmental Studies, Japan*
*Corresponding author: b4tm5022@s.tohoku.ac.jp

1. Introduction

Agricultural nutrient such as phosphorus, potassium and nitrogen are essential elements for food production. These elements are called three major elements of fertilizer and the demand of them has been increasing not only for agricultural industry but also for other industries, including chemical (N,P), galvanizing (P), and automobile industry (P).

In 2050, the world population will reach more than 9 billion and stable food supply is one of the most important issues. Furthermore, amount of bioethanol production has increased about three times in the past ten years. From these reasons, the demand of the three elements will increase as well as that of fertilizer. [1]

The aims of this study were the following three, (1) to grasp supply and demand of nitrogen and phosphorus using material flow analysis; (2) to estimate global phosphorus and nitrogen flows associated with export and import of various commodities; and (3) to analyze phosphorus and nitrogen consumption between the Japanese domestic economy and the global supply chain using the GLIO model. Furthermore, we have quantitatively clarified agricultural nutrients consumption for various countries and discussed the possibilities and bottlenecks of recovery and recycling of N and P from the waste streams.

2. Method

The method of this study was threefold:

(1) Material flow analysis of nitrogen and phosphorus subject to 2005 in Japan. [2]

(2) The estimation of nitrogen and phosphorus accompanied with each item traded among 231 countries and regions basis of BACI. [3] 423 types of N and 281 types for P contained products were chosen from HS code (the number indicating the classification of international trade items unified worldwide).

(3) The agricultural nutrient flows into the 2005 input-output model of the Japanese economy, and integrates international trade statistics on the basis of Global Linkage Input Output (GLIO) model. [3]

3. Result and Conclusion

Our results show that domestic flows of nitrogen and phosphorus. (Figure 1, 2) These elements flow in from overseas and flow out into soil (374kt-N, 273kt-P) used as fertilizer and feed. Table1 and 2 show top five countries about the amount of movement, import, and export of nitrogen and phosphorus accompanied with international trade. Figure 3 and 4 show the balance of nitrogen and phosphorus. Regarding nitrogen, North America and China are the key stakeholders, which have large amount of excess balance of nitrogen. Looking at phosphorus, extracted phosphate ore in Morocco was mostly exported, and consumed in Asian countries, including India and China. North and South America and China have large amount of excess balance of phosphorus, while most African countries, even P ore mining countries, face on the low balance of P.

From the estimated results, nitrogen and phosphorus are flow in as fertilizer and feed, and mostly ended up to flow out the environment in the developed countries. It is expected that the consumption of nitrogen and phosphorus will increase as the economic development in BRICS and VISTA. The more effective utilization of these nutrients and the geopolitical and environmental governances are strongly required in coming decades.

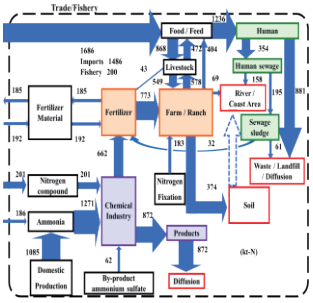


Figure 1 Domestic flows of nitrogen

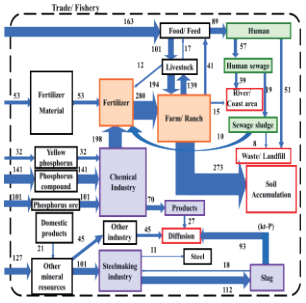


Figure 2 Domestic flows of phosphorus

Table 1 Major international nitrogen flows

Top 5 flows				*Top 5 importer*			*Top 5 exporter*		
From	To	kt-N	Share [%]		kt-N	Share [%]		kt-N	Share [%]
Canada	USA	4,034	3.4	USA	17,086	14.5	Russia	13,161	11.2
Trinidad and Tobago	USA	2,958	2.5	Japan	6,531	5.5	USA	9,398	8.0
Australia	Japan	1,873	1.6	China	5,308	4.5	Australia	5,462	4.6
USA	Mexico	1,239	1.0	India	5,164	4.4	Canada	5,324	4.5
USA	China	1,095	0.9	Germany	4,777	4.0	Ukraine	4,429	3.8

Table 2 Major international phosphorus flows

Top 5 flows				*Top 5 importer*			*Top 5 exporter*		
From	To	kt-P	Share [%]		kt-P	Share [%]		kt-P	Share [%]
Jordan	India	438	2.3	India	1,961	10.4	Morocco	3,219	16.7
USA	China	426	2.3	China	1,033	5.5	USA	2,834	13.3
Morocco	India	415	2.2	Brazil	899	4.8	Russia	2,032	11.1
Morocco	USA	366	1.9	Germany	739	3.9	China	1,208	9.9
USA	Canada	314	1.7	USA	712	3.8	Jordan	858	9.3

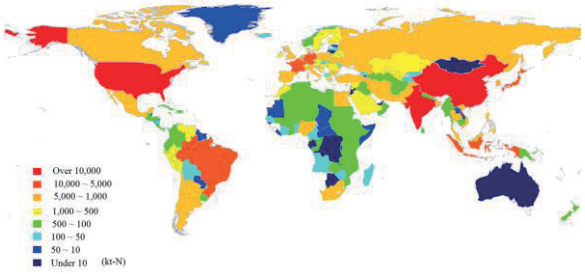


Figure 3 Estimated nitrogen balance

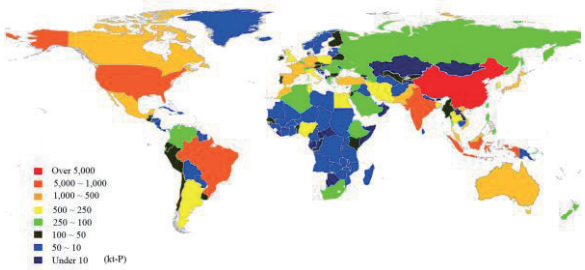


Figure 4 Estimated phosohorus balance

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Water Security and Socio-Economic Metabolism in China: Toward an Integrated Assessment

Tao Wang* and Seiji Hashimoto

Ritsumeikan University, Japan
*Corresponding author: a.t.wang@gmail.com

1. Introduction

An adequate and secured supply of clean water is critical to human health, economic development, and environmental conservation. In China, per capita freshwater availability is barely a quarter of the world's average [1]. Water security thus poses a serious challenge to the planet's largest population and the second largest economy. The effects could spill over to the entire globe by shaking food supply and prosperity.

Material resources, with numerous interwoven relations to water, constitute another pillar for human development. Socio-economic metabolism and material flow accounting offer a framework to compile a great variety of biomass, fossil fuels, minerals, and material commodities [2]. Their methods and theories are promising to be employed to investigate the water-material nexus. By combining water use assessment with material flow analysis, this present research attempts to explore the material-driven water demand in China and vice versa.

2. Water demand and socio-economic metabolism

The consumptive water demand maintained a moderate upward trend in China in the past three decades, growing from 480 giga-m^3 (Gm^3) in 1990 to 610 Gm^3 in 2012. The direct material input, a measurement of the country's socioeconomic metabolism, more than quadrupled in the same period [3], and the gross domestic product (GDP) increased by a factor of nine [4]. The fact suggests that to a certain degree water consumption has been decoupled from material resource demand and economic growth in China.

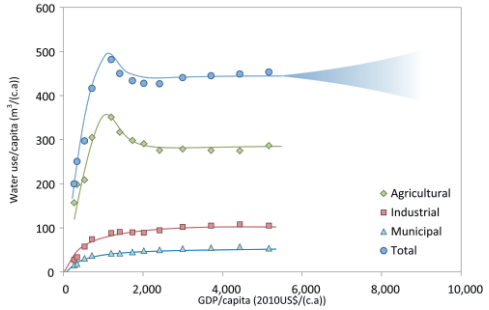


Figure 1. Consumptive water demand in China, ca. 1970–2012.

Agriculture claims nearly two-thirds of China's water demand (Figure 1). Most of this consumption is connected to human demand for biomass materials, including staple foods and livestock [4, 5]. Industrial sectors account for another 20% of total water consumption. >60% of the industrial water has been consumed by production of minerals and basic materials (e.g., pulp and paper, metals, plastics, and chemicals) [5]. For the country as whole, approximately three-fourths of its water consumption is directly driven by demand for materials (including biomass and minerals).

3. Municipal water system and material stocks

Municipal water comprises no more than 10% of China's water demand (Figure 1), nonetheless it needs water in better quality, usually meeting drinking standards. The municipal water cycle in China has been characterized and quantified in Figure 2. In 2012, approximately 57 Gm^3 of raw water was drawn from surface and underground water bodies. After transmission and treatment, 45 Gm^3 of tap water was distributed to the industries, service sectors, and households. 36 Gm^3 of post-use wastewater flows were collected and cleaned in municipal wastewater treatment plants, and merely 3.2 Gm^3 of treated water was reclaimed and recycled (without counting onsite and internal recycling). The present water cycle in China is basically linear and open to environmental sources and sinks. About 40% of the raw water intake may be evaporated, leaked away, or dissipatedly used throughout the cycle.

Vast capital and materials have been devoted to construction of municipal water infrastructure. A material stock accounting has been conducted to compute the quantity of specific infrastructure (e.g., length of pipes and capacity of treatment plants) and the intensity of typical construction materials per infrastructure. It shows that some 2.8 gigatonnes (Gt) of materials were embodied in the infrastructure stock as of 2012, including 1.8 Gt in drainage and sewage pipes, 0.52 Gt in water supply pipes, 0.30 Gt in water facilities and 0.12 in wastewater facilities. In terms of material composition, about 66% of the stocks are sand and gravels, 30% are cement, and 4.1% are cast iron and steel tubes and components.

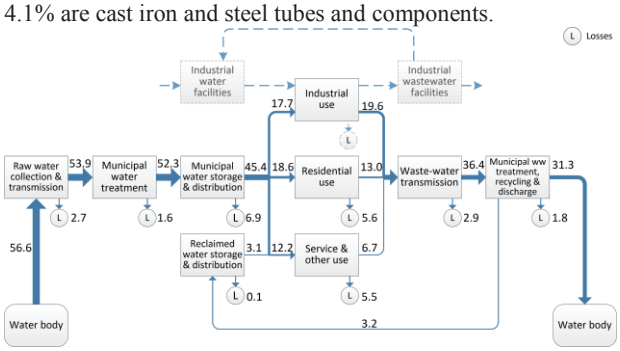


Figure 2. Municipal water cycle in China, 2012, in giga-m^3/a. Data source: [6].

4. Summary

This research examines water use and its connection with the demand for material resources in China. It also assesses the municipal water cycle and material stocks in the water infrastructure. The study may help pay the way toward an integrated assessment of water and material resources in socio-economic metabolism.

Acknowledgments

This study is supported by Ritsumeikan Global Innovation Research Organization (R-GIRO) under the research of water reclamation and recycling in Asia.

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Water Footprint Assessment of Machine Tool

Jahau Lewis Chen,*[1] Yen-Bou Chen,[1] and Hua-Chih Huang[2]

[1]*National Cheng Kung University, Taiwan*; [2]*ITRI, Taiwan*
*Corresponding author: jlchen@mail.ncku.edu.tw

1. Introduction

Water is critically important to human life. However, the demands for fresh water in many regions are much more than those can load. The concept of water footprint came from virtual water which can help us roughly understand the water consuming of a product manufacturing process and after services. Hoekstra and his student published water footprint manual in 2011[1]. Berger and his coauthors [2] studied the water footprint of three Volkswagen passenger cars. The research team of professor Bras [3-4] estimated the water footprint of a 2011 Ford Focus vehicle. Zhao and his coauthors [5] analyzed the water footprint of three machining processes.

This paper presents a methodology for assessing water footprint of machine tools. Detail assessment steps and calculation process for life cycle of machine tools is described in this paper. The difficulty in inventory process and data selection during water footprint assessment will be presented. A case study is used to explain the capabilities of the proposed methodology.

2. Water footprint

The definition of water footprint [1] is classified into three kinds of water that are green water footprint, blue water footprint and grey water footprint. Green water means raining water stored in ground or plants then evaporates in growth or transfer into products. Blue water footprint indicates the water use from groundwater or surface water. Grey water footprint is the amount of water use in diluting wastewater emission to achieve discharge standards. Water footprint of machine tools only has blue and grey water.

3. Water footprint inventory and data selection

The system boundary for water footprint inventory is the direct water consumptions in machine tool life cycle, such as production of materials, manufacture processes of each component, use of electricity and lubrication oil, and transportation. The calculation of water footprint and data selection is in accordance with different life cycle stages. In material stage, the mass and specification of every component of machine tools are investigated. The SimaPro 7 database was selected in material stage for water footprint calculation. During manufacture process stage, the inventory information includes the kind of machining processes and the remove mass or volume in each process for each component. The Ecoinvent database and information in literature [5] were selected in manufacture process stage for water footprint calculation and comparison. In transportation stage, Ecoinvent database is used for calculating water footprint. In use stage, the life of machine tools assumed to be 7 years old. Data of water footprint for electricity consumption in Taiwan is calculated based on the structure ratio of different electricity generation source in Taiwan. The coefficient of water footprint for electricity consumption in Taiwan is 574.78 gal/MWh.

4. Water footprint of machine tool

The EMVC machine tool designed by ITRI is selected as design example to demonstrate the capabilities of proposed method. The specification of EMVC machine tool is shown in Table 1. The processes of water footprint calculation of EMVC machine tool can be divided into four stages, such as material, manufacture processes, use and transportation stages. This machine tool is transported 180 km by using the 16 tons truck. The value of water footprint of EMVC machine tool is shown in Table 2. It is obvious that the water footprint of machine tool is dominated by the use stage.

Table 1. Specification of EMVC machine tool

EMVC machine tool	Specification
Weight	10242.299 kg
Maximum Output Power	11 kW
Operation Rate of Spindle	70 %
Life of Spindle	7 years
Electricity Consumption of Peripheral Equipments	1 kW
Transportation	180 km

Table 2. Water footprint of the EMVC machine tool

Life cycle stage	Water footprint (ton)
Material	17.877
Manufacture process	21.541
Transportation	2.081
Use	1162.581

5. Conclusions

This paper presented the calculation result for water footprint assessment of machine tool. The EMVC machine tool case demonstrated the capability of the proposed method.

Acknowledgments

This Study is supported by The Intelligent Machinery Technology Division, Mechanical and Systems Research Laboratories, ITRI (Industrial Technology Research Institute) of Taiwan.

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Evaluation of Water Use in Paddy-Rice Production on the Basis of Differential Water Footprint

Susumu Uchida*[1]

[1]*Ibaraki University, Japan*
*Corresponding author: uchida@mx.ibaraki.ac.jp

1. Introduction

Water use in paddy-rice production was evaluated on the basis of a differential water footprint (DWF) that had been developed for analyses of water resource. Previous studies have proposed various water flow indicators that can be used to analyze water resources [1-4], and some have proposed water flow indices comparable with carrying capacity, taking into account the subject area of water supply [5, 6].

However, essential water use flow is difficult to define and evaluate. In a previous study [7], we introduced a new concept of "acceptable delay" for the continuous evaluation of the water resource burden and its sustainability. This is the time period within which water is consumed without problems, and is defined for each type of water use. We assumed the amount of water consumed throughout this period, and regarded its rate as the essential water use flow. The ratio of this water use flow to total supply flow in an objective basin is defined as water stress. Furthermore, we defined the area as DWF on the basis of acceptable delay, in which the water use flow is met by precipitation. By integrating DWF with respect to time, the total water resource burden is obtained corresponding to each water use as stock. The unit of area multiplied by time was defined as the integral water footprint (IWF).

Agriculture, in particular paddy-rice production, is the most important water-consuming sector in Japan. In this study, we evaluated water resource consumption of paddy-rice production, using the Ibaraki prefecture as a case study.

2. Methodology

In the analysis, we constructed scenarios of rice production on the basis of the standard schedule recommended by the Ibaraki prefecture, meteorological data, and phenological model. Daily water use was estimated by simulation on the basis of the scenario, in which water demand is met first by precipitation, irrigation water only being used in the case of shortage. Data on precipitation at Tsuchiura and the flow of the Seimeigawa River was used. From this estimation, water use and its sustainability were evaluated through derivation of DWFs and IWFs.

3. Result and discussion

Figure 1 shows the obtained DWFs per cultivation area for 1998 and 2001. For both years, the DWF showed higher values in the latter half of the cultivated period, when pulsed irrigation with much water was needed. The DWF in 2001 is greater than in 1998. This difference is thought to reflect the difference in the amount of precipitation. The effect of considering acceptable delay is shown around point A in Figure 1. This part corresponds to irrigation with the same amount of water as the subsequent irrigations, indicated as peaks to the right. However, this irrigation has seven days of acceptable delay in contrast to other irrigations having a shorter acceptable delay. This caused lower water stress on the days indicated, shown as broader peaks of DWF.

A DWF exceeding 1 indicates that more area is required to provide water for irrigation than the actual cultivation area. Figure 1 shows the maximum DWF reached is 60, however, this does not necessarily represent a lack of water. If the excess is time related, farmers can share water resources with each other by shifting the timing of irrigation, or by storing water in ponds. To analyze the total water balance, annual integration to IWF is needed. They were 1.11 ha/ha-a for 1998 and 2.01 for 2001, which proves that paddy-rice production is based on the debt of water from other neighboring areas.

4. Conclusion

In this study, the effect of introducing the concept of acceptable delay was restricted because the schedule of water use in the scenario was assumed to be tight. However, this new concept will be more useful in the evaluation of various controls in water-resource consumption by considering the dependency of water stress on acceptable delay, together with DWF and IWF.

Acknowledgments

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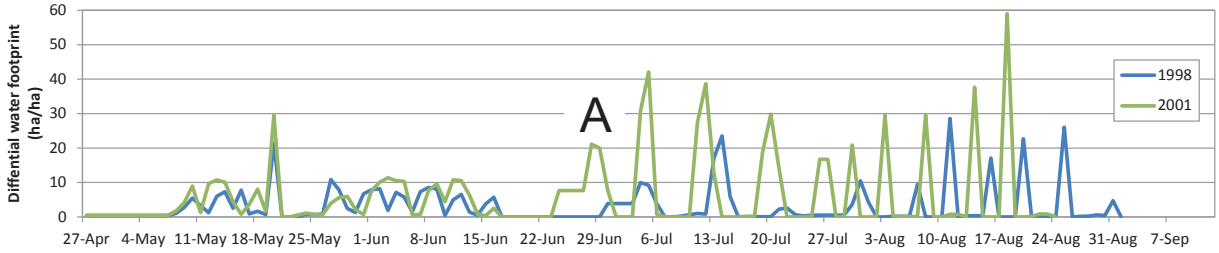


Figure 1. Differential water footprint of paddy-rice production in Ibaraki, Japan

Development of Water Footprint Inventory Database of Asian Countries

Soya Iida,*[1] Yuya Ono,[1] and Norihiro Itsubo[1]

[1]*Tokyo City University, Japan*
*Corresponding author: g1383101@tcu.ac.jp

1. Introduction

The scarcity and the ubiquity of water resources have been increasing all over the world. These problems are caused by the sudden population growth and the improvement of quality of life in the developing country. Additionally, disease and malnutrition are widespread due to the insufficient of food from water shortage. Water Footprint (WF) is an evaluation method measuring environmental impacts related with water use through the entire life cycle of products and service. China's economy has developed rapidly, but serious water problems have emerged because of the increases in water demands and wastewater. It is concerned that water problem may restrict the sustainable growth in Asian country.

2. Purpose

The purpose of this research is to develop water footprint inventory database which enables us to account consumed water amount with the differentiation in types of water resource in China by province. We adopted input-output tables and statistical tables of China to develop water footprint database in China. Applying input-output table make it possible to aggregate direct water consumption and indirect water consumption in upstream of the supply chain. Development of the water footprint inventory database of China classified to province is carried out. We will conduct case studies with Japanese companies that have factories in China using this database to verify the quality of our output.

3. Method

The database on water considering the type of water resource (rain water, irrigation water and ground water) and the form of water (water use and water consumption) was developed in this study. We have estimated 135 sectors of direct water use and consumption of the Chinese input-output table in agriculture, forestry, fishery, industry and other service industries in this study [1, 2]. In addition, we use statistics data of 2007 to cope with age targeted for the input-output tables [3, 4]. We have applied statistics of "China statistical yearbook 2007" in the agricultural, fishery, industry and other service industries sectors, "China forestry statistical yearbook 2008" in the forestry sector [5]. At this time, we divided into seven regions in China and estimated the water consumption considering the type of water resource in the agricultural production of each (Figure 1). The seven regions divided are the northeast (Heilongjiang, Jilin, Liaoning), east (Shandong, Jiangsu, Shanghai, Anhui, Zhejiang, Jiangxi), south (Fujian, Guangdong, Hong Kong, Macao, Hainan, Guangxi Zhuang Autonomous Region), west (Henan, Hubei, Hunan), southwest (Chongqing, Guizhou, Sichuan, Yunnan, Tibet Autonomous Region), north (Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia Autonomous Region), and northwest (Qinghai, Gansu, Shaanxi, Xinjiang Uygur Autonomous Region, Ningxia Hui Autonomous Region).

4. Result & Conclusion

In this study, direct water consumption in the agricultural sector whole of China became 9.2E+11m^3. As a comparison with existing research, Liqiang Ge et al. [6] have been estimated that 8.6E+11m^3 direct water consumption in the agricultural sector of China's total, it can be said to be valid the results of this study. In the northwestern and northern regions, it was found that they supplement most by irrigation because there is little precipitation. In the south region, it is a thriving industrial region in the country, direct water consumption in the agricultural sector was less than the other regions. In the future, we will estimate direct water use and consumption in other sectors, and develop database of China.

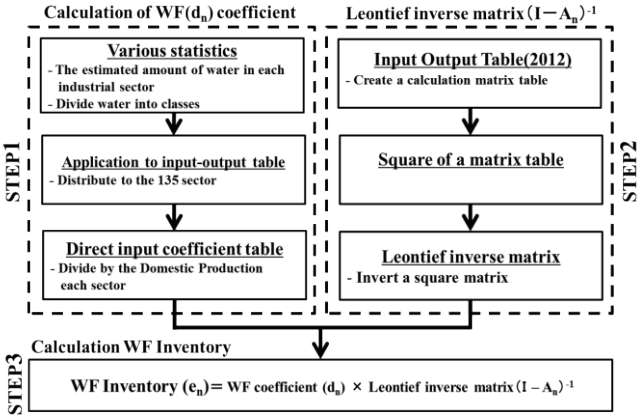


Figure 1. LCI DB development method

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