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J1

- TitleConsequential and attributional environmental assessment of biofuels: Implications<br/>of modelling choices on climate change mitigation strategies.
- Abstract Type Journal. International Journal of Life Cycle Assessment, 2017, doi: 10.1007/s11367-017-1355-2.
- Authors Prapaspongsa, T. & Gheewala, S.H.
- Abstract *Purpose:* The study aims to assess climate change mitigation potentials when using biomass-based fuels to replace fossil energy under consequential and attributional modelling approaches. The objectives are also to determine policy implications and to recommend the specific contexts suitable for each modelling choice by using specific illustrative cases on biofuels.

*Methods:* Consequential and attributional modelling approaches are chosen for life cycle greenhouse gas emission assessment of several bioenergy options. The assessed functional unit is 1 MJ of energy from molasses-based ethanol, palm-based biodiesel and electricity production from rice straw. The fossil fuel comparators are gasoline (for molasses-based ethanol), diesel (for palm-based biodiesel) and coal and gas (for rice straw). The substituted and substituting product systems are modelled under the global and national markets depending on the market delimitation of each product.

*Results and Discussion:* The climate change mitigation potentials when using different approaches are dissimilar because the affected product systems being included in the analysis are not the same. The palm biodiesel could reduce greenhouse gas emissions. The molasses-based ethanol and rice straw-based electricity may or may not mitigate the climate change since it depends on the methodological choices as well as the baseline situations of the product systems being investigated. The main characteristics of consequential modelling as additionality and the inclusion of only actually affected processes under market-based mechanisms while those of attributional modelling as specification and attribution/allocation have limitations. The limitations lead to potential risks on unintended and undesirable consequences (for the attributional model), unfairness and sub-optimisation (for the consequential model) in policy recommendations.

*Conclusion:* This research clearly illustrates how certain modelling choices affect the climate change mitigation potentials of biomass-based fuels in comparison with fossil energy. Specific questions and conditions which could be more suitable for each modelling choice are addressed. The attributional modelling is more suitable for national environmental taxation and emission labelling/accounting for import-export while the consequential modelling is more appropriate for new production development and eco-design. Due to the potential environmental risks arising from the modelling limitations, the consideration of both the widely applied approaches could support decisions more comprehensively.

FundingThailand Research Fund and Mahidol UniversityOrganization



J2

- TitleCorporate Environmental Assessment of a Large Jewelry Company: From a Life<br/>Cycle Assessment to Green Industry.
- **Abstract Type** Journal. Journal of Cleaner Production, 2017, 164, 485-494.

Authors Thammaraksa, C., Wattanawan, A. & Prapaspongsa, T.

Abstract Jewelry and precious metal industry has positively affected global economy via high profits and incomes as well as potentially harmed the environment and society due to its resource intensiveness and pollution. The objectives of this research are to define significant sources of environmental impact throughout a large jewelry manufacturing value chain, and to understand the consequences of using materials from different sources in order to identify potential solutions towards green industry. Feasible solutions to environmental impact reduction regarding material sourcing, energy consumption and waste treatment are recommended based on the comparison of the results. An environmental assessment is conducted following a life cycle assessment framework provided in ISO 14040:2006 and ISO 14044:2006. The assessment focuses on the impacts of environmental interventions from the value chain associated with the company operations in 2013. All in all one businessas-usual, ten alternative and nine sensitivity scenarios are developed to assess the impacts from the company's operations in 2013, to determine potential impact reductions from feasible solutions and to investigate the robustness of the results. The representative data for manufacturing stage were primarily gathered from the company while the data for other stages are secondary data. Gold and silver mining and refining is the largest contributor from the overall supply chain for all impact categories considered. Using recycled gold and silver is the most effective solution to decrease life cycle negative impacts. The use of gold and silver recycled from high-value industries (i.e. jewelry production) produces less adverse impacts compared to gold and silver recycled from end-of-life electronic waste. According to the statistical data, gold and silver mining and refining could be the suppliers capable of supplying gold and silver because of the market constraints of recycled gold and silver. Green mining operations are introduced as alternatives to reduce impact directly generated from mining operations. For manufacturing, electricity consumption reduction shows a potential impact reduction. Using recycled gold and silver is recommended for jewelry manufacturers who plan to reduce environmental impacts. Using gold and silver from green mining is also recommended when the use of gold and silver from mining is necessary. Reducing electricity consumption in manufacturing is also one option for the company since it could be activated directly.

FundingThailand Research Fund and PANDORA Production Co., Ltd.Organization(Researchers and Research for Industry Grants: Master Sci. & Tech Grants 2013)



J3

TitleLife cycle assessment of palm biodiesel production in Thailand:<br/>Impacts from modelling choices, co-product utilisation, improvement technologies,<br/>and land use change.

Abstract Type Journal. Journal of Cleaner Production, 2017, 153, 435-447.

Authors Prapaspongsa, T., Musikavong, C. & Gheewala, S.H.

Abstract The palm biodiesel industry has been promoted for climate change mitigation, energy security and sustainability strategies worldwide. International debates on land use change and unintended consequences from market-driven impacts of biofuel (i.e. biodiesel and bioethanol) production have highlighted the need for an assessment which considers multi-modelling approaches as well as up-to-date improvement technologies. This study assessed potential environmental life cycle consequences of palm-based biodiesel production in comparison with conventional diesel production. Impacts from modelling choices (consequential and attributional life cycle assessment), co-product utilisation during the palm oil milling and biodiesel conversion stages, recent improvement technologies for treating palm oil mill effluent and oil palm breeding, and direct and indirect land use change were assessed using fifteen scenarios. It was found that the different modelling choices as well as the inclusion of direct and indirect land use change highly affected environmental gains and losses compared with the conventional diesel system. The most important contributor to the environmental benefits was utilisation of coproducts. When excluding the use phase (because its value did not vary across the different scenarios; except for climate change), the most important contributor in environmental impacts for terrestrial acidification and marine eutrophication, was emissions from indirect land use change. Increased oil palm yields and improved palm oil mill effluent treatment technologies resulted in overall impact reduction; and should be promoted. Various co-product utilisation pathways have shown different impact reduction potentials. Co-products from palm oil mills should be fully utilised for electricity production, animal feed and oil substitution. Glycerol from biodiesel conversion was suggested to be used for animal nutrition. In conclusion, both modelling choices should be used for supporting policies in different contexts. Policy makers need to be aware of the differences in outcomes and risks of both modelling choices and later on select the specific approach which fits their specific decision context. Co-product utilisation should be optimised in order to increase the total impact reduction. Recommended co-product utilisation pathways, oil palm variety and wastewater treatment technologies can be used for further enhancing the sustainability of palm oil industry.

Funding National Science and Technology Development Agency

Organization



J4

TitleRisks of indirect land use impacts and greenhouse gas consequences: An<br/>assessment of Thailand's bioethanol policy.

Abstract Type Journal. Journal of Cleaner Production, 2016, 134, 563-573.

Authors Prapaspongsa, T. & Gheewala, S.H.

Abstract This study aimed to assess indirect land use change (iLUC) and greenhouse gas (GHG) consequences of Thailand's bioethanol policy by using consequential life cycle assessment (CLCA) and a systematic iLUC model based on global land market. The results indicated the risk that life cycle GHG emissions of cassava- and molasses-based bioethanol systems may outweigh those from their fossil fuel counterparts both with and without the iLUC effects. The iLUC emissions from bioethanol were around 39% to 76% (± 8-15%) of the gasoline GHG emission baseline. Inclusion of relevant suppliers for the use of fully utilised by-products which are renewable energy sources (i.e. molasses and bagasse) highly affected the GHG consequences. Various controlled conditions such as non-fully utilised molasses and bagasse potentially lead to significant GHG reductions. The additional molasses and bagasse production dedicated specifically for bioethanol production potentially contribute to substantial GHG reductions. Further studies are required to determine other environmental impacts from bioethanol and to consider other iLUC modelling choices and emerging research development.

Funding National Science and Technology Development Agency

Organization



No.	J5
Title	LCA for food, fuel and climate change in Thailand.
Abstract Type	Journal. Kasetsart Engineering Journal, 2015, 30, 73-84.
Authors	Gheewala, S.H., Silalertruksa, T., Jakrawatana, N., Mungkung, R., Musikavong, C., <b>Prapaspongsa, T.</b> & Prasara-A, J.

# Abstract

Life cycle assessment (LCA) has been used in Thailand for various applications, especially dealing with agriculture and energy. This paper summarizes the preliminary results of a national project on food, fuel and climate change (FFCC) jointly conducted by various universities in the different regions of Thailand using LCA. The application of LCA to agriculture in the context of food and fuel is considered in various facets – climate change being a major but not the only concern. Other considerations include land use and land use change, water use, materials use, and also social impacts. The production systems of all major economic crops of Thailand including rice, cassava, sugarcane, oil palm and para rubber and their derived products are assessed under a life-cycle perspective for identification of the potential environmental, economic and social hotspots as well as recommendations for policy on promoting sustainable food and fuels production in Thailand.

# FundingNational Science and Technology Development AgencyOrganization



J6

- TitleModels to quantify excretion of dry matter, nitrogen, phosphorus and carbon in<br/>growing pigs fed regional diets.
- Abstract Type Journal. Journal of Animal Science and Biotechnology, 2013, 4:42, doi:10.1186/2049-1891-4-42.

Authors Jørgensen, H., Prapaspongsa, T., Van, V.T.K. & Poulsen, H.D.

Abstract Modern pig production contributes to many environmental problems that relate to manure, especially in areas with highly intensive production systems and in regions like Asia where the regulative control is not effective. Therefore, the objective of this study was to use three different pig diets varying in dietary protein, fibre and fat as representative for Danish (DK), Thai (TH) and Vietnamese (VN) pig production to develop and evaluate different approaches to predict/calculate excretion from growing pigs in comparison with the experimentally determined values. Nine female growing pigs were used in a digestibility and balance experiment. Excretion of dry matter (DM), nitrogen (N), phosphorus (P) and carbon (C) of the experimental diets were determined. Due to the highest dietary fibre content, VN had the lowest digestibility of N, P and C (73, 49, and 73%, respectively) compared with the DK and TH pig diets. From the known diet composition using standard table values on chemical and nutrient digestibly, high accuracy (bias) and low variation was found and the results could be used for prediction on chemical composition and excretion in faeces and urine in growing pigs. Calculation based on standard values regarding nutrient retention in the pig body as used in the Danish manure normative system (DMNS) showed likewise to be quite useful for quantifying the total excretion of N and P. Overall, the results demonstrate that simple models that require cheap and normally available information on dietary nutrients can give useful information on nutrient excretion in growing pigs.



TitleFramework for LCI Modelling towards Green Logistic Systems.

Abstract Type Journal. Environment and Natural Resources, 2012, 10(2), 58-65.

Authors Prapaspongsa, T. & Løkke S.

J7

Abstract In order to establish green logistic systems, life cycle assessment (LCA) is an important tool for evaluating and comparing overall environmental impacts from various options. Most LCA studies rely on readily available secondary databases on transport services such as Ecoinvent database and scientific publications. The most widely applied Ecoinvent database on transport services is aggregated with specific transport variables and statistics based on European and Swiss average data. To modify the life cycle inventory (LCI) database with specific variables (e.g. load factors, driving speed, etc.) is very complicated and may not be possible. Such studies are still lacking due to complexity and resource limitations. This study aims to provide a framework for LCI modelling to conduct LCAs of European freight transport with up-to-date LCI data in terms of emissions and transport variables. The framework comprises of a conceptual transport model, important transport variables and data sources for freight transport by road and by rail in Europe. The data collection was carried out by literature studies and interviews with relevant experts. The framework is useful for LCA practitioners, researchers and industries to include specific transport variables and to adequately assess the environmental impacts from transport activities by road and by rail.



J8

- TitleLCA of comprehensive pig manure management incorporating integrated<br/>technology systems.
- Abstract Type Journal. Journal of Cleaner Production, 2010, 18, 1413-1422.

Authors Prapaspongsa, T., Christensen, P., Schmidt, J.H. & Thrane, M.

Abstract Increased and intensified pig production has raised the needs for proper management systems of pig manure in order to reduce negative environmental impacts. The objectives of this study were to identify the most significant environmental impacts from pig manure management considering a wide range of impact categories and to determine which integrated technology system at which handling stage can achieve the highest impact reduction. Twelve scenarios applying various treatment, storage and land application systems were developed and compared. Life cycle assessment (LCA) with the aim of capturing the actual consequences of the considered scenarios was selected as the tool for impact quantification. The most important impact categories in this investigation are global warming (GWP), aquatic eutrophication (AEP), respiratory inorganics (RIP), and terrestrial eutrophication (TEP). The two latter impacts, caused by ammonia emissions, have not been widely considered in most of previous LCA studies on pig manure management. The main keys for the effective impact reduction are the integration of treatment technology systems aiming at energy recovery with high nutrient recovery and control of greenhouse gas, ammonia, and nitrate emissions at every handling stage. For GWP and AEP, the anaerobic digestion-based scenario with natural crust storage achieves the highest impact reduction because of high efficiencies in energy and nutrient recovery with restricted emissions of GHG and nitrate. For RIP and TEP, the incineration and thermal gasification based scenarios and the scenario without a treatment system applying the deep injection method yield the highest impact minimisation due to the lowest ammonia emissions. This study further indicates the need to consider all significant impacts to decide the best management options taking into consideration local conditions.



J9

TitleEnergy production, nutrient recovery and greenhouse gas emission potentials from<br/>integrated pig manure management systems.

**Abstract Type** Journal. Waste Management and Research, 2010, 28 (5) 411-422.

Authors Prapaspongsa, T., Poulsen, T.G., Hansen, J.A. & Christensen, P.

Abstract Improper management of pig manure has resulted in environmental problems such as surface water eutrophication, ground water pollution, and greenhouse gas emissions. This study develops and compares 14 alternative manure management scenarios aiming at energy and nutrient extraction. The scenarios based on combinations of thermal pretreatment, anaerobic digestion, anaerobic codigestion, liquid/solid separation, drying, incineration, and thermal gasification were compared with respect to their energy, nutrient and greenhouse gas balances. Both sole pig manure and pig manure mixed with other types of waste materials were considered. Data for the analyses were obtained from existing waste treatment facilities, experimental plants, laboratory measurements and literature. The assessment reveals that incineration combined with liquid/solid separation and drying of the solids is a promising management option yielding a high potential energy utilization rate and greenhouse gas savings. If maximum electricity production is desired, anaerobic digestion is advantageous as the biogas can be converted to electricity at high efficiency in a gas engine while allowing production of heat for operation of the digestion process. In conclusion, this study shows that the choice of technology has a strong influence on energy, nutrient and greenhouse gas balances. Thus, to get the most reliable results, it is important to consider the most representative (and up-to-date) technology combined with data representing the area or region in question.



**No.** J10

**Title** Prediction of manure nitrogen and carbon output from growing-finishing pigs.

- Abstract Type Journal. Animal Feed Science and Technology, 2009, 151, 97-110.
- Authors Vu, T.K.V., Prapaspongsa, T., Poulsen, H.D. & Jørgensen, H.

Abstract Intensive pig production may be a hazard to the environment due to plant nutrient leakage and losses. To facilitate efficient and sustainable manure management and reduce oversupplying of crops with nutrients, there is a need for precise assessment of nutrient content in manure and manure excretion. This study has developed algorithms for predicting the amount of excreta and manure content of nitrogen (N) and carbon (C). Data compiled from 285 digestibility and N balance experiments with growing-finishing pigs diets fed diets varying widely in chemical composition were used to establish algorithms. The main input variables were analysed nutrients contents together with intake of dry matter and digestibility of organic matter (diOM). The accuracy and prediction power of the obtained prediction equations were tested with another dataset consisting of 116 digestibility and N balance experiments with varying chemical compositions. Prediction equations related to C was tested using 26 digestibility experiments. The dietary fibre (DF) fractions like crude fibre, non-starch polysaccharides (NSP), analysed DF and calculated dietary fibre (cDF) were all highly negatively correlated to digestibility and positively to manure output. Including more than one or two predictors only marginally improved predicting the C and N content in excreta as well as the daily excretion rates. The best predictor for estimating the daily amount of faeces and daily faecal N and C excretion was diOM, and the second best predictor was cDF. However, the equations became more precise when dry matter intake or animal body weight was added as independent variable. For urine N equations, the dietary protein intake was the best predictor. The partitioning of N between faeces and urine was related to the concentration of cDF with a shift in N excretion in urine to N excreted in faeces as more carbohydrate was fermented. The ratio of C/N in faeces was depending on cDF in the diet. The wide variation in the diets included in the predictions ensures that the equations also are relevant and applicable in developing as well as developed countries as a useful tool for efficient handling and use of manure nutrients in practice.



C1

Title Right Product or Technology for Sustainable Agri-Food Value Chains? Lessons Learned from Rice, Sugarcane and Oil Palm Cultivation in Thailand.

Abstract Type International Conference. Proceedings of the 8th International Conference on Life Cycle Management (LCM 2017), 3-6 September 2017, Luxembourg.

- Authors Prapaspongsa, T. & Gheewala, S. H.
- Abstract Thailand is one of the world's largest producers and exporters of agri-food products. Although the agricultural sector is important for the Thai economy, it is one of the most significant sectors contributing to environmental impacts such as global warming, particulate matter formation and non-point source water pollution. Sustainable agri-food value chains will ensure that feeding the rapidly increasing global population will not be at the expense of the environment and society. This study aims at assessing the influence of various product and technology choices of Thai farmers on the sustainability of agricultural production. Thai farmers often change a product based on considerations of economic benefits. The Office of Agricultural Statistics reported that between 2010 and 2015 some Thai farmers changed from cultivating rice to sugarcane, oil palm and para rubber. The question here is that if a Thai famer occupies a particular piece of land (national average), which agricultural product or technology might give the highest benefits and lowest environmental impacts? Rice, sugarcane and oil palm - the major agri-food chains in Thailand – are included in the assessment. The technologies and management practices taken into account are yield improvements (for all systems), fertilizer and chemical controls (for all systems), open burning restrictions (for rice and sugarcane systems), and alternate wet and dry system (for rice). The life cycle environmental impacts considered are global warming, human toxicity, particulate matter formation, photochemical oxidant formation, terrestrial acidification, and freshwater and marine eutrophication. The socio-economic indicators are product prices and farmer incomes. The data were derived from life cycle assessment studies in Thailand, national agricultural statistics, and were supplemented with peer-reviewed scientific literature. Product and technology/management practices could significantly reduce negative environmental impacts. The current rice and oil palm systems have the highest global warming and human toxicity, respectively, per area. For other environmental impacts, the current sugarcane system is the worst. However, various technologies/practices could be used to reduce the environmental impacts of various products to comparable levels. With respect to socio-economic impacts, technologies/practices have less influence when compared with the product choice. Oil palm has the highest product prices and farmer incomes; and technological changes only affect these aspects slightly. The lessons learned from this research are not only towards comparing the environmental and socio-economic aspects as such, but also the need for other considerations. If the farmers make decisions on product and technology selection based on the highest incomes with the lowest environmental impacts, oil palm might be the most suitable choice. Nevertheless, rice and sugarcane are important agricultural products needed for domestic and international consumption as well as for the national economy. When looking at the whole value chain, socio-economic benefits might be gained by downstream industry (i.e. rice, sugar, and palm oil) whereas the deficits are often in the agricultural sector (at the farm gate). The government should consider these aspects in the national agri-food policies in order to reduce environmental and socio-economic gaps of agricultural systems in the future. Funding

National Science and Technology Development Agency

Organization



No.	C2
Title	Lessons Learned from International Best Practices in Sustainable Maritime
	Transport: Potential Technology and System Adaptation for Life Cycle Management
	of Maritime Transport in Emerging Economies.
Abstract Type	International Conference. Proceedings of the 8th International Conference on Life Cycle Management (LCM 2017), 3-6 September 2017, Luxembourg.
Authors	Prapaspongsa, T., Ren, J., Punuraia, W., Wang, J., Sapsathiarna, Y. & Ornthammarath, T.
Authors Abstract	<b>Prapaspongsa, T.,</b> Ren, J., Punuraia, W., Wang, J., Sapsathiarna, Y. & Ornthammarath, T. Maritime transport enhances national, regional, and international industrial development and economic growth by the global trade of capital goods and intermediate/consumer products. International seaborne trade volumes have increased and reached 10 billion tonnes in 2015 according to United Nations Conference on Trade and Development (UNCTAD) records. Sustainable maritime transport has been largely driven by international regulations and agreements controlling health and safety, labour welfare, marine pollution, and greenhouse gas (GHG) and other gaseous emissions. Sustainable technologies and management in world maritime transport have been applied by ratifying parties or the companies when passing through the specified emission/regulative control areas. The regulations and controls in developing countries are often ineffective and less restricted. UNCTAD reported that developing economies have contributed to the largest share of world seaborne trade since 2007. Hence, economic, environmental and social impacts from marine transport in emerging economies could be the main challenges and bottlenecks in sustainable development of this sector internationally. To enhance sustainable maritime transport and to avoid burden shifting from different stakeholders in the value chains, life cycle management considering all sustainability aspects could be used as a tool. This study aims to identify how life cycle management of maritime transport. The international best practices in sustainable maritime transport analysing sustainability reports of the world's leading shipping companies are Maersk, Evergreen, Neptune Orient Lines - American President Lines, China Ocean Shipping (Group) Company, Hanji Migui O.S.K. Lines and Nippon Yusen Kaisha. With respect to the 2016 Sustainability Accounting Standards Board (SASB) Materiality Map, sustainability indicators (materiality issues in sustainability reporting), which are likely to be addre
	in sustainable maritime transport.
Funding Organization	H2U2U-MISCA-KISE-2016 (Proposal 730888)



C3

- TitleContract Farming A Tool for Sustainable or Unsustainable Agri-Food Value Chain<br/>Management? Case Study on Sustainability Assessment of Banana Plantation under<br/>Contract Farming in Thailand.
- Abstract Type International Conference. Proceedings of the 8th International Conference on Life Cycle Management (LCM 2017), 3-6 September 2017, Luxembourg.
- Authors Pongpunwittaya, P. & Prapaspongsa, T.

Agri-food sectors have been transformed worldwide from independent markets towards Abstract interconnected food supply chains. Contract farming is an operation under an agreement between farmers and agri-business firms which has been used as a tool to enhance agrifood production arrangements and agri-food product trades worldwide. The advantages of contract farming are guarantees in market trade, quality, quantity and price for both farmers and agri-business firms. It can also support the social and economic development of rural communities. Therefore, contract farming helps the government in solving problems on food security and farmer poverty. Hence, the use of contracts has become more attractive to many farmers because the arrangement can offer both an assured market and access to production support. However, the disadvantages and risks associated with contract farming are other market sales, refusal of the agreed buying price, downgraded product quality, errors of buyers' forecasting, etc. Furthermore, contract farming often takes a long period (i.e. 3-10 years) of mono-agricultural production. Mono-cultivation potentially leads to land conversion, loss in biodiversity and eco-systems, overexploitation of groundwater, soil salination, soil fertility reduction, and pollution from pesticide and chemical uses. Moreover, the farmers might overly use fertilisers and chemicals provided by the agri-firms under the contracts. As a result, additional impacts i.e. climate change, soil erosion and degradation, generic erosion might be induced due to the contract farming. To ensure the sustainability of contract farming, an assessment on environmental, economic and social impacts is crucial. Such studies are still very rare and needed.

> In Thailand, the government has promoted the contract farming for major agri-products since 1987. Thailand has a total banana (hom thong) plantation area of 5,443 hectares with a total yield of 113,936 tonnes in 2014. Contract farming has played an important role in banana production in Thailand. This study aims to assess the sustainability of banana plantation under contract farming in Thailand. The study area is Prathumthani province. The sustainability assessment is being carried out by considering environmental, economic and social aspects. Life cycle assessment is applied to assess the environmental impacts (global warming, land transformation, particulate matter formation, terrestrial acidification, freshwater and marine eutrophication) of banana contract farming. The economic assessment considers life cycle costing and NPV. The social assessment considers social and cultural changes in the communities, labours rights and human rights. The primary data are being collected from existing contracted farms (10 individual farmers with a large agribusiness firm). The secondary data (i.e. agricultural and economic statistics) are from relevant governmental agencies and agri-business firms. Based on the preliminary sustainability assessment, it is expected that the banana contract farming may increase positive economic and social impacts (from the guaranteed prices and market) and negative environmental impacts (from the overuse of fertilsers and chemicals). For enhancing the sustainable contract farming, the Thai government is needed to involve in monitoring, facilitating and encouraging stakeholders in contractual arrangements. The impacts of various policy implementations will also be considered in this on-going research.



**No.** C4

TitlePotential life cycle assessment applications for supporting environmental regulationimprovement toward sustainable energy industry in Thailand.

Abstract Type International Conference. Proceedings of the 6<sup>th</sup> International Conference on Sustainable Energy and Environment (SEE 20116) in conjunction with the 6<sup>th</sup> International Conference on Green and Sustainable Innovation (ICGSI 2016) and the 1<sup>st</sup> International Conference on Climate Technology and Innovation (CTI 2016), 28-30 November 2016, Bangkok, Thailand.

Authors Prapaspongsa, T. & Gheewala, S. H.

Abstract Recent public debates and protests on energy industry in Thailand due to concerns on existing and potential adverse environmental impacts, conflict of interest and the lack of scientifically reliable, transparent and easily accessible information have addressed the importance of continuously improved regulations and enforcement. This study aims to identify how LCA can potentially be applied for supporting environmental regulation improvement toward sustainable energy industry in Thailand. This research is carried out by literature analysis. The criteria for choosing regulations to be improved are (1) ease of application, (2) realistic time and manpower resource requirements for the analysis process, (3) limited data requirements. An overall framework of life cycle assessment applications for supporting environmental regulation improvement and enhancing environmental sustainability of Thailand's energy industry is illustrated. Specific types of recommended environmental regulations for the tool application are effluent standards, environmental quality standards, and environmental impact assessment. Future research includes comparative life cycle assessment studies on specific energy sources considering regulated and non-regulated pollutants as well as comparative environmental impact assessment studies with and without life cycle considerations.

Funding National Science and Technology Development Agency

Organization



No.	C5
Title	Carbon, water, and ecological footprints analysis and potential environmental improvements in palm oil and rubber production in Thailand.
Abstract Type	International Conference. Proceedings of the 6 <sup>th</sup> International Conference on Sustainable Energy and Environment (SEE 20116) in conjunction with the 6 <sup>th</sup> International Conference on Green and Sustainable Innovation (ICGSI 2016) and the 1 <sup>st</sup> International Conference on Climate Technology and Innovation (CTI 2016), 28- 30 November 2016, Bangkok, Thailand.
Authors	Musikavong, C., Prapaspongsa, T. & Gheewala, S. H.
Abstract	This research is aimed at integrating assessment of carbon footprint (CF), water footprint (WF), and ecological footprint (EF) of oil palm and rubber products in the production stage and unit process level for potential environmental improvements. For plantation, one tonne of fresh fruit bunch (FFB) and fresh latex were set as the functional units. For the factory, the functional units are one tonne of crude palm oil (CPO), concentrated latex (CL), blocked rubber (Standard Thai Rubber 5, STR 5), STR 20, and ribbed smoked sheet (RSS). Secondary data were used in this study. The rain water and irrigation water were determined as the major sources of WF and EF of FFB and fresh latex whereas CF had nitrogen fertilizer production and use as major source. The hot spot of unit process of CF did not completely relate to the WF and EF. It was acquisition of input from plantation, wastewater, and production process. Most of the EF and WF for CPO, CL, STR 5, STR 20, and RSS production was contributed by rain and irrigation water from plantation. The plantation stage was the main contributor of CF, WF, and EF. The policy makers must focus on potential environmental improvements in this stage.
Funding Organization	National Science and Technology Development Agency



C6

- TitleLife cycle and land use assessment as a tool for enhancing sustainable agricultural<br/>value chains: Case study on major biomass products for food, feed and fuel in<br/>Thailand.
- **Abstract Type** International Conference. Proceedings of the 12<sup>th</sup> Biennial International Conference on EcoBalance (EcoBalance 2016), 3-6 October 2016, Kyoto, Japan.

Authors Prapaspongsa, T. & Gheewala, S. H.

Abstract Enhancement of sustainable agricultural systems plays an important role to sufficiently feed the world while sustaining the environment and resources for future generations. The main aim of this study is to identify the most suitable agricultural systems with highest values/outputs and lowest environmental impacts. Eco-efficiency assessment considering life cycle environmental impacts and system values based on ISO 14045:2012 is chosen as the main tool in this study. Rice, sugarcane and oil palm systems – the major biomass products in Thailand - are selected as illustrative cases. The functional unit is the land use of 1 ha yr (Thailand average). The investigated environmental impacts are global warming, human toxicity, photochemical oxidant formation, terrestrial acidification, and freshwater and marine eutrophication whereas the assessed system value is an economic productivity of land (5-year prices of all products; USD/ha yr). Direct and indirect land use change (LUC) impacts are also taken into account. The data were obtained from national agricultural statistics and existing life cycle assessment studies in Thailand. According to the environment assessment, the difference in the global warming potentials among the agricultural systems is the largest whereas the other impacts are comparable. The oil palm and rice systems yield the lowest and highest global warming potentials, respectively. The main contributions are from different agricultural practices and direct LUC. For the economic productivity of land, the oil palm and rice systems provide the highest and lowest incomes, respectively. With respect to the eco-efficiency assessment, the support of oil palm industry could be recommended since it potentially causes the lowest environmental impacts and yields the highest economic output. Nevertheless, different agricultural systems may provide different functions. This aspect has to also be considered for supporting decisions. Future studies need to consider landspecific datasets, other functionalities, other system values as well as social impacts.

FundingNational Science and Technology Development AgencyOrganization



No.	

C7

- TitleEco-Efficiency Assessment of Various Biogas Technologies for Sustainable Food<br/>Waste Management.
- Abstract Type International Conference. Proceedings of the 5th International Conference on Environmental Engineering, Science and Management, 11-13 May 2016, Bangkok, Thailand.
- Authors Kaoudom, M. & Prapaspongsa, T.
- Abstract The purpose of this study is to evaluate the environmental impact and system value throughout the life cycle of food waste treatment by various biogas technologies. Eco-efficiency assessment (EEA) is applied in this study. In the EEA, life cycle assessment (LCA) is used for environmental assessment whereas life cycle costing is used for system value assessment. The scope covers comprehensive waste collection, transportation, and treatment process including by-product utilization. The functional unit is the treatment of one ton of food waste (wet weight). Four impact categories are considered: climate change, terrestrial acidification, freshwater eutrophication, and marine eutrophication. Three biogas technologies consider in this study which are anaerobic contact, COWTEC technology, and two stage technology. The results showed that the two stage technology is the best option due to the highest eco-efficiency on average. The two stage technology yields the lowest environmental impacts on average and life cycle costing in comparing with other systems. The impact values per ton of food waste handles by the two stage technology are as follows:  $-9.64 \text{ kg CO}_2$  eq. (climate change potential), 0.5 kg  $SO_2$  eq. (terrestrial acidification), -0.04 kg P eq. (freshwater eutrophication) and 0.02 kg N eq. (marine eutrophication). For the system value, the two stage technology has the least investment and operation costs (627 Baht/ton food waste). For future decision support, the consideration of environmental impacts and system values might not be enough. Other implementation aspects such as safety, human resource capacity and system maintenance skills need to also be taken into account.

Funding Mahidol University

Organization



# System expansion and allocation in life cycle assessment: Implications of modelling choices for biofuel on climate change mitigation

Trakarn Prapaspongsa<sup>1,\*</sup>, and Shabbir H. Gheewala<sup>2,3</sup>

<sup>1</sup> Department of Civil and Environmental Engineering, Mahidol University, Thailand
 <sup>2</sup> The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Thailand
 <sup>3</sup> Centre for Energy Technology and Environment, Ministry of Education, Thailand

\*Corresponding author, E-mail address: trakarn.pra@mahidol.ac.th

### ABSTRACT

The study assesses climate change mitigation potentials when using biomass-based fuels to replace fossil energy under various choices in co-product handling (system expansion and allocation). With different modelling choices, the same biomass-based fuels might mitigate or contribute to climate change potentials when comparing with fossil energy. Introduction

Life cycle assessment (LCA) has been widely used as a tool to support decisions for climate change mitigation sustainable consumption and and production. Nonetheless, LCA modelling choices have significant influence on conclusions. To illustrate the consequences of important modelling choices in LCA studies, this research evaluates climate change mitigation potentials from the replacement of fossil energy by biomass-based fuels under various modelling choices in co-product handling including system expansion (typically used in consequential LCA<sup>1</sup>) and system allocation (often applied in attributional LCA<sup>1</sup>). The important biomass-based fuels in Thailand including molasses-based ethanol, palm-based biodiesel and rice straw (being used for direct combustion and electricity generation) are chosen for illustration.

# Methods

The modelling framework for system expansion and allocation based on literature<sup>1</sup> is applied in this work. The assessed functional unit is 1 MJ of energy from biomassbased fuels. The fossil fuel comparators are gasoline (for molasses-based ethanol), diesel (for palm-based biodiesel) and coal and gas (for rice straw). The boundaries of all systems excluding fossil energy are illustrated in Fig.1. The substituted and substituting product systems are modelled under the global and national markets depending on the market delimitation of each product.

# **Results and Discussion**

The climate change mitigation potentials when using system expansion and co-product allocation of all systems are significantly different because the affected product systems being included in the analysis are not the same. To assess climate change potentials of the co-products, the boxes b, d, h1-3 in Fig.1 are the relevant systems under system expansion whereas the boxes a, e, g in Fig.1 are the investigated systems for allocation. The molassesbased bioethanol under system expansion yields higher climate change potential than the fossil energy while the one with co-product allocation has an opposite result. When using both modelling choices, the palm biodiesel can reduce the climate change impacts from the fossil comparator but the climate change potential is lower if



Fig. 1 The palm-based biodiesel, molasses-based ethanol and rice straw systems. The illustrated systems are simplified and only important affected products/systems are presented. The use phase is included in the analysis but omitted from this figure.

considering the affect expanded product systems. The climate change potentials of 1 MJ rice straw range from higher to lower than the fossil energy depending on the substitution pathways in system expansion (h1-3, Fig.1) and the fossil energy sources. For the context of decision making, the system expansion approach is recommended to assess potential risks of climate change potentials; and the co-product allocation with attributed emissions is suggested if the aim is to account the emissions for national environmental taxation and international trade.

# Conclusion

This research clearly illustrates how certain modelling choices affect the climate change mitigation potentials of biomass-based fuels in comparison with fossil energy. System expansion is recommended to be used for assessing the potential climate change risks while allocation is more suitable for national environmental taxation and emission accounting for import-export.

#### Acknowledgments

Financial support from Thailand Research Fund through the research project "Development and Application of Consequential Life Cycle Assessment Method for Food and Fuel in Thailand and Asia" (Grant no.TRG5780218) is acknowledged.

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# Greenhouse gas implications from land use changes: A case study of sugarcane complex for food and fuel production

Trakarn Prapaspongsa<sup>1,\*</sup>, and Shabbir H. Gheewala<sup>2,3</sup>

<sup>1</sup> Department of Civil and Environmental Engineering, Mahidol University, Thailand

<sup>2</sup> The Joint Graduate School of Energy and Environment, King Mongkut's University of Technology Thonburi, Thailand

<sup>3</sup> Centre for Energy Technology and Environment, Ministry of Education, Thailand

\*Corresponding author, E-mail address: trakarn.pra@mahidol.ac.th

#### ABSTRACT

The objective of this study is to assess potential greenhouse gas (GHG) emissions relating to direct and indirect land use changes from the whole sugarcane complex, refined sugar and molasses-based ethanol. A wide range of GHG emissions from land use changes (0.2-29.6 kg  $CO_{2eq}$ /t sugarcane) is obtained depending on the modelling choices and affected systems. In the future, the most relevant context and conditions for each modelling choice should be specifically analysed. Introduction

Land use changes have significantly contributed to global warming problems and recently been addressed in biofuel policies around the world. This study aims to identify potential GHG emissions relating to direct and indirect land use changes from sugarcane complex for food and fuel production. The case study of sugarcane complex in Thailand, one of top-five sugarcane producers and exporters in the global market, is presented.

# Methods

Both direct and indirect land use changes (dLUC and iLUC) under consequential and attributional modelling (CON and ATT) are considered in this assessment. The modelling methods based on literature<sup>1,2</sup> and Thai specific data from literature<sup>3,4</sup> and Office of Agricultural Economics are applied. The functional unit of this assessment is 1 tonne of sugarcane input for food and/or fuel production. In this case study, three systems (Complex system: Sugarcane complex with refined sugar and molasses-based ethanol; Ethanol system: Molassesbased ethanol; Sugar system: Refined sugar) are modelled as demonstrated in Fig.1. CON takes the iLUC and dLUC of systems likely to be affected by the change in demand while ATT considers the iLUC and dLUC of attributed systems using economic allocation factors. There is also land requirement for ethanol conversion process (Fig. 1c) but the value is insignificant and excluded.

# **Results and Discussion**

The GHG emissions of the *complex, ethanol and sugar systems* are ranged from 0 to 0.005 kg  $CO_{2eq}$ /t sugarcane for dLUC and 0.2 to 29.6 kg  $CO_{2eq}$ /t sugarcane for iLUC. The GHG emissions from dLUC are insignificant in comparison with those from iLUC. The values depend on the modelling choices and affected systems. For the *complex system* (CON and ATT), there is no co-product and iLUC and dLUC are both derived from the sugarcane cultivation in Thailand (Fig.1a). For the *ethanol system* (CON), iLUC and dLUC from barley cultivation in Spain (Fig.1b) which displaces the molasses disappeared from the global market are included<sup>4</sup>.



Fig. 1 The complex, ethanol and sugar system boundaries

For the *sugar system* (CON), iLUC and dLUC from sugarcane cultivation in Thailand (Fig.1a) and avoided barley cultivation in Spain (Fig.1b) due to the additional molasses for animal feed (feed energy) are considered. For the *sugar and ethanol systems* (ATT), iLUC and dLUC are from the sugarcane cultivation in Thailand (Fig.1a) and allocated with the economic values of the refined sugar and molasses.

# Conclusion

The greenhouse gas emissions from land use changes of sugarcane complex for food and fuel productions are ranged from 0.2 to 29.6 kg  $CO_{2eq}$ /t sugarcane (mainly from indirect land use changes) depending on the modelling choices. Further study should analyse specific context and conditions which are the most relevant for each modelling choice to be used for supporting food, fuel and climate change policies.

# Acknowledgments

Financial support from National Science and Technology Development Agency through the research project "Research Network for LCA and Policy on Food, Feed, Fuel and Climate Change" (Grant no.P-12-01003) is acknowledged.

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# Water Scarcity Footprint Assessment of Tap Water from Metropolitan Waterworks Authority (MWA), Thailand

<u>Vitoon Chotanapund</u><sup>1,3</sup>, Trakarn Prapaspongsa<sup>1,\*</sup>, and Charongpun Musikavong<sup>2</sup>

<sup>1</sup> Department of Civil and Environmental Engineering, Mahidol University, Salaya, Nakhon Pathom 73170, Thailand

<sup>2</sup> Department of Civil Engineering, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand

<sup>3</sup> Metropolitan Waterworks Authority, Laksi, Bangkok 10210, Thailand

\*Corresponding author, E-mail address: trakarn.pra@mahidol.ac.th

# ABSTRACT

The study aimed to assess the water scarcity footprint of tap water from Metropolitan Waterworks Authority (MWA) by using the ISO14046. The annual inventory data of direct and indirect consumptive water use (CWU) have been collected from all water treatment plant (WTP) of MWA. The CWU in tap water from MWA ranged from 1.34 to 1.59 m<sup>3</sup>/m<sup>3</sup> tap water. The hotspot is located in the distribution system. The MWA tap water production in 2012 and 2013 does not increase the water stress level of Chao Phraya and Mae Klong River Basins However, if MWA fully utilizes production capacity in the future, it may increase the water stress index of the Chao Phraya River Basin to almost reach the stress level. To sustain the water resources usage, the recommended policies are; 1) rebalancing the amount of water withdrawal from Chao Phraya and Mae Klong River Basin 2) continuous implementing the active leakage control.

# Introduction

The increasing of water demand and the degradation of water quality make the water scarcity situation tends to be more severe. The water footprint is the effective tool for showing the linkage between human activity and the possible impact on water use. Metropolitan Waterworks Authority (MWA) has responsibility for serving potable water in central economic area of Thailand, i.e. Bangkok, Nonthaburi and Samutprakarn, which has a high level of water usage. The understanding of consumptive water use and its potential impact would help MWA create the appropriate policy and plan for sustainable development.

# Methodology

The study assessed the water scarcity footprint of tap water for each MWA's water treatment plant according to the ISO14046:2014. The study focused only the quantity (water scarcity footprint). It consisted of three main parts; 1) the inventory analysis, 2) the impact assessment and 3) the policy recommendation for sustainable water resources management. The water scarcity footprint inventory analysis was conducted by using annual data from MWA. The functional unit was expressed as the one cubic meter of tap water that passed MWA water quality standard. The system boundary starts from raw water withdrawal until the treated water distributed to the customers (cradle-to-gate).

#### **Results and Discussion**

The CWU of tap water from MWA was ranged from 1.34 to 1.59 m<sup>3</sup>/m<sup>3</sup> tap water. It comprises direct (surface water) and indirect (amount of water embodied in electricity and chemicals) CWU. The main dominant is the direct CWU. The hotspot is located in the distribution system or known as the water leakage in pipeline system. MWA withdraws the raw water from Chao Phraya and Mae Klong River Basin. The result of impact assessment (water stress index, water deprivation, damage to human health and damage to ecosystem quality) indicated that the possible impact per one cubic meter of tap water is quite low. However, the amount of water withdrawal to serve the demand in metropolitan area is quite high. Moreover, if MWA fully utilized their production capacity, the Chao Phraya River Basin may reach to the stress situation. The recommended policies should focus on the improving the distribution system and reducing the water withdrawal from Chao Phraya River Basin. To improve the distribution system efficiency, the current pipeline leakage reduction program should be continuous implement (MWA has already implemented the active leakage control program). In order to reduce the water withdrawal from Chao Phraya River Basin, MWA should study the feasibility of rebalancing its production capacity between the Bangkhen water treatment (using raw water from Chao Phraya) and Mahasawat water treatment plant (using raw water from Mae Klong).

# Conclusion

The water scarcity footprint assessment is a useful tool in water resources management. It can be used for assessing the system efficiency, the potential impacts along the whole supply chain and the impact hotspot so as to solve the problems effectively. Further study should consider monthly data and water quality as well as include other life cycle stages (i.e., use stage and end-of-life treatment).

#### Acknowledgments

Financial support by Metropolitan Waterworks Authority of Thailand and the Thailand Research Fund under the Researchers and Research for Industry Grants: Master Sci. & Tech Grants 2014 (MSD57I0049) is gratefully acknowledged.

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# Eco-Efficiency Assessment of Sustainable Food Waste Management Systems For Large-Scale Hotels on Samui Island

Monthira Kaoudom<sup>1</sup>, Trakarn Prapaspongsa<sup>1,\*</sup>, Weerawut Chaiwat<sup>2</sup>, Natanee Vorayos<sup>3</sup>, Sate Sampattagul<sup>4</sup>

<sup>1</sup> Department of Civil and Environmental Engineering, Mahidol University, Salaya, Nakhon Pathom 73170, Thailand <sup>2</sup> Environmental Engineering and Disaster Management Program, Mahidol University,

Kanchanaburi Campus, Sai Yok, Kanchanaburi 71150, Thailand

<sup>3</sup> Department of Mechanical Engineering, Chiang Mai University, Muang District, Chiang Mai 50200, Thailand

<sup>4</sup> Center of Excellent on Energy, Economic and Ecological Management (3E), Science and Technology Research Institute,

Chiang Mai University, Muang District, Chiang Mai 50200, Thailand

\*Corresponding author, E-mail address: trakarn.pra@mahidol.ac.th

#### ABSTRACT

The objectives of this study are to assess ecoefficiencies of current and alternative food waste management systems and to recommend the systems for large-scale hotels on Samui island. The ecoefficiency is assessed by considering life cycle environmental impact along with system values. The results show that the biogas systems with best management practices is the most eco-efficient in term of the lowest life cycle environmental impacts and life cycle costs. Nonetheless, with 10% methane leakage in the biogas system, the composting system will be suggested.

#### Introduction

Food waste is one of the most important waste fractions in developing countries. On Samui island, food waste contributes to around 30% and 60% of total municipal waste amount at municipality and at source, respectively. In the meanwhile, hotels are the most important source of waste generation on Samui island - the world's famous tourist destination. Various technologies could be applied to solve environmental problems from food waste. Ecoefficiency assessment considering environment impacts in relation to system values can be used for technology selection. This study aims to evaluate eco-efficiencies of various food waste management systems and to suggest a proper system for large-scale hotels on Samui island.

# Methodology

The study assessed the eco-efficiency of various technologies for food waste management according to ISO  $14045^1$  with the 5 main phases; i. goal and scope definition, ii. environmental assessment, iii. product system value assessment, iv. quantification and v. interpretation. The functional unit is expressed as one ton of food waste. The system boundary includes waste collection, waste treatment, and by-product utilization. Capital goods are also considered. Four different (landfilling system; decentralized scenarios and centralized biogas systems; decentralized composting system) are proposed. Life cycle assessment (LCA) is applied for environmental assessment and considers five impact categories (climate change, terrestrial acidification, fresh water eutrophication, marine eutrophication and photochemical oxidant formation). For system value assessment, life cycle costing<sup>3</sup> is applied since literature<sup>2</sup> found the most important economic parameters for hotels on Samui island as investment cost, operation cost, and payback period. The data of waste generation and composition are obtained from Samui island but the technology data are obtained from actual plants in Bangkok and other provinces.

#### **Results and Discussion**

Based on the LCA phase, the landfilling system has the highest environmental impacts for all impact categories. In contrast, the biogas systems yield the lowest values of acidification. change, terrestrial climate and photochemical oxidant formation potentials. The composting system has the lowest eutrophication potential. For life cycle costing, it is found that the biogas systems are the most economically feasible in terms of investment and operation cost. When comparing between environmental aspects and economic analysis, the best option for food waste management are the biogas systems because its by-product can replace LPG production with potential cost saving and short payback period (i.e. within 4 years). However, if the biogas systems are improperly managed, the methane leakage (i.e. 10%) will lead to significant environmental problems and the composting system will become the most appropriated food waste management technology.

#### Conclusion

This study demonstrated that eco-efficiency assessment is a useful tool for technology selection. Based on the ecoefficiencies of the food waste management systems, the well-managed biogas technology is recommended. With the biogas leakage, the composting system will be a more eco-efficient option. Future studies should consider other implementation aspects such as land requirement and actual capacities for technology applications in Samui.

#### Acknowledgments

This work has been supported by Mahidol University and Center of Excellent on Energy, Economic and Ecological Management (3E), Science and Technology Research Institute, Chiang Mai University.

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# Life Cycle Thinking for Sustainable Consumption and Production in Indonesia: Review of Current Status and Way Forward

Idris M. Kamil<sup>1,2,\*</sup>, Trakarn Prapaspongsa<sup>1</sup>, and Monthira Kaoudom<sup>1</sup>

<sup>1</sup> Department of Civil and Environmental Engineering, Faculty of Engineering, Mahidol University, Salaya, Putthamonthon, Nakhonpathom, 73170, Thailand

<sup>2</sup> Department of Environmental Engineering, Faculty of Civil and Environmental Engineering, Institute of Technology Bandung, Bandung, 40132, Indonesia.

\* Corresponding author, E-mail address: maxdoni@ftsl.itb.ac.id

# ABSTRACT

The objective of this study was to review the sustainable consumption and production (SCP) in Indonesian by using various tools based on life cycle thinking, life cycle assessment, and others. Future needs in order to support SCP policies and implementation in Indonesia were also indicated.

#### Introduction

Indonesia is the most populated country among the ASEAN (40.6% of ASEAN population in 2012). The current and growing Indonesian population will significantly increase pressures on the environment and society due to the increased resource utilization and environmental pollutions. Decision makers need policies and tools in order to manage the utilization of the resources and facilitate the more sustainable production such that the resources and environmental can be sustained for future generations. The government of Indonesia (GOI) has realized the situation, set relevant SCP policies (with a long record in sustainable development policy since 1945<sup>1</sup>) and also established an eco-label certification agency under the Ministry of Environment. Currently, there are two types of eco-labels being considered in Indonesia which are Ecolabels type I and II according to ISO 14024 and ISO 14021. The objective of this study is to review Indonesian activities related to SCP, life cycle thinking (LCT) and life cycle assessment (LCA). The results would indicate future directions of the sustainable development in Indonesia.

# Methods

The reviewed 65 research publications from 2006 to 2015 have been searched by using keywords of SCP, LCT and LCA. The selected publications include international journals, conference proceedings, governmental publications and research reports in English and Indonesian. The list of the reviewed literature cannot be presented in the selected references and can be later provided as a supplementary document.

# **Results and Discussion**

According to the current state of SCP in Indonesia<sup>1</sup>, a numbers of tools were prepared by GOI. Several instruments that were implemented by GOI have also been followed by the industries and local governments (i.e. with the area of waste management in Jogjakarta and

Surabaya). With respect to sustainable energy aspect, LCT and LCA have been applied for assessing impacts of bioenergy and fossil energy. The life cycle environmental impacts of biodiesel, bioethanol, biomethanol, energy recovery from waste management, gasoline, coal and fossil power generation in Indonesia have been assessed. Some studies also include economic and social aspects. LCT and LCA were also applied in other sectors (i.e. textile and agricultural production) and in Indonesian industry. In 2014, six companies were awarded as Indonesia Green Companies 2014 by KAHATI or the Indonesian Biodiversity Foundation. These companies were evaluated based on their commitment and actual outputs in implementing sustainable development and corporate social responsibility policies. For sustainable cities and green buildings, it was found that Government of Jakarta City was the first city in Indonesia issuing the Green Building Code. The office of the Ministry of Public Work is the first building that followed the code. The Governor of DKI Jakarta has issued a decree that old and new buildings should be compliance with the code to reduce energy utilization in all buildings.

# Conclusion

The review shows that the Indonesian government and industry have involved in the implementation of sustainable development concept. The movements of ecoactivities and LCT and LCA applications have also been increased aiming at sustainable consumption and production. For future needs, it is suggested that several steps should be followed (i) to enhance the understanding of SCP concept for all stakeholders; (ii) to invite the public to develop other types of certification bodies; (iii) to increase local and regional capacity building, in term human and financial resources; and (iv) to develop an appropriate communication system at national and international level.

# Acknowledgments

The authors would like to acknowledge the financial support from Mahidol University (Mahidol University Seeding Funding for Visiting Scholars in 2015).

# Selected Reference

[1] Ministry of Environment, Government of Indonesia (GOI), SWITCH-ASIA - Mapping the State of SCP Policies and Tools in Indonesia, (2013).



# Eco-efficiency assessment of water meter maintenance with repaired and new meters at Metropolitan Waterworks Authority (MWA), Thailand

Chutchai Deethavorn<sup>1,2</sup>, Trakarn Prapaspongsa<sup>1,\*</sup>

<sup>1</sup> Department of Civil and Environmental Engineering, Mahidol University, Salaya, Nakhon Pathom 73170, Thailand <sup>2</sup> Metropolitan Waterworks Authority, Laksi, Bangkok 10210, Thailand \*Corresponding author, E-mail address: trakarn.pra@mahidol.ac.th

# ABSTRACT

The eco-efficiencies of new and repaired water meters are assessed to support the regular meter maintenance policy of Metropolitan Waterworks Authority (MWA). The eco-efficiency considers life cycle environmental impacts (climate change, metal depletion and fossil depletion) alongside with system values (life cycle costs). The results show that the 100% new meter installation leads to the highest environmental impacts and intermediate life cycle costs whereas 100% repaired meter installation vields the lowest environmental impacts and the highest life cycle costs. The recommended optimization ratios with the eco-efficiencies preliminarily being acceptable by MWA are 75% new and 25% repaired meter (small size) and 30% new and 70% repaired meters (large size).

# Introduction

MWA has responsibility to serve the good quality of tap water to around 8 million people in Bangkok, Nonthaburi and Samut Prakarn. In total, 2,171,371 water meters are currently used to measure water consumption in the MWA service area. The water meters can be classified according to the function of their use as "new connection meters", "full-term meters" and "maintenance meters". Annually, MWA must manage 62,268 new connection meters, 125,892 full-term meters and 49,597 maintenance meters. The new connection and full-term meters will be newly bought while the maintenance meters might be supplied by new and repaired meters. The existing (old) meters can be repaired internally at MWA and can be used for supplying the maintenance meters. The work also helps develop skills of MWA's officers in meter quality check. Moreover, it reduces resource consumption especially bronze which is the main material of the meter's body. However, the internal meter maintenance has high internal operation costs. The new policy with the main focus at cost reduction might result in the replacement of 100% new water meters for the maintenance meters. This main aim of this study is to determine eco-efficiencies of new and repaired meters in order to provide recommendations on the more ecoefficient source of the maintenance meters for MWA.

# Methodology

The eco-efficiency assessment is carried out basically by following ISO14045<sup>1</sup>. Eco-efficiency is determined by considering both life cycle environmental impacts (climate change, metal depletion and fossil depletion) and life cycle costs (material costs and operation costs). The functional unit is the provision of total maintenance meters at MWA in 2016. The historical and current data

for meter maintenance at MWA in 2014-2015 are applied. In the assessment, two types of water meters (new and repaired meters) with two sizes are taken into account. The meter sizes used at MWA can be classified as small ( $\emptyset$  1/2" -  $\emptyset$  1 1/2") and large ( $\emptyset$  2" -  $\emptyset$  16") with the approximate average cost of 825 and 16,500 THB/meter, respectively. The small and large water meters (the body part) are shown in Fig.1. Three scenarios are assessed as 100% new meters (for both sizes; NEW scenario), 100% repaired meters (for both sizes; REPAIR scenario), 75% new and 25% repaired meters (for small size) and 30% new and 70% repaired meters (for large size) (OPTIMISED scenario).



Figure 1 : Meter's body of 2 type (small and large sizes)

# **Results and Discussion**

For the NEW scenario, the highest environmental impacts (climate change, metal depletion and fossil depletion potentials) and intermediate life cycle costs are obtained. The significant impacts of new meters are from raw material acquisition and in the casting process of body's meter. For the REPAIR scenario, life cycle costs are high because of the high salary rates at MWA in combination with the small-scale production. Based on the specific assessment, the OPTIMISED scenario is the most ecoefficient option with the moderate environmental impacts and lowest life cycle costs and therefore recommended for future maintenance policy at MWA.

# Conclusion

This study assesses the eco-efficiencies of maintenance meters at MWA. The meters with optimised ratios of new and repaired meters are recommended due to the intermediate environmental impacts (climate change, metal depletion and fossil depletion) and lowest life cycle costs. Further studies need to consider other environmental impact categories and system values.

#### Acknowledgments

Financial support by Metropolitan Waterworks Authority of Thailand is gratefully acknowledged.

#### Selected Reference

[1] International Organization for Standardization. ISO 14045. Environmental management - Eco-efficiency assessment of product systems-Principles, requirements and guidelines. Geneva, Switzerland: ISO copyright office. (2012).



# **No.** C14

TitlePolicy implications from consequential LCA applications for future food and fuel<br/>policies: Gainers and losers in a world with constrained materials.

Abstract Type International Conference. Proceedings of the 7th International Conference on Life Cycle Management (LCM 2015), 30 August - 2 September 2015, Bordeaux, France.

- Authors Prapaspongsa, T. & Gheewala S. H.
- Abstract Life cycle assessment (LCA) has been applied for supporting decisions towards sustainable consumption and production at product, policy, national and international levels. Two LCA modelling approaches widely applied are consequential LCA (CLCA) and attributional LCA (ALCA). CLCA aims to assess the environmental consequences caused by the decisions with the use of marginal data whereas ALCA aims to assess the environmental impacts of an existing product system with the use of average or supplier-specific data. In this study, the main objective is to identify major ethical implications of using CLCA to support future food and fuel policies. CLCA is chosen since the policies in question focus on the impacts from the increase in food and fuel demand. Previous studies have addressed ethical limitations of both CLCA and ALCA but solutions on how to overcome the constraints remain in question. A case on bagasse utilization for energy production in bioethanol production plants in Thailand is demonstrated. According to annual balances of production and consumption volumes for the past ten years, bagasse has clearly been fully utilized in Thailand for energy production. The bagasse used for steam production in bioethanol plants are generally supplied by sugar mills. If the LCA is done for bioethanol industry, the increased use of constrained bagasse in the bioethanol system (loser) will affect marginal heat production (i.e. natural gas and fuel oil). If the LCA is done for sugar industry (gainer), the increased sugar production will provide additional bagasse to substitute the marginal heat production. The ethical limitations could be on the risks of unfair LCA results among the ones with good actions (i.e. bioethanol and sugar industries) as well as in comparison with the ones with business-as-usual actions (i.e. bioethanol plants using natural gas and fuel oil). In case that bioethanol plants cannot gain environmental benefits from using the constrained bagasse, it may lead to sub-optimized situation with the direct additional use of conventional heat sources on-site. It is recommended that to support decisions for food and fuel policies it is crucial to present the potential consequences of the additional demand but the share of responsibilities among different stakeholders needs to be specifically discussed and agreed upon. Future studies on how to fairly allocate the environmental consequences could play an important role to overcome these ethical limitations.

FundingThailand Research FundOrganization



### **No.** C15

TitleA Greener Footprint for Jewelry Manufacturing Industry: Case Study on Carbon<br/>Footprint of PANDORA Production Co., Ltd.

Abstract TypeInternational Conference. Proceedings of the 5th International Conference on<br/>Sustainable Energy and Environment (SEE 2014): Science, Technology and<br/>Innovation for ASEAN Green Growth, 19-21 November 2014, Bangkok, Thailand.

Authors Thammaraksa, C., Prapaspongsa, T. & Apichartpattanasiri, S.

Abstract Carbon footprint study of PANDORA Production Co., Ltd. intends to estimate carbon emissions generated from jewelry industry supply chain. The assessment was carried out by using attributional life cycle assessment (LCA) approach – considering average technologies and dealing with multiple-output activities by allocation. There are three scenarios for the assessment. The company operation in 2013 was considered to be a normal operation of PANDORA and assessed as business-as-usual scenario. The results presented that 1.59E+08 kilogram of CO<sub>2</sub> equivalent were emitted from PANDORA supply chain, and more than 90% of CO<sub>2</sub> equivalent were from gemstone mining and precious metal refinery. Therefore, the other scenarios were compiled with different recycling rates of precious metal. The results showed that using recycled precious metals can remarkably reduce carbon emissions emitted to the air, while using precious metals produced from virgin resources contribute the greater impacts since this process extensively consumes electricity and fossil fuel for mining operation. Therefore, using more recycled precious metals and reducing energy and fuel use in mining process are recommended for the company to achieve an overall CO2 reduction. For future studies, it is crucial to collect specific data on recycling technologies for more accurate results as well as to apply other LCA approach to model consequences of the decisions or consequential LCA.

FundingThailand Research Fund and PANDORA Production Co., Ltd. (Researchers andOrganizationResearch for Industry Grants: Master Sci. & Tech Grants 2013)



No.	C16
Title	A Water Footprint of Tap Water: Case Study on the Maha Sawat Water Treatment Plant, Metropolitan Waterworks Authority, Thailand.
Abstract Type	International Conference. Proceedings of the 5 <sup>th</sup> International Conference on Sustainable Energy and Environment (SEE 2014): Science, Technology and Innovation for ASEAN Green Growth, 19-21 November 2014, Bangkok, Thailand.
Authors	Chotanapund, V., Prapaspongsa, T. & Musikavong, C.
Abstract	This study assesses water footprint (WF) of tap water from the Maha Sawat Water Treatment Plant (MS-WTP), Metropolitan Waterworks Authority (MWA), Thailand. The method for water accounting is based on water footprint network method in combination with life cycle assessment concept. The data used in the assessment is collected from the MWA with yearly basis of fiscal year 2013. This cradle-to-gate assessment comprises of the operational water footprint (the amount of blue water usage and loss in process) and the supply-chain water footprint (the amount of blue water usage and loss in process) and the supply-chain water footprint (the amount of blue water embodied in electricity and chemicals). The total WF of tap water from the MS-WTP is about 1.6024 m <sup>3</sup> per 1 m <sup>3</sup> of tap water. The hotspot is in the distribution system which should be the leakage in pipeline network. The MWA also concerns about this issue and has the policy to reduce the water loss in pipeline system. When considering the water stress index (WSI) of the Mae Klong basin, the water deprivation of MS-WTP tap water is 0.0288 m <sup>3</sup> H <sub>2</sub> O <sub>eq</sub> . The full capacity expansion of MS-WTP will increase the WSI of the Mae Klong basin from 0.008 to 0.024 which is still classified as the low water stress. The WF gives more clearly about the efficiency of water usage and the hotspot process. The WF can help increase the public awareness of water usage. Future studies should extend the assessment scope to all of water treatment plants of MWA and the analysis should be based on monthly basis in order to capture the seasonal effect.

FundingThailand Research Fund (TRF) and Metropolitan Waterworks AuthorityOrganization(Researchers and Research for Industry Grants: Master Sci. & Tech Grants 2014)



# **No.** C17

TitleA Tool for Thailand's Green Industry Enhancement: Case Study on Sustainability<br/>Indicators at National Level for Mining Industry.

Abstract Type International Conference. Proceedings of the 5<sup>th</sup> International Conference on Sustainable Energy and Environment (SEE 2014): Science, Technology and Innovation for ASEAN Green Growth, 19-21 November 2014, Bangkok, Thailand.

- Authors Chayaviwattanawong, C., Prapaspongsa, T., Kaoudom, M., Boonya-atichart, A. & Wattanawan, A.
- Abstract According to concept of sustainable development, the mining activities should be done to maximize the needs of current generation by supplying equitable distribution without decreasing the ability for future generations to achieve their own needs. In addition, adopting Green Industry concept is considered to be one alternative to strengthen the sustainability of mining industry in Thailand. However, to achieve that goal, the impact assessment tools for mining industries at national level in Thailand should be promoted. Hence, this study aims to provide a tool for sustainability indicators and link them with corporation among diverse stakeholders in the future. The sustainability indicators were grouped into 3 categories regarding key elements of sustainable development. For the linkage between indicator and corporation, the directions are divided into 2 major aspects by key elements and group of stakeholders. The results show that both indicator development and cooperation among organization should be commonly promoted to execute sustainable development in mining industry.
- Note The research is a part of a group project under the course entitled "*Eco-Efficient Engineering (EGEW 551)*" of International Masters Program in Environmental and Water Resources Engineering, Department of Civil and Environmental Engineering, Faculty of Engineering, Mahidol University.



No.	C18
Title	Thailand's bioethanol policy revisited: understanding the risks of indirect land use impacts and greenhouse gas consequences.
Abstract Type	International Conference. Proceedings of the 4th International Conference on Green and Sustainable Innovation (ICGSI) 2014 and 3rd LCA AgriFood Asia 2014, 22-24 May 2014, Bangkok, Thailand.
Authors	Prapaspongsa, T. & Gheewala S. H. (2014)
Abstract	This study aims to assess indirect land use change (iLUC) and greenhouse gas (GHG) consequences of Thailand's bioethanol policy by using consequential life cycle assessment (CLCA) and a systematic iLUC model based on global land market. The results show that the GHG emissions from the cultivation of feedstock/affected agricultural products due to iLUC and system expansion may far outweigh the fossil fuel emissions. Further studies are required to determine robustness of the results and to consider other iLUC choice modelling such as national and regional land use markets.
Funding Organization	National Science and Technology Development Agency



# **No.** C19

- TitleFramework for climate change mitigation and adaptation in cities by utilizing green<br/>infrastructure.
- Abstract Type International Conference. Proceedings of The First Asian Future Conference 2013 (AFC 2013), 8-10 March 2013, Bangkok, Thailand.
- Authors Prapaspongsa, T., Davidson, C.I., Jindal, R., Wohlers, D., Squier, M., Flynn, C., Tamargo, J., & Maneschi, D.
- Abstract Climate change has threatened global security of ecosystems, human health and natural resources. These threats have increased demand for various mitigation technology solutions (e.g., greenhouse gas emission reduction by energy savings, low carbon technologies, etc.) to be emphasized at the global, national and local levels. In addition to mitigation strategies, it is equally crucial to develop and implement effective adaptation strategies in order to cope with climate change impacts. Green infrastructure technologies such as green roofs and urban forestry are viewed as ones of the best climate adaptation strategies in cities. Sustainable city development should consider ways to simultaneously reduce negative impacts while increasing benefits to the environment, economy and society. This multiphase study aims to develop a framework for climate change mitigation and adaptation in cities with focus on energy savings, reduction in urban heat island effects, and sustainable storm water management by using green infrastructure technologies. The framework will be established by integrating relevant policy frameworks for green infrastructure as related to urban storm water management and green building standards (e.g., LEED, BCA Green Mark, TREES-NC, etc.). The framework will address benefits from applying different green infrastructure technologies as well as existing barriers in technology applications. The complete framework will guide researchers, professionals, and decision-makers to effectively integrate climate change mitigation and adaptation in urban planning and development.

**Note** The AFC 2013 best presentation prize was awarded to the presentation.