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General presentations

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GOING BEYOND ESG REPORTING

ERIC MIERAS* [1]

The coming 10 years have been coined as the decade of delivery for sustainability. That requires that sustainability can be hold to account . Impact Measurement and Valuation is a way to go beyond ESG reporting and informing and to bring sustainability into the decision making process.

Most companies have their reporting around sustainability in place. And most companies also have their targets set. And most companies report on these targets regularly. However, that is not enough to operate at the speed and scale of business. To achieve these ambitious targets companies will have to operationalize these targets in the business and engage with suppliers and customers.

In this presentation we will share a framework to make metrics available for daily decision making. This framework provides insights in not only the environmental, but also the financial and social impact to have the complete picture. This framework is the single source of truth for all teams within your company, providing them with the insights they need to act upon.

The framework will be illustrated with a case of a logistics provider. For them an Impact Measurement and Valuation has been conducted for two or their main Business Units. The Framework for Impact Measurement and Valuation was used to assess the social, economic and environmental impact of their operations. This brought forward that the best performing options from an environmental point of view also had the highest margins, thus creating business value and reducing risk at the same time. Next to that, the top 8 clients were covering 40% of the total environmental impact. By focusing on process optimization of the top 8 clients, this logistics provider can make big improvements on lowering environmental impact.

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THE FUTURE OF LCA

ERIC MIERAS* [1]

LCA has always been the domain of experts. That has led to very valuable insights in the impacts of entire value chains. That knowledge is increasingly recognized by professionals from other fields. But how can we leverage that profound expertise from LCA Experts? As we' re with a few thousand experts and billions of products we have to find a way to scale up the availability and use of Life Cycle Information.

A key aspect is that insights have to be actionable. There is a lot of energy and drive around sustainability and people are motivated to contribute to this shared purpose. Having these insights allows them to move from gut-feeling to fact-based decision making and action. In this presentation examples of how insights can be made actionable for designers, logistics, purchasers and packaging will be presented.

Another crucial element is to move fast. That requires that these insights are based on the same underlying model, so the most important and time-consuming work does not have to be done again and again. Use cases will be presented on how one model is used by many users and for many different purposes.

Of course, there' s always the challenge of making it as advanced as possible. Over the past years we have learnt to keep it simple at the start and focus on the most material aspects. Keeping it simple at the start will actually speed up the (learning) process later on. We will share our experiences from projects where we applied this for environmental performance assessment in case of tenders, product portfolios, design and reporting.

The key take out of this session will be how an individual expert can leverage and unlock the value of her or his work by digitizing the outcome and make it available to a much broader audience.

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TOTAL MATERIAL REQUIREMENT FOR TRACTION LITHIUM-ION BATTERIES BASED ON LIFE CYCLE SIMULATION

SHOKI KOSAI* [2], UKYO TAKATA [2], EIJI YAMASUE[2]

A transition in vehicle types has caused an increase in demand for traction lithium ion batteries (LIBs). Many studies have assessed the impact of mineral resources for traction LIB production in the life cycle assessment (LCA), whilst the volume of natural resource exploitation has yet to be sufficiently considered. In addition, the existing proposed system in the life cycle assessment for traction LIBs have primarily been one-through cycle, but without sufficiently considering the compounded life cycle system with the feed-back loop including repurposing of spent traction LIBs for stationary as well as recycling for producing secondary materials as an input for primary traction LIBs production.

To evaluate the volume of natural resource use for traction LIBs, the land

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disturbances caused by mining activities of primary resources are considered, which matches the concept of total material requirement (TMR). TMR involves direct and indirect resource inputs as well as the accompanying unused extraction or hidden flows related to mine waste through land disturbances, which is one of the forms of material footprint.

Firstly, this study obtained the TMR of traction LIB for the stage of production using virgin materials mined from natural ores and secondary materials recycled from discarded traction LIB and for the stage of repurposing for stationary. Then, the compounded life cycle system with feed-back loop is modeled by using system dynamics, considering the global demand of traction LIBs during the periods 2010-2050. Finally, the overall TMR in the compounded life cycle system across the globe is examined with conducting Monte Carlo simulation.

It was found that the recycling process contributes to the reduction of natural resource use for the traction LIB in 2050 by 16%.

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WE WANT IT ALL, BUT DO WE NEED IT ALL? MATERIAL STOCKS OF SOCIETIES AND THEIR INTERRELATION WITH ECONOMIC GROWTH AND WELLBEING

BARBARA PLANK* [1], DOMINIK WIEDENHOFER [1]JAN STREECK, [1]FRIDOLIN KRAUSMANN, [1]DORIS VIRÁG,[1]HELMUT HABERL[1]

Tackling the unfolding environmental crisis requires a fundamental transformation of the scale and structure of the global socio-economic metabolism (UNEP-IRP 2019; Haberl et al. 2019; Pauliuk and Hertwich 2015), i.e. the socio-economic uses of materials and energy fueling production and consumption and ultimately resulting in waste and emissions. Material stocks of infrastructure, buildings and machinery are the material basis of production and consumption and lock-in resource use for operation, stock-building and through end-of-life waste. Previous work indicated that the development of material stocks seems to be tightly coupled to economic growth (Krausmann et al. 2017) and high levels of societal wellbeing require a sustained history of high levels of resource use (Mayer et al. 2017). The Stock-Flow-Service Nexus has been proposed as a systemic approach to analyze decoupling and efficiency potentials (Haberl et al. 2017).

Herein, we systematically investigate the interrelations between socio-metabolic resource use patterns, material stocks and economic growth as well as selected societal wellbeing indicators. For this purpose, we are developing a global, national-level, economy-wide material stocks and flows database. The database is compiled using input-driven dynamic material stock modelling, fully consistent with economy-wide material and energy flow analysis (EW-MEFA) principles (Wiedenhofer et al. 2019). We differentiate 183 countries, 16-20 material categories, 6-10 stock types for all years from 1900-2015 and implement a systematic, detailed assessment of uncertainty.

We will present first results of our global country-level database and relate these to common indicators on economic growth (e.g. GDP, green GDP) and wellbeing (e.g. HDI, SPI). By utilizing data on material stocks and flows for the period from 1900 to 2015, long-term socioeconomic trends can be traced that reveal path dependencies of different socioeconomic development trajectories and their relation to societal wellbeing.

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LCSA INTERPRETATION AND COMMUNICATION – A FOCUS ON THE CONSTRUCTION SECTOR

JANA GERTA BACKES* [2], MARZIA TRAVERSO[2]

Sustainable development is recognized as one of the major challenges of our generation, whereby life cycle thinking (LCT) or life cycle sustainability assessment (LCSA) is seen as a strategic decision-support tool. The construction industry is responsible for about 10% of the global Gross Domestic Product (GDP) and employs 100 million people, at the same time contributes significantly to resource depletion, energy consumption and CO_2-emissions. At present, the number of published LCSA studies in the construction sector is comparatively small (13% of 105 studies, published between 2008-2019) – leading to the assumption that only a small amount of decisions in this sector was and is based on LCSA or LCT. To significantly foster the partnership between LCSA and the construction sector, an understanding of backgrounds and options of LCSA application in this sector is necessary – which motivates the following methodology: A worldwide survey is conducted via an online questionnaire to ask LCSA experts - independent of the construction sector - about their use and interpretation of LCSA. At the same time, two surveys are distributed to people working in the construction sector. One survey is focusing on today's decision makers in the construction industry, including questions like how important sustainability in the construction sector is to them, which certification systems are known, whether they are familiar with LCSA/LCT and what role sus-

tainability plays in their daily decision-making. The second survey is launched with future decision makers in the construction sector (students) to find out whether something needs to be aimed for in education in order to deeply anchor LCT/LCSA in the construction sector and among future decisions.

The methodology itself and first results are to be presented at the conference. In the long term, this research will support the materialization of sustainability visions in the construction sector.

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ACHIEVING ENERGY AND WATER ACCESS IN REMOTE TROPICAL COMMUNITIES: ENVIRONMENTAL SUSTAINABILITY OF CURRENT AND FUTURE SCENARIOS

JHUD MIKHAIL ABERILLA* [1] , ALEJANDRO GALLEGO SCHMID [2] ,LAURENCE STAMFORD [2] ,ADISA AZAPAGIC [2]

Access to clean energy and water have been recognised as important Sustainable Development Goals to be achieved by 2030. While progress has been made in recent years, gaps in the rural and urban divide continue to exist. Planning of energy and water services in developing regions is further complicated by the complex interactions of these resources within the energy-water nexus. This study proposes an integrated approach to the development and evaluation of energy and water supply systems as applied to remote communities in the Southeast Asian context. The proposed approach investigates and takes advantage of multiple and intersecting supply chains for electricity, cooking fuels, and potable water. Starting from the current situation, future scenarios are defined through combined simulation and optimisation. The environmental sustainability of utility provision in each scenario is evaluated using life cycle assessment. Currently, annual household consumption is estimated to have a carbon footprint of 1.7 t CO_2-eq., with 51% derived from bottled water and only 6% from electricity. Meanwhile, the household water footprint is 2,229 m3/yr, of which 91% is embedded water. On average, the environmental impacts are found to be mainly attributed to the water supply (62%), followed by cooking fuels (33%) and electricity (5%). Air pollution and eutrophication could be reduced by ¿40% under business-as-usual conditions, but other 14 impacts would increase by 2-63% resulting from continued dependence on bottled water and electricity from diesel. A scenario defined by self-sufficient utility systems leads to a ¿12% reduction in 17 impact categories, except terrestrial ecotoxicity which increases by 5%, both due to utilisation of waste biomass for cooking. The combined analysis of the three utilities carried out in this study shows that community planners and local authorities should consider other aspects of household consumption in addition to electricity when devising sustainability strategies.

The methodology itself and first results are to be presented at the conference. In the long term, this research will support the materialization of sustainability visions in the construction sector.

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UNIT STRUCTURES OF RENEWABLE ENERGY ACTIVITIES: AN ANALYSIS USING THE 2011 INPUT-OUTPUT TABLE FOR THE NEXT-GENERATION ENERGY SYSTEM

AYU WASHIZU* [3] , SATOSHI NAKANO [4]

An input – output table for the analysis of a next-generation energy system (IONGES) was created. This IONGES effort incorporates renewable-energy sectors into the 2011 input – output table published by the Ministry of Internal Affairs and Communications, Japan. The sectors incorporated in the IONGES data cover power generation facility construction sectors and power generation sectors for 15 types of renewable energy. The IONGES data consist of the following two types of table: a table incorporating renewable-energy sectors as they existed in 2011 (2011 IONGES) and a table incorporating renewable-energy sectors up to the composition ratio assumed in 2030 (2030 IONGES). We designed the table in anticipation of future changes in renewable energy dissemination policies. IONGES was used to compare the input structure of each renewable-energy sector and each supply chain brought about by it. The ripple effect of the supply chain on entire economy was also visualized as a “unit structure.” The unit structure shows all intermediate goods transactions that occur directly and indirectly through the supply chain of the j-th good. Through visualization of the unit structures, IONGES can make it possible to verify new input – output structures by using renewable energy. In addition, the unit structure shows the “structural” unit cost associated with the one unit (1 million JPY) of facility construction or generation for renewable energy. We compared structural unit costs during construction and operation of different renewable energies. We also calculated

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the “structural” CO_2 emissions (t-CO_2) associated with the one unit (1 million JPY) of facility construction or generation for renewable energy. Renewable-energy types with relatively large equipment utilization rates and long useful lives have a large total lifetime CO_2 reduction effect with respect to thermal power.

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Fuel Consumption and CO_2 Emissions from Seafood Production in Karimunjawa, Indonesia

Dheanara Pinka* [1], Kazuyo Matsubae [1]

The complexity of tracking CO_2 emissions influences the broad understanding of the seafood production sector. Fishing, as the most energy-intensive method of food production in the world, burned billion liters of fuel. The CO_2 emissions calculation from the fishing production in small islands is often ruled out due to its complexity. Karimunjawa islands categorized as “small island”, are located in the greatest seafood production area in Indonesia. Karimunjawa islands account for a significant part of the global fishing supply chain and contribute to global carbon emissions. However, the amount of CO_2 emitted in Karimunjawa is not clear. This study estimated the volume of CO_2 emissions by calculating the carbon footprint from transportation-water-borne-navigation, which was defined in the Intergovernmental Panel on Climate Change (IPCC) 2006 guidelines. We found that the average amount of CO_2 emitted in Karimunjawa (2.59 kg CO_2 eq) was higher than the total amount of CO_2 emitted by the fisheries industry globally (1.7 kg CO_2 eq). The result shows that the increase of CO_2 emissions from the fisheries sector needs widespread concerns. Also, the efficiency of fuel use should be part of the main agenda in the future so that the fisherfolk can better understand how to lower their CO_2 emissions.

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Material needs and energy transition: synergies and trade-offs toward circular economy deployment to sustain national Net Zero-Emission strategies - Case study on France

Antoine Teixeira* [2]

Paris 2015 climate agreement has been a major step forward to tackle the rise of global mean temperature below 1.5° C above pre-industrial levels. For European countries, it implies to reach net-zero energy-related GHG emissions by mid 21st century. Regarding the French National Low Carbon Strategy (NLCS) recently released, it encompasses deep transformations of key economic sectors by renewing most of the infrastructures and equipments installed and by deploying a low-carbon content capital which will necessarily increase most carbon-intensive material demands (steel, cement, etc.). However, literature pointed out (i) material demand is already expected to double until mid-century following economic trends and (ii) material constraints are usually neglected in energy prospects leading to underestimate material demand forecast. The actual material growth could more than offset carbon neutral objectives and more stringent policies are needed to reach net-zero GES emissions. Our study aims (i) to access the discrepancy about material demand between NLCS and actual material needs and (ii) to explore in which way circular economy policies could alleviate the material burden of the energy transition.

We involve an Input-Output analysis describing the interactions between 200 sectors (of which 33 raw materials and 30 manufacturing materials distinguishing primary and secondary sectors). We perform a comparative static analysis between contrasted scenarios until 2050: (i) Current Policies (CP) scenario expects to follow current trends on material efficiency gains and GES reductions ; (ii) Net-Zero Emissions (NZE) scenario encompasses policies aiming at reaching carbon neutrality by 2050 ; (iii) Circular Economy (CE) scenario includes additional policies about recycling expansion and material efficiency gains. We confirmed that the material demand of carbon-intensive industries is underestimated by NLCS in both CP et NZE scenarios. Circular economy policies considered could afford to reduce GES emissions and broader circular economy policies are still needed to reach carbon neutrality.

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UTILIZATION OF AGRICULTURAL WASTEMAIZE COB IN CONSEQUENTIAL LIFE CYCLE ASSESSMENT

TITAPORN SUPASRI* [1] , RONALD MACATANGAY [2] , SATE SAMPATTAGUL [3 4]

This study aims to evaluate the environmental impacts related to emissions within a set system boundary through the life cycle of biomass utilization from maize cobs in Chiang Dao district, northern Thailand using a consequential LCA (system expansion) approach to present the consequences of important approach in LCA studies which are considering the endpoint impacts on the human health damage. The calculations and assumptions are identified based on secondary data, such as the existing databases in SimaPro, such as ecoinvent data v3.0, Thai national database, and IPCC. Moreover, this study collected the related parameters in order to consider the appropriation for various biomass utilization production scenarios under CLCA modelling approach such as price, calorific value, nutrient content and nutrients for animal feed. The substituted and substituting product systems are modelled under the global and national markets depending on the market delimitation of each product. As regards the results of the CLCA modelling approach, the study assessed the environmental performances of biomass fully utilization from maize cobs in Chiang Dao district using a CLCA (system expansion) approach to present the consequences of important approach in LCA studies. This research present how modelling choices affect the environmental impacts of biomass fully utilization from maize cobs. The product systems being effected under global and national markets depend on the market delimitation of each product. The additional maize cobs production dedicating specifically for biomass energy production from maize cobs potentially contributes to substantial environmental impacts reductions and biomass fully utilization. Further analysis will take into consideration on the market responses and social aspect based on the pilot study. The results of this study can also be used to further enhance policy information on biomass management in the agricultural area for maximum efficiency and sustainability biomass utilization into the future.

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A NOVEL APPROACH FOR MAPPING MATERIAL STOCKS OF BUILDINGS AND INFRASTRUCTURE FROM REMOTE-SENSING DATA AT THE NATIONAL SCALE AND BEYOND

DOMINIK WIEDENHOFER* [5] , DORIS VIRÁG [5] , FRANZ SCHUG [6 7] , DAVID FRANTZ [6] , SEBASTIAN VAN DER LINDEN [8] , PATRICK HOSTERT [6 7] , HELMUT HABERL [5]

Buildup, maintenance and use of societal material stocks such as buildings, infrastructures, machinery or other long-lasting products are major drivers of globally surging resource use and emissions (Krausmann et al. 2017; UNEP-IRP 2019). Spatial patterns of buildings and infrastructures play an important role in determining societies' resource use patterns and are hence under scrutiny when pondering strategies to foster sustainability, e.g. by reducing resource use to mitigate climate change (Lanau et al. 2019). Currently, two types of data are primarily used to map building and infrastructure stocks: (1) nighttime lights and (2) cadastral data, which both have important limitations.

We here present results of an alternative approach that derives material stock maps from a stock-driven modelling using freely available remote sensing data derived from newest generation satellites, combined with information from OpenStreetMap. Maps of built-up area, building height and building types derived from optical Sentinel-2 and radar Sentinel-1 satellite data at an original spatial resolution of 10m are used as a basis for spatially explicit material stock estimation at the national level. Machine-learning algorithms trained with several regional/local 3D-building cadasters are used to broadly identify building types. Material intensity factors per m2 respectively m3 of infrastructures and buildings are then used to calculate the mass of buildings and infrastructures per pixel at aggregated 10-100m spatial resolution.

We demonstrate this novel approach with results for Germany, Austria and the USA and discuss strengths and limitations of this approach. We finalize with an outlook on next steps in mapping the material stocks of other countries.

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SUPPORTING FOOD PACKAGING DESIGN INTEGRATING CONSUMER PREFERENCES AND ENVIRONMENTAL IMPACTS

NAOKI YOKOKAWA* [1] , ERI AMASAWA [1] , MASAHIKO HIRAO [1]

This study aims to assist packaging designers to contribute to sustainable product life cycle through their designs. Packaging has many functions to meet various demands from stakeholders in the product life cycle but inevitably becomes waste after conveying and consuming its contents. Because functionality enhancement in hopes of influencing consumer decisions tends to proliferate environmental impacts, packaging designers generally face the trade-offs between the functional and environmental aspects. For example, multi-layered packaging can prolong the expiration date but may increase the environmental impacts from its production and the end-of-life. However, it is difficult for packaging designers to comprehensively expect the trade-offs during their design stages. The trade-offs need to be uncovered to benefit packaging design.

To uncover the trade-offs, we assessed designs of food packaging from the functional and environmental aspects with a case of potato salad products. We assessed each aspect and integrated the results into eco-efficiency. To assess a functional aspect, we adopted a choice-based conjoint analysis and analyzed the utilities on product functions through a questionnaire survey. The summation of the utilities on product functions was the total utility of designs, where we regarded the utilities as the consumers' perceived values. To assess an environmental aspect, we conducted a life cycle assessment of the designs. The environmental impacts of functionality enhancement were assessed by comparing the environmental impacts of the design with and without the enhanced function. Finally, eco-efficiency was computed as the ratio of the utility to the environmental impact, which presented the integrated results. The eco-efficicney of the product functions ranked the redesigns, whereas the eco-efficiency of designs indicated the relationships between the utilities and the environmental impacts. With the eco-efficiency, this analysis presented information about the trade-offs between both aspects for supporting packaging design integrating both aspects.

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ALTERNATIVE APPROACH TO QUANTIFY MATERIAL INTENSITY PARAMETER OF BUILDINGS FOR MATERIAL STOCK MODEL USING BIM

XAYSACKDA VILAYSOUK* [2] , SEIJI HASHIMOTO [3]

Global materials extraction is increasing at an unpreceded rate, which the construction materials account for more than half. A massive amount of construction materials would be needed to deliver housing, infrastructure system for the development in the coming years. Understanding the composition of materials— that accumulated as the in-use stock and potentially going to release back to the environment— is crucial for circular economy development as well as urban mining. The bottom-up stock model is commonly used to study the flows and stocks of materials, which provide more detailed information compared to the top-down approach. However, the data of material intensity, which necessary for the bottom-up model, is difficult to obtain. The traditional approach for material intensity study is time and resource-intensive processes. Additionally, the material intensity is site-specific, and only available for several countries, even rarely exist for the case of developing countries. Building Information Modelling (BIM) is digital a 3D parametric model used in the architecture, engineering, and construction (AEC) industry for design, construction, fabrication, and building management and operation. BIM generates a data-rich 3D model that includes not only 3D geometric data but also relevant information such as schedules, cost information, building components information, material information, etc. In this research, we propose the alternative approach for material intensity study of building using BIM technology. The main advantage of conducting material intensity using BIM is the high level of reproducibility. This new approach could be implemented for almost every country in the world to provide a new dataset for the material intensity. This would help to improve knowledge and improve the accuracy of the bottom-up stock model in many countries.

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LIFE-CYCLE RESOURCE PRODUCTIVITY AND ECO-EFFICIENCY OF WOOD AND IRON MATERIALS

SEBASTIEN MICHAEL RENE DENTE* [3], TOSHIAKI MATSUDA [3] , MITSUNORI HIRAI [3] , SEIJI HASHIMOTO [3]

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Resource are extracted from the environment, embodied into products, stocked within the society and finally discarded to the environment. To improve the socio- economic metabolism of our societies, circular economy strategies such as the improvement of recycling rates are advocated in the literature. Still, an indicator able to track the cumulative value added and environmental impacts along the life cycle of materials is missing. The present work aims at filling this gap by calculating the life-cycle resource productivity and eco-efficiency of wood and iron materials consumed in Japan for the period 1990 – 2011. The new indicator is constructed by combining physical input – output tables of the materials, the value-added data extracted from monetary input-output tables and the environmental impact extracted from Japanese LCA database IDEAv2. Results show that the amount of wood entering the Japanese economy diminished by 36% from 49.8 Mt in 1990 to 31.9 Mt in 2011. The resource productivity of wood varies slightly during the period staying within the range of 43-46 JPY/kg. In 1990, 35%, 28% and 22% of the value added come from sawnwood and roundwood processes, building and infrastructure processes and paper products making processes. In 2011, these figures have evolved to reach respectively 23%, 27% and 33% of the 2011 generated value added by wood materials demonstrating the effects of the Japanese paper paper recycling policy in Japan. Results related to environmental impacts and iron materials are still underdevelopment and will be presented during the conference.

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GLOBAL SCALE ANALYSIS ON THE REGIONAL CARRYING CAPACITY OF FRESHWATER CONSUMPTION AND ITS EXCEEDANCE

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Sustainable water use is an important social issue that is also set as a goal of Sustainable Development Goals (SDGs) by the United Nations. The concept of planetary boundaries is applied for water use to assess the sustainability of human activities, whereas the challenges on the definition of regional carrying capacities at watershed levels and identification of the causes of boundary exceedance need to be overcome. We analyze the current state of the carrying capacity exceedance of freshwater and its sources at watershed levels for the whole world.

Here we show that 24% of our current total freshwater consumption exceeds the carrying capacities of watersheds. Our fundamental demand of freshwater for domestic and irrigation use accounts for 60% of the overconsumed part of the total freshwater consumption. We deprive 60% of water requirement for eco-systems in watersheds on average to satisfy our current freshwater demand, which may result in significant effects on ecosystems. Demand for traded crops in the global supply chains indirectly contributes to over-consumption of freshwater in producing watersheds, while around 5% of overconsumption of freshwater is globally saved through virtual water trade for many consuming countries owing to the dependency on producing countries. However, overconsumption of freshwater is imposed in some producing countries in addition to their national demand to satisfy the demand of consuming countries. The balance between the reduction of pressure on planetary boundaries and sustainability at the watershed level is a crucial issue for the sustainability of freshwater use.

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A BOTTOM-UP MODEL FOR THE ANALYSIS OF FUEL CELL VEHICLE CONSUMPTION COST – TOKYO AS A CASE STUDY

QIONG ZHANG* [4] , TOMOHIKO IHARA [4] , JINYU CHEN [5]

Fuel cell vehicles (FCVs) are recognized to have the potential to reduce fossil fuel dependence and carbon emissions. Japanese government has included the promotion of FCV adoption as a part of national economic development agenda. However, the implementation of this initiative is facing challenges, such as the low adoption rate due to the excessively high consumption costs of FCVs. According to existing research, despite of subsidies, FCVs have no advantage on economic cost compared with conventional vehicles, which decreases the consumers' willingness of FCV adoption. Therefore, it is necessary to analyze the composition and trends of FCV consumption cost in order to provide the government with practical suggestions.

In this study, a bottom-up model for the consumption cost of FCV analysis is established. The consumption cost consists of purchase cost, maintenance cost, fuel cost and depreciation cost, which are analyzed separately. Purchase cost analysis is based on market information integration. Maintenance cost is estimated by social survey. Fuel cost varies greatly due to individual diversity. Individual driving distance via GPS data and hydrogen market price are put into the driving simulation model to obtain the distribution of individuals fuel costs.

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Depreciation cost is determined by the depreciation rate estimation. Due to the rapid development of the hydrogen industry and the FCV industrial production, dynamic parameters such as hydrogen prices and vehicle prices, are assigned different values for future scenario analysis.

In addition, a case study in Tokyo also is conducted. The components of consumption cost have been analyzed and compared, in order to find out the influencing factors of the difference. Finally, suggestions for future improvements are provided.

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SPATIO-TEMPORAL CHANGES IN GLOBAL DEFORESTATION FOOTPRINTS OVER 15 YEARS

NGUYEN TIEN HOANG* [1] ,
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An unprecedented increase in the number of Amazon rainforest fires coupled with the pressure of economic development has become a major global concern at the turn of the new decade. Although the relationship between deforestation and global supply chains has been confirmed in the literature, how the spatial patterns of deforestation are embodied in international trade is still poorly understood. Using remote sensing data and multi-region input-output model, here we quantify and map the spatio-temporal changes in global deforestation footprints over 15 years (2001 – 2015) at a 30-m resolution. While obtaining net forest gains, China, India, and the G7 countries (except for Canada, in which forest cover area is decreasing) have increased the deforestation footprints outside their borders. We find that tropical countries (e.g., Brazil, Madagascar, Argentina, Indonesia, and Côte d'Ivoire) majorly export forest-risk commodities (e.g., cattle, soybeans, coffee, cocoa, palm oil, and timber) to the G7 countries and China. Residents in the G7 countries drive an average loss of 1.4 – 16.1 trees or 25 – 152 m^2 of forest yr^{-1} per capita through their consumption in 2015. We suggest that the zero-deforestation policies need to be reformed to improve transparent monitoring of the supply chain and promote effective public governance as a platform for developing private initiatives in the long term.

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Reducing Environmental Impacts of Clothing through Waste Prevention

Maja Wiprächtiger* [1] , Martina Rapp [1] , Melanie Haupt [1] , Stefanie Hellweg [1]

Although given priority in many countries' environmental protection agenda, a broad implementation of waste prevention activities (WPA) has not been observed yet. The successful implementation of WPA activities is, among others, hindered by ambiguous definitions of waste prevention (WP), lacking targets, and the difficulty of evaluating the success of WPA. The environmental superiority of waste prevention (WP) over other strategies, e.g. recycling, is only assumed, albeit difficult to assess. In this study, we propose an approach for the environmental assessment of WPA, by (i) putting forward a definition of WP, (ii) developing an approach for the environmental assessment of WPA, and (iii) applying it on the selected case study of clothing in Switzerland.

The textile industry is responsible for a considerable share of global pollution, inter alia, caused through the massive overconsumption of clothes. Annually, 16 kg/person of clothes are purchased in Switzerland, the majority being imported. Most impacts of garments are caused during the production, far away from the place of consumption. Thus, the need for solutions aiming at reduced resource consumption from clothing production, use, and disposal, through a more circular use, is substantial. Therefore, we assessed several WPA, such as increased reuse, repairing of torn clothes, sharing, and reduced consumption, for clothing in Switzerland through a combined assessment with material flow analysis and life cycle assessment. High savings on impacts on climate change (- 40%) could only be achieved through drastic change of consumer behavior, i.e. reduction of consumption. Some savings (-10%) were observed for increased sharing and mending of garments. Due to the low substitutability of clothes (extent to which a second hand garment replaces a new garment; 35% in developed, 45% in developing countries), increased reuse, locally or abroad, did not show environmental benefits compared to business as usual.

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Developing Effective CO_2 and SO_2 Mitigation Strategy Based on Marginal Abatement Costs of 316 Coal-Fired Power Plants in China: A Parametric Approach

Tomoaki Nakaishi* [2]

In China, coal-fired power plants are the main contributors of CO_2 and SO_2. In 2015, China was the world's largest emitter of these pollutants. This study employs a directional output distance function (DODF) approach and parametric liner programming (PLP) approach to investigate the CO_2 and SO_2 emissions efficiency, emissions reduction potential, and marginal abatement cost (MAC) of 316 coal-fired power plants in China. The average emissions efficiency of CO_2 and SO_2 is 0.48 and 0.61, respectively, which indicates that China's coal-fired power plants have the potential to reduce CO_2 and SO_2 emissions by 52% and 39%, respectively, on average. The average CO_2 and SO_2 reduction potential for 316 power plants are 1517 kt and 3773 t, respectively. The average MAC prices for CO_2 and SO_2 are 598 Yuan/ton and 22,401 Yuan/ton, respectively, indicating that the reduction of CO_2 and SO_2 emissions from China's coal-fired power plants is considerably expensive. Our estimates provide government with groups of plants that should preferentially improve the emissions efficiency to effectively reduce the CO_2 and SO_2 emissions from these plants. Furthermore, we have solved the optimization problem for maximizing CO_2 and SO_2 emission reductions based on the relationship between the estimated emissions efficiency and the MAC to identify the total cost to reduce CO_2 and SO_2 as much as possible, maximum possible emission reduction for each allocated budget scale, and optimal budget allocation for each power plant. The framework presented in our study provides useful information, which can be used by policy makers to design effective mitigation strategies for CO_2 and SO_2 emission generated from China's coal-fired power plants.

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Rapid Prototyping Pilot for Enhancing the Uptake and Value of LCA for Product Evaluations and Innovation Decisions

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Despite the fact that Life-Cycle Assessment (LCA) has a history of over 30 years of method development, sound technical underpinnings, and standardization under the ISO scheme, uptake and application of LCA has not achieved full market penetration. Over the past several years it has become apparent that there is a gap between LCA providers and results users. One obvious gap is that the results of LCA studies do not align with the characteristics (functional attributes and features) of next generation and innovative products. Another is that LCA is not understood to be a demanded and critical component of decisions. Not many organizations have what we term "translators" as intermediaries between LCA providers and users who are not LCA experts. A survey conducted with both practitioners and users revealed that the Interpretation component of LCA is often a contributor to lack of use or limited value of results.

A multi-phase project, jointly supported by SETAC, ACLCA, and FSLCI, has been developed. After initial scoping and some requested input from the community, it was decided to conduct a short-term pilot study known as a Rapid Prototyping (RP) exercise. This RP effort has two main elements: first, identification, evaluation, and critical analyses of cases studies that have overcome (successes) or failed to overcome (lessons learned opportunities) the barriers and second, outreach to key members of the provider and user community to add additional insight and to help create stories to articulate how to more effectively use LCA results. Aspects could include data visualization and enhancement of an LCA interpretation framework.

Results will develop guidance and implementation plans for this application area as well as plans for future phases that address additional applications that contribute to sustainability. Our vision of success is an increased relevancy and demand for LCA results.

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Towards Environmentally Sustainable Healthcare: A Novel Application of Organizational LCA to an Acute Care Hospital

Alexander Cimprich* [13] , Steven B. Young [13]

SDG3, good health and well-being, is supported by a critical and complex service sector. However, through its own operations, the healthcare industry has a sizable environmental footprint – typically amounting to 5-10% of national greenhouse gas emissions in developed economies like Canada or Japan. Yet, as our 2019 review indicates, literature on healthcare sustainability is fragmented. To build an evidence base for healthcare management and clinical decision-making, we bridge the gap between "top-down" approaches (i.e., aggregated environmental footprinting of healthcare on a national level, typically conducted using economic input-output models) and "bottom-up" approaches (i.e., granular environmental footprinting of healthcare-related activities and products, typically conducted using process-based LCA models). We conduct a novel organizational LCA of an acute care hospital in British Columbia, Canada. In the process, we test and demonstrate the use of our newly developed LCI database – the Consolidated Environmental Footprint Data System (CEFDS) – that systematically consolidates and extends information from existing LCI databases and LCA literature. CEFDS presently includes LCI data for 200+ new processes – organized using the United Nations Standard Products and Services Codes classification system – needed for our hospital study. We connect "foreground data" on the hospital's operations over a one-year period (using a mix of physical and financial data to cover energy and water

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use, waste streams, supply-chains, and outsourced services) with "background data" in CEFDS. For the environmental footprint of supply-chains, comprising nearly 3,000 unique items purchased by the hospital, we developed a new method that enables statistical inference based on a relatively small sample of 182 items. Our results demonstrate that a substantial part of healthcare's environmental footprint is from "invisible" aspects like emissions of vented anesthetic gases and embodied emissions of supply-chains (e.g., for pharmaceuticals and medical devices) and outsourced services (e.g., for hospital laundry and food services).

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ADVANCING METHODS AND DATA FOR "META-LCA": THE CONSOLIDATED ENVIRONMENTAL FOOTPRINT DATA SYSTEM (CEFDS)

ALEXANDER CIMPRICH* [1], STEVEN B. YOUNG [1]

LCA has conventionally focused on products as an approach for systematically evaluating the "environmental footprint" of product systems. Ongoing methodological development is aimed at scaling up the LCA approach to consider multi-product systems – what we term "meta-LCA." Examples include organizational LCA (i.e., LCA of an organization's operations over a given timeframe), diet LCA (i.e., LCA of dietary choices), and "life LCA" (i.e., LCA of a human life). In our research, we significantly advance methods and data for meta-LCA by testing and demonstrating the use of our newly developed LCI database – the Consolidated Environmental Footprint Data System (CEFDS) – through a novel application of organizational LCA (as elaborated in our presentation entitled "Towards environmentally sustainable healthcare: A novel application of organizational LCA to an acute care hospital"). Using the United Nations Standard Products and Services Codes (UNSPSC) – a comprehensive and granular classification of over 19,000 categories of goods and services throughout the economy – CEFDS systematically consolidates information from existing LCI databases and LCA literature. In CEFDS, we generated process-level LCI data for 200+ products as needed for our hospital organizational LCA. CEFDS serves as an interface between "foreground data" (i.e., data on the quantities of products used by the hospital) and "background data" (i.e., data on the upstream production and downstream end-of-life treatment of the products). Through this interface, we envision a feedback loop in which existing CEFDS background data – like the data we generated in our hospital organizational LCA – are used in new meta-LCA studies, and new background data generated in those studies are added to the CEFDS database, where they are made available for additional future meta-LCAs. This feedback loop could accelerate the development of increasingly sophisticated and comprehensive environmental footprinting approaches to build an evidence base for SDG12, sustainable production and consumption.

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THE SHORT-TERM EFFECTS OF THE COVID-19 PANDEMIC ON HOUSEHOLD CONSUMPTION BEHAVIOR AND CARBON FOOTPRINTS IN JAPAN

YIDA JIANG* [2], TOMOHIKO IHARA [2]

The COVID-19 pandemic massively impacts global economy in 2020 and is found to have caused global carbon emissions to decrease relative to previous levels. While studies have mainly approached the pandemic's impacts on carbon emissions through weighing against previous levels, a comparison with the expected levels in 2020 should be more reasonable as lifestyles and emission patterns evolve temporally. On the other hand, few existing studies have examined the impacts from the consumers' perspective, though the pandemic's impacts are also reflected in household consumption patterns.

To bridge these research gaps, from the consumers' perspective, we evaluate the changes in the carbon footprints of households in Japan in 2020 by examining the differences between the observed levels and the expected levels of consumption-induced household carbon emissions. Forecasts of monthly Japanese household carbon emissions in 2020 are made using time series analysis on the monthly household carbon emissions in Japan from 2000 to 2019, which are derived from city-level monthly household expenditure time series data using environmentally extended input-output tables. Impacts of the COVID-19 pandemic on household carbon footprints and the implications for carbon-mitigation policymaking targeting household consumption behavior are then discussed.

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PM2.5 Emission-related Mortalities in India: A Supply Chain Analysis

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Air pollution and its health-related effects is a major concern globally, as each year, many people die from air pollution-related diseases. This study aims to determine the number of consumption-based PM2.5 emission-related deaths ascribable to India's power supply sector based on structural path analysis combined with health impact inventory database at sector level. We identified critical supply chain paths for direct (production) electricity use and indirect (consumption) use. We also considered both domestic and foreign final demand and its effect on PM2.5 emission-related deaths. Our results provided several conclusions. First, the effect of indirect electricity usage is approximately four times larger than that of direct usage. Second, a large percentage of pollution-related deaths can be attributed to India's domestic final demand usage; however, the final demand sectors' usage is inextricably linked to the intermediate sectors' electricity usage. Third, foreign final demand sectors from the Middle East, the United States, and China contribute indirectly toward PM2.5 emission-related deaths, specifically the rice export supply chain. The results concerning the rice industry leads us to conclude that the Indian government should implement urgent measures to curb electricity use in supply chains of rice to thereby reduce the number of PM2.5 emission-related deaths.

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Climate change impacts on rice production by prefecture in Japan

Caixia Li* [4], Ken'ichi Matsumoto [4]

This study provides an overview of the most important factors of climate change affecting rice production and the method to calculate the degree of the climate change impact on agricultural production by prefecture in Japan. The main purpose of this study is to analyze which meteorological factor affects the most on rice output, besides, whether the impact is positive or not. Nowadays, global warming out of climate change possibly causes the production of crops fluctuating heavily. There is a characteristic of lacked cultivated land and farmers in Japan. One way of protecting rice production is to reduce the possible rice loss from climate change.

Climate change is a change in the usual weather found in a place within a long time, mainly includes temperature, precipitation and duration of sunshine change from passing time. These factors are applied to evaluate the degree of climate change impacts on agricultural production. Cobb-Douglas production function is applied to describe the relationship between the production factors and rice production. To analyze the impact of climate change on rice production, we selected labor, area, machines worked for rice cultivation and harvest, fertilizer used in rice growing period, temperature, precipitation, duration of sunshine, wind speed, and technology level as independent variables This research applied panel data of Japan's 47 prefectures during the period 1978 – 2018. We expect the most important meteorological factor affecting rice production is temperature and precipitation affect rice production little because of the adequate rainfall and better drainage technology in Japan. In addition, we can to provide some practicable suggestions for agricultural sustainable development.

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Evaluation of transportation demand management package policy in local areas: A case study of Itoshima City, Fukuoka Prefecture

Hinako Suzuki* [4], Ken'ichi Matsumoto [4]

Traffic congestion has been occurring nationwide due to an increase in the number of private vehicles, and environmental problems, such as noise and air pollution, have become more serious. In terms of tourism trends in Japan, tourism in local areas where public transportation and roads are not sufficiently developed is becoming popular. As a result, the increase in the number of tourists using private vehicles is causing traffic congestion in various places. This may lead to the destruction of nature and decrease in the attractiveness of tourist attractions, which can reduce the number of tourists. However, it is difficult to operate transportation policies with only limited financial resources in local areas. In this study, we examine

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the possibility of alleviating traffic congestion caused by tourism in Itoshima City, Fukuoka Prefecture, by implementing a transportation policy that charges tourists as transportation demand management. This policy is a package model in which a "tourist fee" is collected from tourists who use private vehicles, and the revenue from the fee is used to activate public transportation. To achieve the purpose, we used the contingent valuation method with double-bounded dichotomous choice to ask the willingness-to-pay (WTP) of the tourist fee for the tourists of Itoshima City. We found that the median WTP for all respondents was JPY 414 and the mean was JPY 541. Further analysis showed that the WTP was higher for female, people with higher incomes, those living father from Itoshima City, and those who used rental cars. These results suggest that the revenue from the tourist fee would be sufficient to cover the costs of transportation improvement. Furthermore, the number of tourists using private vehicles is expected to decrease with the introduction of the policy.

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SOCIO-ECONOMIC MATERIAL STOCKS AND THEIR ROLE IN REDUCING FUTURE RESOURCE USE IN THE UNITED STATES OF AMERICA

JAN STREECK* [1] , QUIRIN DAMMERER [1] , DOMINIK WIEDENHOFER [1] , FRIDOLIN KRAUSMANN [1]

Socio-economic material stocks of infrastructure, buildings and machinery are the basis of production and consumption and an important determinant of current and future resource use. Globally, they consume more than half of all extracted materials (Krausmann et al. 2017), and due to their long lifetimes, shape future resource use and waste flows over long time spans (Pauliuk and Müller 2014). Therefore, an understanding of stock properties is important to explore future resource use patterns and possibilities to reduce pressure on primary material extraction.

One of the largest consumers of materials worldwide are the United States of America (USA) with a substantial influence on global trends (Gierlinger and Krausmann 2012; Ritchie and Roser 2017; UNEP 2019). To assess the role of stocks for long-term resource use in this affluent industrialized economy, we here present results of an inflow-driven stock-flow model (Wiedenhofer et al. 2019) for economy-wide material use and stock accumulation in the USA from 1870 to 2017. Based on the dynamics of stocks and resulting end-of-life (EoL) outflows from stocks, we investigate waste management and circularity considerations and present two prospective scenarios until 2100 to highlight the long-term effect of stock-flow dynamics.

In the scenarios, we explore the dynamics of future material requirements to build and maintain stocks under the assumption of saturating versus growing stock levels. Furthermore, we investigate prospective EoL outflows from stocks and the potential for material loop closing to reduce pressure on primary resource extraction. We conclude that, if improvements in recovery of EoL outflows can be achieved, these have the potential to cover large parts of overall material requirements for stock build-up and maintenance in the coming decades. This will, however, need major adjustments to EoL management and the establishment of domestic recycling industries within the USA.

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FOOD NITROGEN FOOTPRINT BASED ON NUTRIENT-EXTENDED INPUT – OUTPUT (NUTRIO) TABLE

AZUSA OITA* [2] , KIWAMU KATAGIRI [3] , TETSUYA EGUCHI [2] , RYOKO MORIOKA [2] , KENTARO HAYASHI [2] , KAZUYO MATSUBAE [3]

Food consumption is a major driver of nitrogen pollution caused by crop and livestock production, wastewater, and fossil fuel combustion for energy and transportation. The food nitrogen footprint is an indicator that quantifies the total reactive nitrogen (nitrogen species other than inert nitrogen gas) emissions throughout the lifecycle of food. Previous studies have mainly investigated nitrogen emissions sourced from nitrogen input to crop cultivation. We applied a novel approach, the nutrient-extended input – output (NutrIO) method, to the food nitrogen footprint of Japan, accounting for nitrogen input from chemical fertilisers and other ammonia-derived industrial products, organic fertilisers, crop nitrogen fixation, and wild fish catch. The nitrogen footprint of Japan in 2011 was estimated at 21.7 kg-N capita^{-1} year^{-1} as a sum of 16.7 kg-N capita^{-1} year^{-1} sourced from agriculture and fisheries and 5.12 kg-N capita^{-1} year^{-1} from chemical industries other than fertilisers. In addition, unintentional nitrogen input from fossil fuels accounted for 54.3×10^3 kg-N capita^{-1} year^{-1}, most of which was denitrified by the addition of ammonia and energy. Household food consumption and demand for restaurant services brought about 12.5 kg-N capita^{-1} year^{-1}. Reflecting the high demand for nitrogen input per production for wheat and barley cultivation, and increased physical amount per economic output by subsidies, the wheat and barley sector was the highest in nitrogen intensity as the sum of direct and indirect input per unit output (1.50 kg-N per million Japanese

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yen), which is much higher than 0.12 kg-N per million Japanese yen for the rice sector. By identifying sectors with high nitrogen intensity, the NutrIO method provides us with a better understanding of the industrial sector subsidies and other expenditures which could effectively contribute to reducing nitrogen pollution by encouraging agricultural and other production practices and techniques to increase nitrogen use efficiency.

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GLOBAL IRON ORE DEMAND BY CONSIDERING SERVICE DEMAND AND QUALITY OF SCRAP

REINA KAWASE* [1]

To keep the rise in average global temperatures to 1.5-2.0 ° C above pre-industrial level, GHG emissions should be achieved to "Net Zero" in second half of 21st century. Steel sector is one of the energy intensive sector and especially the emission factor of blast-basic oxygen furnace process which uses iron ore is 3-4 times that of electric arc furnace whose main resource is scrap.

This study estimates global iron ore demand as a virgin resource up to 2050 by estimating steel demand and scrap generation. Steel demand by goods is divided into 37 categories, and its driving forces are services which are supplied by goods stocks containing steel. The countries are aggregated into 35 regions. In future scenario, the followings are assumed; countermeasures(CMs) for steel demand reduction, scrap recycling rate(identifying potential scrap generation, real scrap generation, and recycled scrap), technology progress of electric arc furnace(making a high quality steel by scrap), demand-supply balance of scrap by considering scrap quality.

Crude steel demand in 2050 is 2.4 billion ton (TRD: trend scenario: CMs are introduced at the current level) and 2.0 billion ton (TGT: target scenario: CMs are introduced at the maximum level). Assuming that recycling rate of old scrap (= recycled old scrap/old scrap generation) is 90%, recycled scrap (including home, process and casting scrap) is 1.6 billion ton(TRD) and 1.4 billion ton(TGT), which is not more than 70 % of crude steel demand. This gap causes the demand of 1.5 − 2.0 billion tons of iron ore continuously towards 2050 from now on.

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RECOMMENDATIONS TO CALCULATE AND COMMUNICATE AVOIDED GHG EMISSIONS

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In order to minimize their contribution to climate change, companies must innovate to decrease the greenhouse gas (GHG) emissions of their products and processes throughout their life cycles. To promote their efforts, companies would like to communicate the amount of GHG emissions that is avoided by their solutions. However, the calculation and communication of these numbers is controversial, as a questionnaire conducted by the Institute of LCA Japan (2018)[4]. demonstrated. The French association SCORE LCA, backed by multiple companies, initiated a project with the purpose to identify how the avoided emissions generated by a value-chain actor can be calculated, communicated, and interpreted. Within the project, a state of the art of available guidance documents to evaluate avoided emissions was done. Two methods were selected and applied to case studies: the guidance of the French "Entreprises pour l' Environnement" for an attributional LCA (ALCA), and the consequential LCA (CLCA) methodology. Key choices that influence the calculation of avoided emissions are the application of ALCA or CLCA, the identification of the reference solution, and the modeling of co-production and recycling. Furthermore, the choice between ALCA and CLCA influences the possibility to calculate the contribution of a single value-chain actor and to aggregate the results of different products. In line with requirements of ISO 14044 and ISO 14020, recommendations were done for the communication of avoided emissions using distinctive graphs and suggested vocabulary, to avoid any misinterpretation of the results.

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THE IMPACT OF VARIABLE RENEWABLE ENERGY PENETRATION ON WHOLESALE ELECTRICITY PRICE IN JAPAN

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The Merit-order effect (MOE), which renewable energy sources can decrease wholesale electricity prices, has an important role for achieving low carbon society. After the liberalization of electricity market, traded volumes on Japan Electric Power Exchange (JEPX) Day-ahead spot market are drastically increased from 2016 to 2019, yet price spikes still often happen. Price spikes are a huge risk for electricity retailers, hence the reduction of them are needed. This study aims to investigate how price distribution is influenced by penetration of variable renewable energies (solar PV and Wind). Quantile regression analysis is applied to capture the heterogeneity effect of renewable energy penetration into wholesale electricity price in each price range. Data coverage is from 1st April 2016 to 31st March 2020 and hourly data is used. JEPX spot price is set as a dependent variable and independent variables are lag spot price, spot price volatility, PV production, wind production, and control variables selected based on previous literatures. Furthermore, comparative analysis for subdivided regional area market in Japan is built to clarify price effects of each price range. The results show that the MOE of PV decreases while the one of wind increases from year 2016. One interpretation of this result is that only solar PV were penetrated significantly by Feed-in-Tariff system. In addition, the key finding from the results of regional analysis is that MOE of PV is getting higher as price decreases in all areas whereas MOE of wind is the highest at the high price range in Eastern Japan. In conclusion, taking account of area characteristics and types of renewable energy is important to stabilize spot price because MOE varies by areas and price quantiles.

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THIN SILICON FILMS REDUCE LIFE CYCLE GHG EMISSIONS OF CRYSTALLINE SILICON SOLAR CELLS

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Silicon (Si) wafer production processes (smelting, purification, sawing,

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etc.) contribute up to 70% of the total energy consumption of conventional crystalline Si solar cells. Reducing the required Si amount (200 μm thick) could therefore reduce the environmental impact. Extensive efforts have been made to reduce the wafer thickness and high purity Si consumption for decades, and it is very hard to reduce the thickness further. To overcome the bottleneck, alternative Si film (20 μm thick) fabrications using rapid vapor deposition (RVD) were investigated. The RVD enables fast direct growth of Si film on substrates (10 μm/min). The challenge is to detach and transfer the Si film from substrates efficiently. Here, we performed an LCA to compare the life cycle GHG emissions of two alternatives: layer transfer with porous Si (LTPS), and vapor deposition of liquid and in-situ melt crystallization (VDL-MC). The LTPS utilizes porous silicon as a sacrificial layer to detach the Si film, which is a readily applied technology from the semiconductor industry. The VDL-MC is an emerging technology that utilizes amorphous carbon as the sacrificial layer (avoid the use of energy-intensive Si). We examined the impact of main configurations on both technologies based on our lab experiment data as well as scenarios for prospective industrialize production. These include the size of cell (small or standard), process (batch or continuous), reuse of substrate (no or 30 times), efficiency of Si deposition, and other parameters. We found that the GHG emissions of Si film fabrication with LTPS ranged from 8801 kg (lab-scale) to 24 kg CO_2e/m^2 (industry-scale). And with VDL-MC ranged from 1650 (lab-scale) to 17 kg CO_2e/m^2 (industrial-scale). In short, the LCA showed that thin silicon films are promising to reduce the GHG emissions of crystalline silicon solar cells (180 kg CO_2e/m^2-silicon wafer).

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Material flows of two-wheelers in Cambodia imported from Asian countries as used products

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In recent decades, road transportation means have significantly been required in developing countries. The incremental demand has resulted in an increase in the import and export of used products between developed and developing countries. Reuse contributes to the extension of the overall lifespan of transportation means and to the improvement of affordability in developing countries. As transportation means have already been used for some years in other countries, the practical lifespan of means newly reused in the developing country gets shorter than the duration of the new ones. Consequently, it is expected that an increasing number of end-of-life vehicles (ELVs) is generated in developing countries more quickly. Notably, the proper treatment and recycling system, particularly in developing countries, has yet to be fully developed, causing vital environmental pollution and the dissipation of resources. Thus, estimating the number of obsolete two-wheelers reused in such countries is of significant importance to establish a well-sophisticated recycling-based society.

This study focuses on two-wheelers in Cambodia as a case study. Cambodia has a great share of used two-wheelers imported from Asian countries. The objective of this study is to predict the number of obsolete two-wheelers considering second and third users in Cambodia. The estimation was performed by using the population balance model, logistic function, and Weibull distribution. Through the analyses, it was found that the number of discarded two-wheelers in Cambodia in 2030 (132,000 units) will increase by 1.53 times compared to that in 2020 (86,000 units). The strategies of disposal mitigation and resource recycling treatment for discarded two-wheelers generated in Cambodia were further discussed on the basis of several scenarios.

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Consideration and Application of Evaluation Indicators of Regional Circular and Ecological Sphere (CES) for the Utilization of Woody Biomass

Yajuan LI* [2] , Toru Matsumoto [2] , Atsushi Fujiyama [2]

The “Regional Circular and Ecological Sphere” utilize the SDGs’ concept of integrated solution of multiple issues, complements and supports resources according to the characteristics of the region while maximizing the use of local resources.

Purpose: estimate the availability of woody biomass in Kitakyushu City and to conduct a comprehensive evaluation from three aspects: environment, economy and society.

Forest Resource Survey: we estimated the amount of forest resources using the Kitakyushu Forest Register and GIS-based forest interpretation data. As for the estimation of the amount of thinned timber that can be harvested,

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firstly, the amount of thinned timber among unused timber was estimated using the forest data of Kitakyushu City and the system for predicting the production of Japanese cedar and cypress tree plantation in Fukuoka Prefecture. Next, the economic value of woody biomass was examined mainly from two perspectives: heat utilization and power generation. Finally, we estimated direct job creation.

Calculation results: 12,000 tons of unused wood chips can be supplied per year for 36 years from 2016 to 2051, and during this period, the total amount of new carbon storage by tree growth is about 68,000 tons, the amount of CO_2 absorption was estimated to be about 249,000 t-CO_2. From the economic point of view, the purchase of wood chips of 146 million yen due to the local circulation of wood fuel is expected to save about 50 million yen in intermediate input. The average purchase price of imported wood chips is 20,000 yen/ton, and it is estimated that if 12,000 tons of unused wood chips can be supplied in the city per year, about 98.4 million yen can be saved annually.

Social perspective: biomass power generation of unused thinned timber using materials worth about 146 million yen is expected to create about 20 jobs.

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Trend Analysis of SDG Disclosure by Major Japanese Companies

Takafumi Ikuta* [1]

In terms of ESG management, it becomes important for companies to explain their contribution to SDGs. In Japan, the GPIF, which started ESG investments in 2017, clearly stated that the ESG can go a long way in accomplishing the SDGs. Globally, the IIRC (2017) and the GRI (2017, 2018) have proposed non-financial disclosure guidelines that reflect the SDGs.

While major listed companies start to disclose their information on SDGs, they do not seem to use the information strategically to increase their corporate value. Rosati & Faria (2019) noted that SDG reporting is still underinvestigated in the corporate sustainability literature, and it is not yet clear what the factors are that might influence it.

This study investigates the status of SDG disclosure in more than 200 Japanese companies that have been ranked in the Forbes Global 2000 each year since 2016, based on published information. In particular, this study applies statistical methods to clarify how the status of SDG disclosure differs depending on industry characteristics and company rankings.

The ratio of companies disclosing information on SDGs increased from 33% at the end of 2016 to 94% at the end of June 2020. The manufacturing industry was the first to take the initiative, but the gap with the non-manufacturing industry has almost disappeared. The content of efforts for the SDGs has also become concrete. More than 70% of the companies not only mentioned SDGs in their top messages, but also reported on the overall relationship between companies that reflect SDGs in their ESG policies and their businesses. Also, in the June 2020 survey, 20 companies showed relationship between SDGs and their businesses at the 169-target level, not the 17-goal level. Impact evaluation of the SDG contribution with the corporate activity still needs to improve.

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Life cycle thinking of oil palm-derived biomass utilization: Application of Malaysian palm kernel shell (PKS) for biomass-power generation in Japan

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Imported biomass plays an important role in power generation in Japan. Palm kernel shell (PKS), a promising biomass that provide high calorific values and has the advantage to co-combust with coal is imported into Japan from Indonesia and Malaysia. PKS is a valuable by-product generated during crude palm oil (CPO) extraction from fresh fruit bunches in palm oil mills (POM). In year 2018, Japan imported 1.27 Mt of PKS, which contributed to 68% of total PKS exports from Indonesia and Malaysia [Strauss and Kusano, 2019]. To analyze sustainability of utilizing such biomass for power generation in Japan, life cycle of PKS should be studied. This study covers cradle to grave life cycle of PKS from land use change (LUC) for oil palm cultivation in Malaysia to utilizing of PKS for biomass-power generation in Japan. Greenhouse gas (GHG) emission, eutrophication and water footprint (WF) analyses were performed in this work. The objective is to improve environmental awareness on PKS life cycle for enhancing sustainability of Japanese power

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generation industry. Evaluations were conducted with consideration of four types of LUCs, four boiler fuel applications in POM, two palm oil mill effluent (POME) treatment systems in Malaysia and, two PKS transportation distance schemes and two biomass-power generation scales in Japan. Information on palm industry in Malaysia, PKS exporting mechanism and biomass-power generation in Japan were gathered. Supplementary data were gathered from published databases and articles. Based on result, LUC displayed heavy GHG emissions while, a significant influence by POME treatment was observed in all GHG emission, eutrophication and WF outcomes. This study suggests PKS as a sustainable biomass-power resource for Japan, which also promotes on balancing the biomass resource share between countries.

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THE ENERGY-X-NEXUS AND LIFECYCLE APPROACHES

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The Energy-X-Nexus is a broad approach to the analysis of energy systems and their influence on and from other societal support systems. The X in this case could be a resource system such as water, food, land, or an impact such as environment, emissions, or a socio-economic systems such as growth, trade, development. In the past, the "X" component has been dominated by water and food. This paper will present a comprehensive review of nexus approaches from the past, as well as potential directions for the future. Moreover, it will look at the various overlaps with, and contributions from, lifecycle and material flow approaches.

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CONSUMER BEHAVIOR ON SUSTAINABLE FOOD CHOICE AND THE EFFECT OF DETAILED INFORMATION PROVISION

NATSUMI SAKUMA* [4] , KIYO KURISU [4] , KENSUKE FUKUSHI [5]

Consumers' food consumption is a key issue to contribute to several SDGs goals, such as climate change, responsible consumption and production, and health to name a few. Especially the consumption of animal-based food has high impact on greenhouse gas emission and other environmental outputs, non-communicable diseases (NCDs), animal welfare or public health risks of antibiotic resistance. The product selection or reduction of animal-based food involves drastic changes such as dietary transition, however the current methods to promote behavioral change remain limited. This study will analyze the effect of information provision on consumer food choosing behavior. Information of sustainable food consumption is not widely acknowledged by the public yet, hence the information provision strategies and effects are currently uninvestigated. Moreover, academic studies focusing on sustainable food diet and information provision is limited. This study is unique in three ways;

(1) analyzed the effect of variety of sustainability issues regarding food choice, consisting of environmental issues, health issues, animal welfare, antibiotic use and seafood production management

(2) conducted 15 minutes detailed information provision on scientific content about food diet and sustainability, using findings from existing LCA and epidemiologic studies.

(3) conducted an in-depth qualitative analysis of the influence of information on consumers' behavior

The analysis was done through online group interviews together with a presentation style information provision presented by the author. The group interview participants were recruited to form 6 groups of 3-4 participants. The group is consisted of participants from the same food orientation and different socio-demographic characters. The interview investigated mainly three topics, general food choosing process, attitudes towards sustainable and healthy food diets, and responses to the information provision content.

This study can be applied in designing policies and programmes promoting consumer awareness or behavior change towards sustainable food diets.

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NITROGEN AND PHOSPHORUS LOSSES DURING CONVENTIONAL AND VERTICAL FARMING IN MIYAGI PREFECTURE, JAPAN

JIARUI LIU* [1] , AZUSA OITA [2] , KAZUYO MATSUBAE [1]

Nutrient management is a key requirement of agriculture to minimise negative effects on aquatic ecosystems, such as eutrophication. Vertical farming (VF) is a potential solution for improved nutrient management and climate change adaptation. This study identified VF development in Miyagi, Japan, which was damaged by the Great East Japan earthquake in 2011 and calculated nutrient losses due to conventional farming. We conducted a quantitative comparison with conventional farming and VF on nitrogen (N) and phosphorus (P) footprints of high import rate vegetables. Subsequently, we confirmed how N and P footprints are reduced based on consumption scenarios in Miyagi with different import rates. The effect of VF in post-disaster agriculture was investigated in this study to improve the adaptability of crop production.

The results show that the total footprints of the current situation are 1151 tN year^{-1} and 199 tP year^{-1} in Miyagi, and the highest footprints in conventional agriculture were Welsh onion with 272 tN year^{-1} and 58 tP year^{-1}, whereas the lowest was celery with 13 tN year^{-1} and 2 tP year^{-1}. Nutrient footprints decreased with increasing food self-sufficiency. Total footprints in Miyagi can maximally reduce approximately 428 tN year-1 (37.2%) and 71 tP year^{-1} (35.5%) with VF. The highest reduction rate was exhibited by pumpkin, whereas the lowest was exhibited by Welsh onion in each scenario. Reduction through possible VF grown vegetables is the highest, whereas the reduction rate of potential VF grown vegetables ranged from 25% to 50%, the highest in each scenario. The potential VF grown group had a better reduction effect, while reducing nutrient footprints of possible VF grown group is necessary. For adaptation to sustainable agriculture, VF is an anticipated innovative agricultural development to be implemented in other countries affected by frequent natural disasters such as Indonesia, Thailand, and Korea.

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INVENTORY GENERATION FOR LCA OF CELLULOSE NANOFIBER-REINFORCED PLASTICS THROUGH EXPERIMENTAL MEASUREMENT AND PROCESS SIMULATION

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Cellulose nanofiber (CNF) is one of the emerging technologies that can be produced from plant-derived resources and have advantages of mechanical properties in lightness and strength. For the implementation of such emerging technologies into society, its environmental performance should be examined with the options in process systems. In this study, process inventories for LCA of cellulose nanofiber-reinforced plastic were generated through experimental measurement and process simulation.

We focused on a production method which can disintegrate the cellulose fibers by kneading the pulp with polymers, while various techniques for CNF production are currently under development. Paper pulp was selected as the raw material of CNF because of its high availability from existing market. The acetylation of paper pulp is effective for improving the chemical and mechanical properties when CNF is used as the filler of composite with polymers, e.g. polypropylene, polyethylene or polyamide. Acetic anhydride is generally used as the reactant for the acetylation with the generation of acetic acid as byproducts and significant amount of unreacted acetic anhydride flows out from reactor. We investigated the effect of separation and recovery of excess acetic anhydride and the byproduct acetic acid, which had been treated as waste liquid in laboratory scale. Multiple process alternatives for recycling chemicals were compared. The inventories of the mechanical kneading process were acquired through measurement of power consumption in demonstration plant. The scale-up effects were discussed and investigated with CNF experts.

We generated process inventories through process simulation for multiple design alternatives for acetylation. Separation and recovery of excess acetic anhydride and the byproduct acetic acid was revealed to be mandatory. Additionally, Kneading process inventory was generated through measurement of power consumption in multiple production scale. We found that GHG from kneading process can be reduced by the future process improvement and scaling up.

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Global Scenarios of Resource and Emissions Savings from Systemic Material Efficiency in Buildings and Cars

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Reducing greenhouse gas (GHG) emissions from material production requires novel production processes or CO_2 capture and storage. It is an expensive and slow transition. Recent policies call therefore for reducing material use through resource efficiency and the circular economy. Comprehensive scientific assessments of these strategies are unavailable, also because integrated-assessment-model-based GHG mitigation scenarios lack the necessary product- and material-specific detail. Here we present a high-resolution approach for tracking material flows and energy use of products throughout their life cycles, focusing on passenger vehicles and residential buildings. Service demand scenarios are combined with engineering-based product archetypes and material cycle models. We estimate future changes in material flows and operational energy use due to efficiency measures in the supply of materials, such as increased yields and scrap used, the use of materials, such as light-weight designs and material substitution, and the use of products, such as increased service efficiency and extended service life. Together, these material efficiency strategies can reduce cumulative global GHG emissions until 2060 by 16-39 Gt CO_2e (passenger vehicles) and 28-72 Gt CO_2e (residential buildings), depending on climate policy assumptions. By 2050, aggregate demand for materials from virgin resources can be greatly reduced in these two sectors: by 60-70% for cement and copper, and 80-95% for steel and plastics. The use of wood and more intensive use are promising strategies in residential buildings, while ride sharing and shared fleets of trip-appropriate cars allow for a reduction of materials use and operational emissions in passenger transport.

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Food Nitrogen and Phosphorus Footprints for Indonesia

Farah Wirasenjaya* [6] , Azusa Oita [7] , Kazuyo Matsubae [6]

Nitrogen (N) and phosphorus (P) consumption is common in food production because these nutrients are vital as fertilisers for agricultural products. However, N and P emissions from food production can cause several problems for the environment and human health. As an agrarian country with a large population, Indonesia has a high demand for food and nutrients, which contributes significantly to N and P issues. The N and P footprints are consumption-based quantitative indicators used to measure N and P loss to the environment during food production along food supply chains and food consumption. Using a bottom-up approach, we assessed the Indonesian N and P footprints as total emissions of food production and consumption. In 2013, the estimated Indonesian N and P footprints were 13.7 kg-N capita^{-1} year^{-1}and 2.1 kg-P capita^{-1} year^{-1}, respectively. Rice, the primary food source for Indonesian people which encompass approximately 40% of all food consumed in weight, contributes the highest portion of the N and P footprints for food, which account for 32% and 33%, respectively. Oil crops also contributed a significant percentage of the footprint, reaching 22% and 28% for the N and P footprints, respectively. The total food N and P footprints in Indonesia have generally been increasing mainly due to the changes in diet and low N and P use efficiency. Thus, we suggest planning further measures, such as developing and popularising methods for more efficient farming and implementing policies for improved management of N and P, to prevent more damage from N and P loss in the environment.

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Digital Transformation in Supply Chains: Chance and Requirement for Improved Life-Cycle Sustainability

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Digital Transformation (DT) is reaching into science, economy and society. It is a chance to analyze, improve, test virtually but holistically, before physical changes are decided that proof inadequate. Scientific, societal and economic transformations work best, if science is in alignment, societies have a common understanding of necessities and industry is applying standards. DT – avoiding just more non-conclusive information further delaying important decision/changes – needs science, policy and industry to understand its different responsibilities. DT is - specifically in LCA/sustainability - a challenge, because many different information sources and data points are needed, however in a consistent and manageable way to be able to fit into consistent overall and digitalized (life-cycle-)models to produce consistent results. DT can be game-changing towards life-cycle-sustainability allowing better collaboration, automatization, justification and communication of life-cycle related facts. While "core models" and the "back-ends" of the LC- approaches already are in Digital Transformation (e.g. digitalized import/export interfaces, data test routines, connection of LCA-tools to enterprise software, automated system set-ups, parameter/system variation options, interlinked LCA-reporting based on underlaid software models), the "front-end" or upstream systems are only beginning Digital Transformation: Information collection upstream in the supply-chain is done via pdf or e-mail lacking any standard in detail and (machine-readable) format. The presentation aims not to claim completeness concerning all the aspects needed for a successful Digital Transformation in life-cycle sustainability approaches, but will present concrete necessary aspects that are mandatory to address from our experience: like mindset of different stakeholders, collection and connection of consistent proxy data and verified data in coexistence, toolboxes of LCA with Risk Assessment and Artificial Intelligence, application in R+D and production and regulation as well as in appropriate prospective technology and supply-chain system analysis avoiding "predictions and doctrine based crystal balls".

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Analysis of cropland and water scarcity footprints for sustainable food supply chains

Nao Shimizu* [1], Jun Nakatani [1], Kiyo Kurisu [1], Tsuyoshi Fujita [1], Yuichi Moriguchi [1]

Food products have dominant impacts on cropland and water footprints. As cropland and water are essential for crop production but geographically unevenly distributed, it is important to consider land-water nexus and regional difference in land and water scarcity. However, there exist a limited number of studies which analyze the nexus of cropland and water footprints associated with regional food consumption considering land and water scarcity. Also, it has been discussed that sustainable regional food consumption requires limiting dependency on crop supply from specific areas and associated use of scarce resources in specific areas. But there are research gaps on quantitative discussion on (1) the structure of crop supply and associated footprints, and (2) the relationship between crop supply and food demand. Against this backdrop, this study aims to estimate cropland and water footprints considering regional difference in land and water scarcity, and provide implications for reduction in footprints based on the analysis which is focuses on the structure of food supply chains, taking Japan as a case study. First, we estimated cropland and water scarcity footprints associated with crop supply to Japan in 2004-2006 and 2014-2016. As land and water scarcity, NPP (net primary production) of potential vegetation, and the characterization factors based on the AWARE (available water remaining) model were considered respectively. Then, we evaluated the degree of concentration of crop supply and associated cropland and water scarcity footprints based on HHI (Herfindahl-Hirschman Index). Also, we analyzed the domestic flows from crop supply to food demand using the model based on 2015 Input-Output tables for Japan. Based on the above-mentioned frameworks, we analyzed the factors behind the change in footprints from 2004-2006 to 2014-2016, and then discussed implications for reduction in footprints.

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Environmental impacts of servicizing : A case study of Life Cycle Assessment in Cloud services with a low carbon and resource circulation system

Tomoko Konishi-Nagano* [2], Takuya Nagamiya [2], Yasunobu Suzuki [2], Masayuki Hamakawa [2], Mitsuhiro Senda [3]

Recently, the concepts of sharing without possessing goods and circular economy have come widespread globally. Companies are also increasingly using the cloud to share servers. On the other hand, it has discussed whether

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there are trade-offs between CO_2 emissions and the contribution to resource efficiency. Therefore, we investigated to estimate environmental effects of cloud services as one of the Servicizing. The function unit is a data processing volume. Fujitsu has achieved highly efficient resource recovery for ICT equipment such as servers and storage at its data centers, through the reuse of maintenance parts (Use of refurbished parts) and post-use recycling. In addition, the optimization and energy-saving operation of air conditioning equipment in the data center. In this case study, the difference between the environmental impacts of the two scenarios was used to calculate. The baseline scenario is an on-premise scenario in which ICT equipment is purchased by businesses and used in their own server rooms for a certain period of time, after which it is disposed of. In the cloud service implementation scenario, ICT equipment is used in Fujitsu's data centers to provide data processing services to users. Certain equipment updates are performed in the data center. Still usable parts may be refurbished and used as maintenance parts. The results of the estimation show that the effect of the low carbon point of views the reduction of the total CO_2 emissions including production and usage stages, and the reduction effect of avoidance of new production. The effects of resource recycling point of views were estimated as reductions in natural resource consumption and waste, and slightly improvements in resource recovery efficiency. Thus, the development of sevicizing based on a low-carbon and resource circulation system will be pursued to provide much greener services.

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Environmental Impact of Telework: The survey of telework performance during the voluntary restraint period

Tomoko Konishi-Nagano* [1], Yasunobu Suzuki [1], Kazuaki Inukai [1], Masayuki Hamakawa [1]

The Fujitsu Group has established the "FUJITSU Climate and Energy Vision," a medium- to long-term environmental vision with the goal of bringing the Fujitsu Group's CO_2 emissions to zero by 2050, as well as contributing to the achievement of a decarbonized society and the adaptation to climate change. Under the circumstance, Fujitsu has started teleworking to prevent infection of COVID-19, and has been encouraging its 80,000 employees to telework in Japan. However, it can be concerned that the environmental impact from the office will decrease, but that of the home will increase. For this reason, we conducted the first questionnaire survey on household electricity consumption and so on. Target employees are at Sustainability Unit of Fujitsu, and term of survey is from March to August 2019 and March to August 2020. (29 valid respondents and 196 monthly sample data) The environmental impact at home due to telework was compared with the previous year. As a result, the results were conducted quantify the increase at home, the decrease at the office and the increase in the data center due to telework. In addition, the results showed that the environmental impacts differed between family members with and without those living at home during the daytime. In the future, the scope of the survey will be expanded continually. And it will lead to the promotion of ways of working that contribute to low carbon society, such as greening the amount of energy that has increased due to telework and the selection of ways of working based on family members and attributes. Thus we promote work-life shift with greener teleworking through these researches and employees' actions that how to contribute to both reduce CO_2 emissions and a new diverse work-life balance as a new normal.

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Development of electrodialysis for Cl recovery from PVC wastes supported by simulation and ex ante LCA

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To realize sustainable development goals and circular economy, it is urgent to develop advanced recycling technologies and establish a material circulation system. However, the emerging technologies will also bring additional life-cycle environmental impacts. To weigh the balance of potential benefits and the impacts, it is essential to carry out life cycle assessment (LCA) during the lab-scale development stage, which is the so-called ex-ante LCA. This study focused on the development of a Cl recovery process for promoting poly (vinyl chloride) (PVC) waste recycling. Globally, PVC is the third-largest produced plastic resin, of which the synthesis is major consumption of Cl from chlor-alkali industry. During the waste management of PVC wastes, undesired Cl-compound is an intractable issue in thermal treatments. Cl recovery process was developed to high-efficiently recover Cl as industrial salt and valorize hydrocarbon. It consists of the dechlorination (de-Cl) of PVC in NaOH/ethylene glycol (EG) with ball milling at 190 ℃ and the electrodialysis (ED) for simultaneous recycling of EG and NaCl. Previously, the development target of Cl recovery process was deduced based on the potential life-cycle energy consumption and greenhouse gas emissions versus the design of the de-Cl process. Here, the design of the ED process was investigated to understand the extent of consumption and emissions by LCA. Lab-scale ED experiments were performed to obtain the data for modeling the process under various operation conditions. Then, a commercial-scale ED process was simulated to provide the process inventory. Meanwhile, the additional product purification was considered by conceptual chemical process simulation to assure the consistency of material and energy balances. Finally, the environmental impacts were evaluated by Eco-indicator 99 to identify the optimal design and potential hotspots. We suggested the membranes and voltage need further investigation to reduce the major impacts from excess EG consumption by solvent penetration.

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INFLUENTIAL FACTORS ON HOUSEHOLD FOOD WASTE PREVENTION BEHAVIORS IN CHINA

YINGLEI WU* [1] , KIYO KURISU [1] , KENSUKE FUKUSHI [1]

Food waste has received growing concerns globally in recent years. Among all the countries, China will become a potential hot-spot of food waste in the near future. However, few studies have been conducted about household food waste in China so far. Additionally, most of the proposed models to evaluate the influential factors on the food-disposal behavior in previous researches were too simple, which were difficult to be connected with the prevention countermeasures. In this research, we built a comprehensive framework to explore the effects of influencing factors on the household food waste behaviors, by extending the basic TPB model with several psychological factors and the food waste related routines. Based on the models, we designed the corresponding questionnaires and conducted the online surveys in Beijing, Shanghai, and Wuhan, in China, and also conducted the surveys in Tokyo and Bangkok for comparison purpose. 600 respondents were gained in each city, and 3,000 samples in total. The results showed that Chinese people significantly wasted food more often than Tokyo and Bangkok people when eating cooked dishes. The trend was the same with the eating out situations; the share of Chinese people who always finish all the food when eating out was considerably smaller than that of Tokyo and Bangkok people. In addition, we extracted six personalities based on the factor analysis and the results showed that people with higher agreement levels on utilitarian value, hedonic value, individualist, and fatalist tended to have stronger intentions to save food at cooking stage and when eating out. Lastly, the model analysis results showed that the attitude was the strongest factor to explain the intention to save food waste, and the intention was connected to the food-disposal behavior in all cities except for Bangkok, where a big gap was observed between the intention and the behavior.

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SOCIAL LIFE CYCLE ASSESSMENT OF FOUR MAJOR OIL CROPS FOR SUSTAINABLE PRODUCTION

HENG SHUE TEAH* [2] , HENG YI TEAH [3] , AYA SUZUKI [2]

Palm oil is one of the world's most widely used vegetable oil but is subject to distressing controversies on the environment and social fronts. The actual impact of palm oil, however, must be understood by comparing it with its substitutes, i.e., soybean oil, rapeseed oil, and sunflower oil. This comparison is seldomly attempted by researchers due to its exhaustively wide scope. To this end, life cycle assessment (LCA) method is an useful aid due to its utilization of macroscopic databases. Few LCA studies have compared the environmental impacts of vegetable oil alternatives while none have compared the social impacts. Our study aims to fill this void. We employed a Social LCA (SLCA) methodology and analyzed the data obtained from Social Hotspots Database (SHDB). The SHDB provides social impact indicators on the crop producing countries. We selected relevant indicators and grouped them into six impact categories, i.e., human rights, working condition, health and safety, water and sanitation, governance, and poverty. We then aggregate the country-specific results to see the oil crop-specific results. Our analytical approach is twofold. First, we employed a product-system approach that augments social impact of each country-specific sector by the activity variable 'work hours'. We find that the results are highly correlated with this measure. In the subsequent analysis we assumed away the effect of 'work hours'. We call this product-country approach as it does not consider impacts of the sourced inputs. Overall, we find that palm oil is the worst performing crops on both approaches, but eliminating work hours in the analysis significantly reduced the gaps with the other substitutes. Also notable is the impacts of the crops are unevenly distributed among each producing country. Discussions on the implications of 'work hours' and recommendations to improve the social performance of the vegetable oil industry conclude the paper.

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PROSPECTIVE LCA FOR DEVELOPMENT AND MANUFACTURING OF PHARMACEUTICALS - ENVIRONMENTAL LOAD REDUCTION EFFECT BY TRANSGENIC SILKWORMS -

HIROYUKI NAKAMURA* [1], HIDEKI SEZUTSU [2] , NORIHIRO ITSUBO [1]

In this study, although the environmental load per product unit is large in the experimental scale, Prospective LCA, which is expected to reduce the environmental load in the production scale, was applied to the manufacture of pharmaceuticals.

In order to resolve the problem of heavy environmental impact by using selected raw materials and special equipment for manufacturing pharmaceuticals, GHG emissions of climate change on the production of antibody drug substances for pharmaceutical materials using transgenic silkworms with high protein productivity is targeted.

The evaluation boundary was raw materials, electric power and wastes.

The calculation was processed using primary data from Immuno-Biological Laboratories Co., Ltd., the inventory database is IDEA2 (Inventory Database for Lifecycle Analysis) and 2011 version WIO (Waste Input-Output table), and the impact assessment method is LIME2 (Life-cycle Impact Assessment Method based on Endpoint modeling).

From this calculation, the electric power consumption of the clean room to prevent the contamination of viruses and bacteria has a large influence in the extraction / purification process.

Subsequently Prospective LCA was carried out after scenario planning of future technology and energy system from various technical information in addition to the conventional LCA data. In contrast to the current experimental scale, at the pilot scale, the floor area of the existing clean room was effectively used, and the manufacturing capacity per unit time has been improved by the system of multiple equipment. In addition, at the production scale, a new chromatography process, the latest continuous processing equipment and an energy-saving clean room were introduced.

As a result, it was confirmed that GHG emissions, including raw materials, transportation, and disposal, could be reduced to about 1/5 in the pilot scale and about 1/10 in the production scale compared to the experimental scale in the extraction / purification process.

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DEVELOPMENT OF ONLINE NEEDS-BASED WORKSHOP SUPPORT SYSTEM

SEISUKE HORIO* [3], HIDENORI MURATA [3] , HIDEKI KOBAYASHI [3]

Living-sphere approach, which focuses on sustainable consumption and production, has been proposed. This approach is intended to encompass the complete relationship between region-specific basic needs and durable products. As the region-specific basic needs, this approach uses the framework of fundamental human needs proposed by Chilean economist Max-Neef. This framework consists of fundamental human needs and satisfiers. Max-Neef argued the fundamental human needs are universal, but the satisfiers fulfilling these fundamental human needs depend on region, culture, and period. The satisfiers have been extracted by needs-based participatory workshops, but in this situation of COVID-19, the workshop can hardly be held as participatory.

In this research, we have developed an online needs-based workshop method. Based on use cases obtained by analyzing past needs-based workshops, this method combines some digital applications such as online meeting software, online whiteboard software and some self-made software to encourage a smooth discussion among participants. We applied this method to some online workshops in Japan and compared the result of the online workshops and the participatory workshops held until last year to analyze and validate this online needs-based workshop method.

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FATE OF SELECTED PRIMARY MICROPLASTICS IN JAPANESE ENVIRONMENTAL COMPARTMENTS

AMILA ABEYNAYAKA* [1], SELIM KARKOUR [1], NORIHIRO ITSUBO [1]

Integration of potnetial impact of plastic litter into the life cycle assessment (LCA) process is getting the attention of the LCA community. This intigration requires substantial work in both lifecycle inventory (LCI) and life cycle impact assessment (LCIA). Primary microplastics (PMP) is a result of the linear economy. Fate analysis of PMP is significant in environmental management approaches such as LCA and circular economy (CE). Previous studies have estimated the environmental emissions of

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PMP. However, the findings were based on a very low number of real datasets, which were extrapolated to general projections on a global scale. The present study focused on the distribution of several types of PMP [microbeads (MB), road-markings (RM), textile-microfiber (TM) and tire-wear (TW)] in several environmental compartments (land, water, and air) of Japan. We developed fate models for each type of PMP to distribute it among each compartment. To obtain high-resolution data, the spatial distribution of consumption patterns, point [i.e. wastewater treatment plants (WWTP)], and non-point sources were considered. A prefectural level information comparison was also conducted. Eliminated MB, TW, AG and RM fractions were 92.7, 17.9, 20.3 and 18.7% respectively. Fractions of MB, AG, and TW ending inland were 1.0, 11.2 and 17.2% respectively. MB, TW, and RM reaching the freshwater compartment were 4.2, 74.3, and 75.2% respectively. The higher fractional elimination of TM and MB were due to recapture at the WWTP as sludge followed by incineration. Certain types of PMP have a higher potential of reaching marine environments due to properties such as low specific gravity. Relatively new products of the linear economy are adding extra environmental burden. There is a pressing need for regulatory measures based on LCA and CE aiming at the issue of PMP.

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EXPLORING THE EFFECTIVENESS OF EXPERT CONSENSUS PATHWAY TO CONFRONT GRAND CHALLENGES IN TAIWAN

FU-WEI TSAO* [1] , HWONG-WEN MA [1] , KUEI-TIEN CHOU [2] , CHIA-WEI CHAO [3] , DAVID WALTHER [3]

The whole world is faced with many grand challenges such as climate change, aging society, income inequality and ecosystem collapse. Though these threats are deemed independent from each other in the short term, studies have shown that they could aggregate to amplify the impact in the long-term. To mitigate these challenges, this study proposes Taiwan expert consensus pathway with foresight analysis as a policy scenario and evaluates it with Taiwan 2050 Foresight System Dynamic Model, TaiForSD. In the analysis, we first identify grand challenges in the aspect of society, technology, economy, environment and governance with horizon scanning method. We further apply Dynamic Argumentative Delphi survey method (DAD) to narrow down critical forward looking issues which experts expect to change Taiwan. In the TaiForSD model, we combine International Futures (IFs) and Taiwan Integrated Environmental Assessment Model (TWIEA). IFs is a long-term integrated assessment model with 11 endogenized sub-models representing agriculture, demographics, economics, energy, environment, governance, infrastructure, international politics, health, and technology. To measure environmental impact rigorously, this study adopts soft-link approach to link TWIEA, which uses Life Cycle Assessment tool, to IFs model to quantify risk from human health, terrestrial ecosystems and resource scarcity. According to our assessment results, expert consensus pathway could curtail most grand challenges in Taiwan in the future, but their impact varied. By 2050, we find the pathway could lift industries value added by 50% and reduce pension expenditure by 26%, but worsen healthcare expenditure by 60%. Although the amount of carbon emission is projected to cut 50% in 2050, there is still 80 million tons of CO_2 to be cut to meet carbon neutrality by 2050, indicating we need more strategies to cope with grand challenges.

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IMPACT ASSESSMENT METHOD FOR CLIMATE CHANGE ADAPTATION PLANNING FOR SUPPLY CHAINS

KATSUYUKI NAKANO* [4] , MANABU WATANABE [5]

Climate change affects all aspects of life by increasing the frequency of extreme weather events, and its impacts influence across countries and industries through disruptions of the supply chain. The LCA framework for adaptation planning (LCA-AP) is a method for assessing the impact of climate change on the supply chain. This study reports the theoretical framework of this method and the progress of the development of impact assessment models.

Climate risk results from three factors: exposure, hazard, and vulnerability. According to LCA-AP, exposure is quantified as inventory data. The number of workers and the scale of economic activity in each unit process were used as inventory data. Hazard refers to the frequency and intensity of climate-related physical events, and vulnerability represents the social and economic robustness to respond to these. Indicators that consider both are used as damage factors. The expected losses for each unit process due to climate-related events is assessed by multiplying the inventory data and the damage factors. The damage factors, death ratio, and GDP-loss ratio in each country were created from the international disaster databases and the United Nation's statistics.

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This method can identify high-risk processes in the supply chain for each type of disaster. However, it was found that the damage factors varied, depending on the data collection period. Furthermore, since the damage factors were obtained from the actual damage value, the characterization model—a bottom-up type of environmental model—was incomplete. To evaluate the impacts of future effects such as sea-level rise, a characterization model for each climatic event is needed. A possible solution for this is the "impact-chains" analysis, a conceptual approach developed by the German institution GIZ, which identifies and visualizes the cause-effect relationship between climate risk and exposure, hazard, and vulnerability.

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LCA ON THE RETRIEVAL AND WASTE MANAGEMENT OF DERELICT FISHING GEAR

FALK SCHNEIDER* [1]

Derelict fishing gear (DFG) is one of the most abundant and harmful types of marine litter that gets increasingly retrieved from the ocean. It comprises of different polymers, steel and lead lines as well as contaminants such as dead fish, salt and sediment. The presented research evaluates the potential environmental impacts of DFG treatment pathways, so that an optimal waste management system can be established for this novel waste stream.

The study applies an attributional LCA to a (1) mechanical recycling, (2) chemical recycling, (3) energy recovery and (4) disposal scenario. The scope spans from the retrieval and transport processes to the waste treatment until outputs are either sent to landfill or modelled to replace an average production mix. The life cycle inventory derives from industrial experiments and secondary data. A contribution, sensitivity and uncertainty analysis were conducted to identify significant sources of environmental impacts and to evaluate the robustness of the results.

The results showed that the mechanical recycling and energy recovery achieved the lowest potential environmental impacts. The disposal and chemical recycling were not environmentally competitive because they could not offset their emissions or required too much electricity. The transport distances and energy mix as well as market and technological assumptions had a relatively low sensitivity while changes to the waste composition significantly affected the results. The uncertainty ranges of the scenarios frequently overlapped. Yet, results with a confidence level of 95% could be obtained in nine of twelve investigated impact categories.

The presented research embodies the first LCA study on marine litter waste treatment options. While the results indicate that a mechanical recycling and energy recovery are the least environmentally harmful options, technological, economic and social factors should also be considered before a decision is made.

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MATERIAL FLOW OF SINGLE-USE PLASTIC OF FOOD PACKAGING GENERATED BY RETAILERS IN TAIWAN

CHEN-HUA WANG* [2] , HUI-YU HUNG [2], HSIN-TIEN LIN [2]

Among the worldwide plastic production, plastic packaging and containers are the largest application and the increasing amount of food packaging generation in retailers and their improper discharge is causing environmental impact. However, the heterogeneous composition and the accompanying negative impact cannot be solved by any single contributor of the value chain of plastic. Therefore, this study investigates the material flow of single-use plastic packaging generated by retailers in Taiwan focusing on the material loss of different stages.

The information from retailers, consumers, and waste treatment plant managers was collected through three methods: field research, telephone surveys, and on-site interviews. We found that in Taipei, the material used in food packaging is 94.5% recyclable, the consumer recycling accuracy is 85.3%, and the material recovery rate in the waste management plant is 79.8%. Although the values seems high separately, the actual recycling rate of plastic packaging is the product of "recyclable content ratio", "recycling accuracy ratio" and "material recovery ratio" at each stage.

The results showed only approximately 65% of food packaging produced by the retailers will eventually be recycled as material, and nearly 35% is incinerated, buried, and discharged into the environment. Overall, this work identified three ratios in different stages affecting the actual recycling rates of the single-use plastic packaging in retailers. The three ratios affecting the actual recycling rate of different food items are also presented to recognize the reasons of poor recycling and provide insights for recycling promoting strategies.

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A STUDY OF ELECTRIC VEHICLES SPECIFIED FOR RIDE-SHARING

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Connectivity, automation, sharing and electrification — the four technology trends that make up CASE — are widely seen as shaping the future of mobility. Besides, through smartphones and the internet, sharing economy platforms are facilitating the creation of markets and better use of underutilized assets. According to the research, the ride sharing market is projected to grow at a CAGR of 20% from 2018 to 2025, to reach a market size of USD 218 billion by 2025 from USD 61 billion in 2018. As shared mobility services expand, automanufacturers have started developing vehicles specified for ride-sharing purpose.

On the other hand, tough emissions targets have been set in all major countries to reduce the vehicle traffic's contribution of CO_2, which contributes to about 14% of the total global CO_2 emissions. While no CO_2 emissions directly come from EVs, they run on electricity that is, in large part, still produced from fossil fuels. Moreover, most researches show that EV requires more energy and produces more emissions than a conventional vehicle in the manufacturing phase. Hence, it is crucial that the cost and environmental impacts throughout the EV's lifecycle are taken into account in the early design phases.

This paper focuses on the Life Cycle Design of EVs specified for ride-sharing purpose. After taking stakeholders' requirements into consideration, brand new alternative conceptual designs of the said product are proposed based on the existing product (Toyota's e-Palette), and evaluated using Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) methods, so as to compare the CO_2 emission and costs required throughout their lifecycles. It is worth noting that the result of both LCA and LCC are divided by the product of maximum passenger capacity and the distance travelled, with the aim of ensuing a fair comparison.

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THE EVALUATION OF BIODIVERSITY IMPACTS DUE TO DESERTIFICATION

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The proposed research considers developing a quantitative assessing method for the desertification, a historical global environmental issue affecting human's life as usual. With holding 38% of the global population and around 42% of earth's surface land, dryland ecosystem was considered an essential share among the future environmental researches.

The assessing methods for desertification are heading forward to the comprehensive and visualized. Consequently, in this study, we apply one of the LCIA methods to draft a framework describing the Omni bearing process from the causes of desertification to which impacts related. The climate change and global land use as the synthetic inventories in the first stage, the estimation conducted from first-stage parameters give an analytic result of desertification for midpoint, for which under the different scenarios the characterization factors could be completed. Reaching out to the endpoints, we consider the Ecosystem quality and human health as the main contents. We give a priority in considering the impact of biodiversity loss due to the desertification. By incorporating the ecological method to model the suitable habitat situation in a predictable temporal interval. At the same time, the characterization factors which bridge the midpoint and endpoint can also be conducted.

At the present stage the results show that under the future scenario the desertification evolves in some regions, for instance, the Mediterranean region, the north-south America etc. For the endpoint, the results are tested gives an apparent response along with the potential desertification emergence, which means that the around over 60% of this kind habitat is shrinking. The current results give a pretty positive position to move ahead to the next stage, planning to complete the characterization factors between the inventory and the midpoint further to the endpoint.

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TIME SERIES ANALYSIS ON FOOD NITROGEN FOOTPRINT IN THE INDIAN SUBCONTINENT ASSOCIATED WITH RELIGIOUS FOOD TABOOS

AURUP RATAN DHAR* [4] , AZUSA OITA [5] , KAZUYO MATSUBAE [4]

Nitrogen (N) is the key protein source for all living organisms. A substantial amount of the reactive N (nitrogen species except nitrogen gas) used

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in food production is lost to the environment, whereas some is consumed as food. Excessive reactive N in air and water contributes to critical environmental and health problems. The N footprint explains anthropogenic N loss to the environment related to consumption. This study estimates the N footprint of food influenced by cultural and religious food taboos in the Indian subcontinent from 1961 to 2013 and makes a prediction for 2050.

A religion-sensitive N-Calculator method was developed to assess the food N footprint. The food consumption cultures of four major religious communities in the Indian subcontinent, namely, Muslims, Hindus, Buddhists, and Christians, were considered. Food consumption data were collected from the FAOSTAT database from 1961 to 2013. To forecast the food N footprint values from 2014 to 2050, a long short-term memory recurrent neural network (LSTM-RNN) approach was applied.

The results revealed that the average food N footprint in the Indian subcontinent increased from 7.96 kg-N capita^{-1} year^{-1} in 1961 to 9.41 kg-N capita^{-1} year^{-1} in 2013. Animal-based foods were found to have a relatively higher N footprint per unit N intake than plant-based foods. Vegetarian Buddhists, followed by lacto-vegetarian Hindus, had the lowest food N footprint compared to non-vegetarian Muslims and Christians. As the religious verdicts prohibit the majority of the populations in the Indian subcontinent from consuming animal-based foods, all religious communities were found to be highly dependent on plant-based foods. The food N footprint in the Indian subcontinent was forecast to marginally decrease by 1.5% from 2013 to 9.27 kg-N capita^{-1} year^{-1} in 2050. This study recommends promoting diet awareness among religious communities for improved food N management.

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SPATIALIZED CHARACTERIZATION FACTORS OF WATER CONSUMPTION: CONSIDERING HETEROGENEITIES OF RECEIVING ENVIRONMENTS

CHIA-CHUN LIN* [1] , PEI-TE CHIUEH [1]

The inherent characteristics of water resources, such as heterogeneous distribution and renewability, make the assessment of water consumption impacts challenging. Recent researches focused on quantifying the cause-effect chain relationship of water consumption with consideration of the domestic compensation abilities. Therefore, the characterization factors could be spatialized by the regional water resources status as well as socioeconomic factors. These achievements provide systematic information about the consequences of water consumption. However, when applying these methods to improve water management within a country, more precise spatial scale of where the damage would be needed. In this study, we developed a water affected matrix to derive spatialized characterization factors with a new spatial scale. The water consumption impact is a resource allocation issue and the receiving environment (affected area) is related to the water supply system. Therefore, the water affected matrix was designed to carry the spatial information of source watersheds and the service areas by mapping the data provided from water supply systems. Furthermore, the attributes of affected users, such as population density or land-use profile, were used to address the potential distribution of damage receptors and water consumption impacts. Three main watersheds in Taiwan were selected as case study areas to demonstrate how the matrix works and its applications. The map results of spatialized characterization factors show that the affected area is not necessarily within the boundary of the watershed. Moreover, the damage is heterogeneous within the affected area, which used to be a single average value. With the spatialized characterization factors, it is expected to provide more detailed spatial information to support regional decision making and effective strategy implementation.

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THE MATERIALITY OF MOBILITY. A CASE STUDY FOR THE CITY OF VIENNA, AUSTRIA

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Sustainable resource use calls for substantial changes to existing infrastructures, which lock societies into current resource use patterns. Urban mobility is a case in point: existing material stocks of infrastructure and vehicles require substantial amounts of materials and energy for maintenance and operation in order to provide mobility services, thereby causing considerable emissions. In Vienna, traffic-related GHG-emissions increased by 59% between 1990 and 2014. Acknowledging its responsibility to contribute to the UN SDGs, the City of Vienna aims for a CO_2-neutral transport sector until 2050 and for a reduction of the related per-capita final energy consumption by 70%.

We investigate the material and energy demand of personal mobility in the

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urban context of Vienna using stock-driven, bottom-up material and energy flow analysis and cover material stocks of roads, rail, subway and tram infrastructure and interfaces or vehicles such as cars, bicycles, trains, trams and busses for all mobility within city territory. We quantify material flows for maintenance, expansion, as well as primary energy use and emissions linked to personal mobility and compare a number of stock-flow-service indicators for four different mobility modes: pedestrian mobility, bicycle mobility, public transport and motorized individual traffic.

Results show that public transport delivered most mobility services (38% of all trips). Pedestrian mobility achieved the highest service delivery of stocks while using less resources and generating lower emissions per service unit than any other mobility mode. Traffic surfaces dominated the material requirements of mobility and are mainly (78%) used by motorized individual traffic. We discuss the potential of various policy measures planned by the City of Vienna in relation to our findings and conclude that considering stock-flow-service relations of mobility modes can support prioritizing future urban planning. We highlight the importance of infrastructure-related measures and the need for better monitoring especially of mobility service indicators.

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Environmental and economic performance improvement of a high value-added Thai Riceberry product

Panit Chancharoonpong* [1], Rattanawan Mungkung [2 3], Shabbir H. Gheewala [4 5]

Thai riceberry rice, a deep purple whole grain rice with high nutrients, antioxidants, and softness, is increasingly popular among consumers. To raise the sustainability level of Thai riceberry product to respond to the national policy on sustainable agriculture, the environmental and economic performance of high value-added product from Thai Riceberry rice products were assessed from a life cycle perspective. This study aimed to identify improvement options of the riceberry-based hair conditioner (250 ml, in PET bottle), via life cycle assessment and eco-efficiency assessment. The unit of analysis was set as the sold unit. Product Environmental Footprint was used as the impact assessment method, while the product system value was based on the selling price of the product. The study revealed that the raw material acquisition stage was the major hot spot contributing to more than 80% of all impacts. Opportunities for reducing the impacts on the environment were focused on re-design for eco-packaging by using recycled PET bottles and shifting from traditional farming practice to alternative wetting and drying water practice (AWD) during the farming stage could potentially reduce all environmental impact indicators by 7-51%. All of these improvements had the potential to increase eco-efficiency, especially on the energy use indicator by 105% and global warming indicator by 36%. In addition to increasing eco-efficiency, riceberry can also increase value-added from 2.5 USD to 188 USD per 1 kg of riceberry when processed to riceberry hair conditioner. Overall, the development of riceberry hair conditioner showed that processed products from riceberry can generate more value-added. Therefore, it was suggested by this study that growing riceberry rice and producing high-value-added products should be promoted. This study can demonstrate that the eco-efficiency assessment can help enhance product differentiation for consumers and can also assist producers to improve the environmental and economic performance of products.

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Life Cycle Sustainability Assessment of Urban Transportation: A Case Study of Bangkok

Witchakorn Sittipong* [6 7], Kultida Boonyarith [6], Panarin Pakornkarn [6], Vongsakorn Chandratana [6], Nanthanat Angsubhakorn [6], Viganda Varabuntoonvit [6 8]

Bangkok, the capital of Thailand, is currently facing a traffic congestion issue caused by the enormous number of private vehicles. In 2019, the city was 11th ranked of the world's highest traffic index, while public transportation took only two percent of the total registered vehicles. This trend leads to an abundance of environmental, economic, and social impacts. Public transport was proposed as the key to mitigating the problem. This research aims to assess and compare the sustainability of public transportation in Bangkok.

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The public bus and rapid transit were selected as a case study due to the highest public utilization rates. The methodology applied the Life Cycle Sustainability Assessment (LCSA), which contains 3 evaluation tools, i.e., Life Cycle Assessment (LCA), Life Cycle Costing (LCC), and Social Life Cycle Assessment (S-LCA) to identify the impact on environmental, economic, and social perspective along with the life cycle service system. Then the impacts were integrated as a single indicator which represents the sustainability indicator. The results pointed out that public bus is more superior in term of environmental and economic impacts, while rapid transit took advantage of the social concern. The environmental hot-spot of the railway system came from rail construction activity. The increasing number of passengers for the rapid transit system can enhance more sustainability of the service. The conclusions and recommendations were provided for the sustainability development of public transportation in Bangkok.

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Nexus Evaluation of Alternative Sector Configurations for Integrated Planning of Water and Energy Supply

Esmaeil Ahmadi* [1] , Benjamin Craig McLellan [1]

This study aims to assess the economic, technical, and environmental impacts of different system configurations, such as centralized, decentralized, and alternative technology mixes, on transition plans to achieve a higher share of renewable energy and desalination supplies for regions facing water scarcity and have ready access to seawater. This study demonstrates and assesses on-grid decentralized renewable-powered desalination systems for sustainable water and energy supply planning as the main contribution. A nonlinear methodology, which matches the characteristic of the nexus concept, is applied to design transition pathways for interconnected energy and water sectors in the southern coast of Iran. For studying synergies, two-factor learning curves are developed to estimate the pace of technology deployment and the path of decline in overall costs, which are assumed to be a function of experience and knowledge in this study. Even though rural areas in Iran are listed as a priority in strategies for achieving sustainable development goals (SDGs), policymakers are unable to engage rural areas in the planning for water supply with desalination and a share of renewables. The proposed scenarios with decentralized desalination in an integrated planning of both water and energy supply, constitute an alternative solution to provide a just opportunity for rural areas to benefit from a secure water supply and heavy subsidies, while avoiding conflicts apparent in a separated planning.

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Positioning the Areas of Protection Natural Resources and Human Health used in Life Cycle Impact Assessment within Life Cycle Sustainability Assessment

Guido Sonnemann* [1], Jair Santillán-Saldivar [1], Sonia Valdivia [2]

Life Cycle Sustainability Assessment has been defined as a combination of environmental life cycle assessment, social life cycle assessment and life cycle costing for the economic dimension. Within environmental life cycle assessment the following three areas of protection have been established to evaluate damages as part of the life cycle impact assessment stage: Ecosystem Health, Human Health and Natural Resources.

In this presentation, the question on how to position the Areas of Protection Natural Resources and Human Health within Life Cycle Sustainability Assessment will be discussed. Recent work on integrating criticality assessment within life cycle assessment as a complementary indicator contributing to the Area of Protection Natural Resources has raised the issue of how to deal with economic assessment within Life Cycle Sustainability Assessment. Another challenge has arisen with the Area of Protection Human Health considering that human healthcare is seen as a social aspect in Life Cycle Sustainability Assessment.

Based on a discussion of these points, the presentation will propose a framework on how to position the Areas of Protection Natural Resources and Human Health used in Life Cycle Impact Assessment within Life Cycle Sustainability Assessment. It is expected that this framework will guide industry and other decision-makers in performing technology assessments that aim at innovation covering the three dimensions of sustainable development.

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Lifetime of consumer appliances and its factors: findings from a Japanese national government's survey

Haruhisa Yamamoto* [3], Shinsuke Murakami [3], Masahiro Oguchi [4], Daisuke Nishijima [5]

Product lifetime extension is vital for the circular economy. Detailed understanding of the actual product lifetimes and reasons for replacement is required to take effective measures. In this study, the lifetime of consumer appliances, reasons for their replacement and the influence of demographic variables were analyzed based on Consumer Confidence Survey, which is a Japanese government's survey that includes consumer durables replacement in its survey items. The lifetime of small-size appliances became longer recently. Device failure was prevalent for medium- and large-size appliances, whereas a desire for upgrade was the major replacement reason for small-size appliances. However, the difference between the lifetime distribution of devices replaced due to device failure and that due to the desire for upgrade was quite small, and the lifetime of devices due to moving was especially short. Moreover, the higher the age of the head of the household, the longer the product lifetime regardless of its replacement reason. Based on these results, effective measures according to different product types, and consumer groups that product lifetime extension should be specifically encouraged are discussed.

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The impact of reconstruction in auto mobile supply chains on global carbon footprint

Keitaro Maeno* [6], Shigemi Kagawa [6], Shohei Tokito [7]

Due to the disruption of global supply chain (GSC) caused by the COVID-19 pandemic, many countries are taking actions to eliminate their excessive dependence of GSC on a specific country, especially China, and to reconstruct their GSCs. When these actions are implemented, it is very important to construct the green supply chain that is aimed to mitigate comprehensive CO_2 emissions from whole of GSC. This is because the climate change is still a serious problem and the idea that try to reduce CO_2 emissions from each industry is crucial for the sustainability.

Therefore, to provide useful information for policies to effectively reduce

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comprehensive CO_2 emissions from reconstructed new GSCs, firstly, we developed a new framework to estimate the impact of hypothetical structural changes in global supply chains on the global carbon footprint associated with the production of a specific final demand sector.

Secondly, we estimated changes in CO_2 emissions from the reconstructed new GSCs in a hypothetical world in which all industries in Japan's automobile supply chain do not import specific intermediate goods produced in China.

The results show that this hypothetical reconstruction of Japan's automobile supply chain has the CO_2 increasing and decreasing effect for each sector within its GSCs. In addition, from the results, it is revealed that the net CO_2 emissions increase the most (+858kt-CO_2) when the Japan' s automobile supply chain does not use China's "Basic metals" sector. Furthermore, we found the "Basic metals" and "Electricity, gas" sectors in Russia and Korea have the remarkable CO_2 increasing effect, in other words, that are the driving force behind the future Climate Change in each case.

Finally, we proposed the climate policy for Japan' s automobile supply chain reconstruction to reduce comprehensive CO_2 emissions from its reconstructed GSCs.

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Relative significance of competitiveness determinants of solar photovoltaic power generation in China —Porter Diamond model and AHP

Tiantian Zhang* [1], Ken'ichi Matsumoto [1]

The importance of solar photovoltaic (PV) power generation to China's renewable energy has been increasingly recognized. Many provinces in China have adopted various measures to attract PV power generation. This study mainly uses the Porter Diamond model and analytic hierarchy process (AHP) to clarify the relative importance of the PV power generation industry of competitiveness determinants among various provinces, Using the qualitative analysis of the diamond model, constructing an evaluation model, finding the advantages and disadvantages of different regions of China, to solve the above problems, using the index evaluation system and AHP, establishing the impact factor evaluation model, quantitative analysis. We selected 13 determinants, which are classified into several categories, including production factors, demand conditions, related and supporting industry, strategy, structure, and horizontal competition categories, for analysis. The results show that in addition to the production factors and demand conditions, the related and supportive industry, strategy, structure, and horizontal competition in the same industry have the same or stronger influence. This study also points out that some traditional factors, such as gross regional product, solar radiance ratio. are also significant to the PV power generation industry. The relative importance of the determinants clarified through this study provides a standard to determine the actions of policymakers and decision-makers.

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Analysis of Taiwan Resource-based Indicators

Chiao-Ling Lyu* [2], Ying-Hsuan Huang [2], Hao-Chun Chia [2], Chih-Ying Lin [2], Kun-Hsing Liu [2], Ying-Ying Lai [3], Yi-Hua Lee [3], Yao-Cheng Wang [3], Chien-Chang Wu [3]

In Taiwan, MOE and EPA both implemented their plans to promote the concept of a circular economy. Therefore, two indicators of Resource Productivity (RP) and Cyclical Use Rate (CUR), also considered internationally, are utilized here to measure the effectiveness of the plans.

Based on the previous result of Resource Circulation Analysis System supported by EPA Taiwan, RP and CUR are generated annually, and depending on different comparison purposes, Nominal Gross Domestic Product (GDP), Real GDP, and Purchasing Power Parity (PPP) are respectively used to recalculate the RP in Taiwan from 2010 to 2019. The RP (Nominal GDP/DMC) gradually increases from 1.56 to 2.47 USD/Kg. The RP (Real GDP/DMC) gradually increases from 1.65 to 2.50 USD/Kg. The RP (PPP/DMC) gradually increases from 3.12 to 5.35 USD/Kg. The RP (PPP/DMC) of different countries in 2017 are listed out and Taiwan was the second highest country and only less than the Netherlands. Moreover, the RP (Nominal GDP/DMC) in 2019 has exceeded the goal set in 2020, which is about 69.4 NTD/Kg.

The CUR varies from 15.52%-20.53% in 2015-2019. The increased cyclical uses of general waste and the construction surplus soil are the main reasons to cause the CUR increase. Among the general waste, the cyclical use of the incinerator bottom ashes increases due to the policy. Inspired by Japan, the CUR indicators can be divided into four sub-indicators to respectively inspect the four types of materials, organic chemical resource, organic biomass resource, metal resource, and non-metal resource, in which the CUR of the non-metal material has increased mostly due to the increased construction surplus soil cyclical use for another large governmental plan that is not included in main circular economy plans.

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A PROPOSAL FOR CONSISTENT LINKING BETWEEN EMISSION FRACTION ESTIMATION AND TOXICITY CHARACTERIZATION IN LIFE CYCLE ASSESSMENT OF PESTICIDES

LONGLONG TANG* [3] , KIYOTADA HAYASHI [3]

Fate process simulation has been applied to life cycle inventory (LCI) analysis for calculating pesticide emissions reached in various environmental media, while fate processes (e.g., transfer between environmental media) have also been modeled in the calculation of toxicity characterization factors (CFs) for life cycle impact assessment (LCIA). However, a clear definition for distinguishing the two kinds of fate processes is currently missing. For example, a pesticide emission model (e.g., PestLCI 2.0) calculates pesticide emissions transported outside the targeted agricultural field. In this case, on-field fate processes (e.g., transport and degradation) may potentially be doubly counted in LCI analysis and LCIA. On the other hand, the Glasgow workshop proposed primary distribution, i.e., fate and distribution processes occurring immediately after pesticide application (e.g., drift, depositions on soil and water on and off the field), as emission fractions. However, it is difficult in this case to consider the dynamic nature of water management in the characterization process.

This study aims to propose a framework for consistently linking pesticide emission fractions with toxicity characterization models. As fate processes in LCIA are usually assumed to be steady at the regional or global scale, we propose the fate modeling that simulates the pesticide transfer between on-field environmental media and that introduces dynamic reactions of emission fractions caused by local management. Our proposal connects the whole fate process chains from pesticide application to environmental impact generation through avoiding over- and under-estimation. In addition, the consistent framework can visualize emission dynamics caused by various management practices by adopting the new emission fractions. These characteristics will be useful for establishing sustainable management practices through the use of LCA.

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Circular Economy Strategies in Practice: Ecological Potentials of Linking Value Chains in the Metalworking Industry

Wiebke Hagedorn* [1 2 3], Kathrin Greiff [3], Katrin Bienge [1], Christa Liedtke [1]

One of the biggest challenges for society is the environmental burden caused by global production and consumption of goods and services, that moves the world towards and across the planetary boundaries. Around 25% of the global emissions caused by industry are ascribed to the steel sector (Allwood 2011). This means an impact of 3.3 billion t CO_2 eq emitted during total steel production and processing in 2018 (worldsteel 2019). The circular economy (CE) offers a solution to fundamentally change production systems thus decreasing the environmental pressure and realising SDG 12.

The aim of the project Circle of Tools (CoT) is to implement the CE concepts remanufacturing and repurposing in the metalworking industry. At the same time, an environmental assessment should show, how large the contribution of CE concepts is. This requires the development of a methodological approach. This paper presents the analysis of repurposing meaning that two industrial partners altered their production processes to manufacture circular products with two different functions. That way, the supply chains of the two manufacturers are linked and the steel is reused without requiring recycling, i.e. energy-intensive remelting processes.

For the environmental impact assessment, first, the linear supply chains of the products, an industrial machining knife and a wood turning tool, were analysed applying the LCA methodology. Secondly, a circular scenario was assessed. By using the primary data of the industry partners, individual LCI data sets could be generated and used for the assessment. First results show the hotspots – heat treatment and grinding process - of the production processes. The analysis and practical implementation indicate that the material characteristics are decisive regarding the grinding process.

However, this goes along with challenges regarding the quantification of inputs. Other challenges regard the integration of product systems with different functional units and determining the changed product life time.

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Life cycle inventory of lithium production: assessment of current datasets and gaps to improve LCA studies

Aina Mas Fons* [4], Rachel Horta Arduin [4], Philippe Loubet [4], Alejandro Abadias Llamas [5], Celaida Gayle Gumban [5], Guido Sonnemann [4]

The energy transition is one major global challenge. This transition requires a shift to new technologies, which increase the demand for certain critical raw materials such as lithium (Li). Rechargeable Li-ion batteries have transformed portable electronics and seem to also be the chosen technology for e-mobility.

Measuring the environmental impacts of new technologies is important to support the changes required towards a sustainable energy transition. Life Cycle Assessment (LCA) is used to quantify and compare the environmental impacts of products throughout their life cycle. Among others, the results of LCA studies are highly impacted by the life cycle inventory (LCI), which consists of primary and/or secondary data from databases and/or literature. The goal of this work was to evaluate the current LCI data available for Li production. The evaluation includes datasets available in LCA databases and published in scientific papers.

Within the ecoinvent database, the world's leading life cycle inventory database, the Li extraction datasets are organized based on the type of source: brine and spodumene. Brine extraction is known for its water consumption. However, when evaluating its Life Cycle Impact Assessment (LCIA) results, only a small amount is considered, which is mainly related to the production of electricity (upstream) and not the Li process itself. When evaluating LCIA outcomes of Li from spodumene, climate change impacts are mostly due to the upstream impact of electricity production. Among other improvements, data on Li production share could be used instead of a global mix. Given the importance of Li for batteries production, and the data available in the current LCI datasets, improvements should be done. This work is under development as part of the TripleLink project funded by EIT Raw Materials, and includes coupling of process modelling with HSC Chemistry and LCA assessment with openLCA.

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UNDERSTANDING THE GEOPOLITICAL SUPPLY RISK OF HELIUM (HE): A MULTINATIONAL PERSPECTIVE

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This contribution assesses the geopolitical supply risk of global helium supply, focusing on the top helium-importing countries. Helium is a non-renewable resource identified as critical by the USA, EU and other nations. There is little extant research on the helium life cycle, its resource criticality, its environmental footprint, and quantifying its material losses (which for helium exit the Earth). Global helium production in 2019 was approximately 160 billion cubic meters, refined from economic concentration in hydrocarbon natural gas. Roughly 30% of production is used as a cryogenic coolant in magnetic resonance imaging (MRI) machines, supporting the healthcare sector, while other uses include research and advanced manufacturing. Helium production is concentrated in three countries (the USA, Qatar and Algeria); it is stored and transported as a cryogenic liquid, then distributed as a liquid or compressed gas, making its logistics challenging and time-constrained. Shortages occurred in 2012 due to maintenance shutdowns and, in 2017, due to the Qatar trade blockade. We quantify and analyze the supply risk for ten major importing countries (China, Japan, South Korea, Taiwan, Germany, France, the United Kingdom, Mexico, Canada, and Brazil) over four years (2015-2018). An original database on helium processes and supply chain supported our calculation of the GeoPolRisk indicator. Given that helium is a noble gas, which does not change its form or mix over its life cycle, new methodological insights allow a multinational trade perspective. Results show patterns in national helium supply and diversification of supply mix. Evidence suggests Japan has managed supply more effectively than other nations: after a significant helium shortage in 2012, the nation has reduced risk substantially. Country-level and company-level management of helium affect responsible consumption and production (SDG12) of this non-renewable resource and its use, enabling good health and well-being (SDG3).

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LIFECYCLE CO_2 EMISSIONS AND COST OF CHANGES TO AIRCRAFT LIFETIME IN JAPAN

MINAMI KITO* [5 6], SHIGEMI KAGAWA [5] , KEISUKE NANSAI [6]

Airline industry CO_2 emissions have increased rapidly; air transportation releases approximately 2.8% of global fuel-combustion-based CO_2 emissions in 2019. Aircraft passenger demand has grown at a rate of 6.2% per year over the past 10 years. Many studies have shown that introducing new fuel-efficient aircraft contributes considerably to reducing CO_2 emissions from the aviation industry, however they did not consider important factors of both aircrafts replacement and aircraft lifetime. Therefore, the environmental impacts of the change in the increase of the demand for new aircrafts as well as the change in the air transportation service have not been addressed well. Focusing on Japan, this study explored the introduction of new passenger aircraft as a CO_2-reduction policy. To this end, the lifetime distribution function for passenger aircraft was specified. Lifecycle CO_2 emissions and the associated costs between 1965 and 2019 were then estimated. The results showed that single-aisle aircraft followed a Rayleigh distribution with a mean of 13.42, while twin-aisle aircraft followed a normal distribution with a mean of 19.82. The results also indicated that if the average fuel intensity of aircraft inflow improves steadily, the shortened lifetime and introduction of more fuel-efficient aircraft contribute to a decrease in lifecycle CO_2 emissions. However, comparing the reduced rate of CO_2 emissions and the increased rate of cost, the introduction of new aircraft was shown not to be cost-effective as a CO_2-reduction policy. This study concluded that extending the lifetime of single-aisle aircraft and shortening the lifetime of twin-aisle aircraft between 1965 and 2019 was the best option from the perspective of CO_2 emissions. Airline companies need to recognize that strategies to reduce CO_2 emissions by only replacing aircraft are costly.

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Detecting a low-carbon supply-chain in a recovery plan for future natural disasters; the case of a Nankai Trough earthquake in Japan

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As the frequency of large-scale natural disasters increases worldwide, besides the spillover economic impacts, there are also concerns about the environmental impacts of reconstruction, such as an increase in greenhouse gas (GHG) emissions. This study aims to develop a supply-chain model to implement a sustainable recovery plan using a hypothetical Nankai Trough earthquake as a case study. We used a multiregional input-output table for Japan' s 47 prefectures and developed an inoperability input-output model to facilitate identification of the supply chain structure that would be required for reconstruction and for estimating the associated GHG emissions. The model identified critical differences in the supply chains required for meeting the reconstruction demand without and with GHG emission constraints—Ordinary recovery and Green recovery. In Ordinary recovery, the result showed that the reconstruction demand in disaster regions increased total production by ¥ 300 trillion and GHG emissions by 32% compared to the scenario before the disaster. These increases were attributed primarily to emissions in the cement and cement products, electric power, and transportation sectors. However, through supply chain optimization in Green recovery, it was possible to mitigate this increase in GHG emissions to 1%. In addition, it was shown that the selective introduction of low-carbon technologies would be effective in regions where production increases are expected due to disaster recovery efforts. To achieve a resilient low-carbon society, each country should consider developing low-carbon recovery plans.

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Environmental impact assessment of the emerging technology recycling applying advanced electrical pulse fragmentation: Case studies on lithium-ion batteries and photovoltaic panels

Izuru Suwa* [5] , Aya Heiho [5] , Yi Dou [5] , Chiharu Tokoro [6] , Yasunori Kikuchi [5]

Recycling systems are one of the most important infrastructures to mitigate the consumption of natural resources. In Japan, recycling systems have been promoted and developed to decrease the amount of final disposal for plastics, papers, and home electric appliances. Recently, it is necessitated to address emerging technologies, which have increasingly been implemented into and will have been gathered as wastes from markets in near future. These technologies have several uncertainties in supply and demand balance by social shifts and in product components by technological innovations. Therefore, their recycling systems must be designed with adequate assessment from multiple aspects. Life cycle assessment (LCA) is one of the effective methods to search for appropriate technology combination in recycling and to analyze the environmental effects. In addition to LCA, material flow analysis (MFA) can also contribute to estimating the amount of waste products and the scale of the technologies to be implemented. In this study, we are tackling the recycling of lithium-ion batteries and photovoltaic panels by applying advanced electrical pulse fragmentation. We conducted LCA to quantify environmental impacts originating from the recycling with or without the pulse fragmentation. Global warming potential (GWP) and resource consumption were adopted as the impact category in this study. The results showed that novel recycling with pulse fragmentation has the potential to reduce GWP and resource consumption. Especially for lithium-ion batteries, we also conducted MFA to estimate the waste volume. Combining the results of these assessments, we discuss the perspectives to be considered for the recycling of lithium-ion batteries applying advanced electrical pulse fragmentation.

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Estimation of Cr and Ni content in carbon steel scrap by using dynamic material flow analysis model

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Steel is the largest consumed metal in the world, with 1.87 billion tonne production in 2019. According to the accumulation of the in-use stock of steel, steel scrap will become the main iron source around 2050. However, the properties of recycled steel could be degraded due to contamination of impurity elements, which is derived from other materials used in the same final product and which has been already contained in steel. For avoiding the expected issue, the origin of impurity elements should be revealed. This study aims to estimate the content of Cr and Ni in carbon steel scrap in Japan. We constructed dynamic material flow analysis (MFA) model based on Markov chain model and Input-Output (IO) analysis. Markov chain model can consider the state transition of each process (e.g., Cr in Ferrochromium to Cr in Fe-Cr-Ni stainless steel and other alloy steel) by a transition matrix. The basic framework of transition matrix was derived from IO table which describes relation between industries with a conversion from a monetary unit to physical units. In this study, we added the matrix related with recycling process in detail to distinguish element from contamination of other materials and already contained in steel. Cr and Ni content in carbon steel scrap were estimated 0.070% and 0.022% respectively. It is found that 46.3 kt of Cr (out of 70.2 kt in carbon steel scrap) and 13.0 kt of Ni (out of 21.6 kt) is caused by contamination of alloy steel in carbon steel scrap, which is not functionally recycled. If these elements could be functionally recycled by separating alloy steel from carbon steel, 6.6% of the primary resource of Cr for steel production and 6.2% of that of Ni can be avoided.

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Product characteristics influencing customer acceptance for Product-Service Systems: a literature review

Koji Kimita* [1]The University of Tokyo, Japan , Eri Amasawa [1]

Due to the limitations of the current linear economic model, i.e. the take-make-use-dispose model, our society must move towards a circular economy – which is restorative by design and aims to keep products, components and materials at their highest utility and value at all times. Against this background, Product-Service Systems (PSS), which create value by integrating a physical product and a service, have been heralded as one of the most effective instruments for the transition to a circular economy. Despite the high expectations for PSS, in practical terms, many companies have struggled to achieve the expected environmental and economic benefits. Therefore, many researches have been investigated to reveal reasons for the failure of achieving expected benefits. However, limited studies have discussed characteristics of products that are assumed to be suitable for PSS. To address this problem, this study aims to clarify characteristics of products that are suitable or unsuitable for PSS from the viewpoint of customer acceptance. In specific, a systematic literature review was conducted for synthesizing the product characteristics. As a result, we found five benefits and risks that are related to product attributes and use. The benefit corresponds to “reduction of product life cycle costs”, while the risks include “loss of emotional value”, “lack of control and autonomy”, “hygiene and safety issues”, and “data security and privacy issues.” These benefit and risks are associated with product attributes and use that cause them. For example, benefit of reduction of product life cycle costs is increased in the case of products needed for a short time. Risk of hygiene and safety issues is perceived in products containing textiles and close to consumers. These results could be useful for designing a product and service that will be acceptable for consumers.

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Implementation of consequential approach Life Cycle Assessment in non-woody biomass waste biorefinery development

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To increase the environmental and economic performance of non-woody biomass waste, converting it into valuable products, is an attractive solution. Biorefinery can be used for converting biomass into energy and valuable chemical products. The life cycle assessment (LCA) is widely used in the biorefinery framework for assessing its environmental impact since the last decade. However, the consequential approach in this LCA still has room to explore. This paper has shown several case studies of consequential LCA for the biorefinery development framework. In Indonesia, oil palm empty fruit bunches (EFB) and sugarcane bagasse are the two potential non-woody biomass waste. As the largest crude palm oil producer in the world, Indonesia produces abundant empty fruit bunches (EFB) waste. Sugarcane bagasse is the other potential non-woody biomass in Indonesia because there are several big sugar industries in Indonesia. Indonesia produces 43.5 million tons/year of EFB and 11.2 million tons/year, respectively. Several biorefinery products, such as bioethanol, cellulose pulp, and furfural, can be produced from the biomass wastes. In the consequential approach, proposing the specific strategy in the biorefinery framework gave a new perspective for reducing the environmental impact. However, by applying the consequential LCA, more efforts to quantify and address the consequential effect was needed to be done. The one advantage in the consequential LCA is avoiding the double-counting LCA. The breakdown of the overall environmental impact in the existing and proposed scenarios through the consequential approach was valuable for industrial-level decision-makers. Our analysis of consequential LCA for EFB and sugarcane bagasse for valuable biorefinery products, such as bioethanol, cellulose pulp, and furfural, were attractive based on the environmental point of view.

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Urban-mined Olympic Medals as a Symbol of Circular Economy

Kohmei Halada* [4], Kenichi Nakajima [5], Takeshi Kuroda [6], Yoshiaki Imai [7], Tadakazu Kagami [8], Hirobumi Ohta [9]

The winner's medals of 2020 Tokyo Olympic & Paralympic are made from recycled metals. JOC carried out the project named Tokyo 2020 project("Minnano Medal project" in Japanese which means everybody participated medal), and 78,908 tons of used small electric appliances and 6,210,000 of used cell phones had been collected by citizens themselves with the support of 1621 local governments. All raw material of medals was supplied by this project. This is the first case in the history of Olympic. Small electric appliances recycling system, which launched from 2013, supported the base of this achievement. In the presentation, three significances on sustainability are mentioned. First, the sustainable resource management of circulation. The accumulated demand of metals until the end of this century will overshoot the amount of reserves with several times. Circulation based resource management is inevitable. Second, reduction of the burden in resource mining. Great amount of total material requirements is on the rucksacks of small electric appliances and cell phones. Material circulation will reduce not only the raw material of products themselves but also the environmental resources behind them. Third, mitigation of E-waste. Electric appliances such as cell phones contains various hazardous substances, as well as gold, silver and copper. The pollution of hazardous substance from electric appliances can be protected by appropriate recycling which has higher traceability such as Japanese recycling system of small electric appliances. Adding to the traceability, the importance of residue recycling is insisted in order to reduce the final waste.

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ASIAN' S CIRCULAR CONSUMPTION BEHAVIOR - MARKET REVIEWS AND CONSUMER PERCEPTION INVESTIGATION FOR A REFURBISHED SMARTPHONE IN JAPAN, SINGAPORE, AND INDONESIA

YOON-YOUNG CHUN* [1], MITSUTAKA MATSUMOTO [1] , KENICHIRO CHINEN [2] , KIYOTAKA TAHARA [1]

Refurbishment is a promising solution to our society's transition into a circular economy when properly harmonized with our consumption behaviors. An investigation into circular consumption behavior in Asian countries merits attention at a time when the Asia region is driving a considerable amount of the world's consumption. This article presents consumers' perceptions and green purchasing behaviors toward a refurbished smartphone in three Asian countries like Japan, Singapore, and Indonesia. It also provides a brief review of the refurbished market related to the target countries' mobile/smartphone industry. The findings suggest the concern about the quality of a refurbished product and price and an individual's sensitivity to innovation are important to predict Asian consumers' consumption behavior toward a refurbished smartphone.

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A MATERIAL PROPERTY BASED LCI ANALYSIS MODEL FOR MATERIAL SELECTION IN LIGHT-WEIGHTING VEHICLES

JUNXI LIU* [3], PANASIUK DARYNA [3] , ICHIRO DAIGO [3] , TAKEO HOSHINO [3]

Weight reduction via lightweight material substitution can reduce the total vehicle life cycle greenhouse gas emissions. Two factors are crucial in terms of material selection. One is the material substitution ratio (MSR) which is highly dependent on the materials' properties. But there is a lack of discussion on how to calculate the MSR based on material properties so far. The other is the choice of recycling approaches (RAs) in life cycle inventory analysis (LCI), which refers to how to allocate the environmental impacts associated with recycled materials. Likewise, there is a lack of discussion on its impacts on material selection in light-weighting vehicle LCA studies. Therefore, this study aims at constructing a material property based LCI analysis model for material selection in light-weighting vehicles.

For the material selection preference, the life cycle GHG (LC-GHG) emissions from material production, vehicle use phase, and end-of-life (EoL) phase are calculated. This study considers three representative recycling approach, i.e., the cut-off approach, end-of-life recycling (EoL-R) approach, and waste mining (WM) approach. The material selection methodology based on a material index which was proposed by Ashby is used for MSR calculation.

Eventually, we have constructed a property based material selection method to calculate the MSR for specific vehicle parts and systems. Besides, it is recognized that the selection of recycling approaches would have an impact on the LC-GHG emissions, which is usually a lower impact in the EoL-R approach. When the vehicle fuel cycle' s environmental impact decreases by shifting to electric vehicles, the impacts from material production and recycling will increase. Therefore, more detailed material flow analysis for materials is needed to get the recycling relevant parameters in each recycling approach, especially for those new materials having large avoided burden due to material recycling and less recycled at present, like Mg alloy.

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POTENTIAL OF RESOURCES RECYCLING FROM SPENT LI-ION BATTERIES IN JAPAN: A FUTURE PERSPECTIVE

YI DOU* [3], AYA HEIHO [3] , IZURU SUWA [3] , YASUNORI KIKUCHI [3]

Promotion of electric vehicles (EVs) is thought as one of the key solutions for realizing a net zero-emission society. However, the rapidly increased demand of Li-ion batteries not only brings about a quickly increasing consumption of rare metals, but also impacts on current recycling systems. Predicting the generation of spent Li-ion batteries in the future can provide a concrete evidence for science-based policy making to solve the dilemma in promoting the EVs. Although many papers and reports have done the prediction considering the market mechanism, the most of them ignored the feedback from policies and technology development that surely leads to the dynamic changes in material flow.

To fill in the gap, this study developed a dynamic material flow model to forecast the potential of resources recycling from spent Li-ion batteries in Japan, considering the dynamic correlation between influencing factors such

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as macro socio-economy, battery technology diffusion, resource recycling, and EV-related promotion policies. Several scenarios are studied focusing on the ambitious target on promoting EVs and recycling systems to catch the uncertainties in the prediction. Results indicated both the macro socio-economic trends and EV-promotion policies play as global factors on the generation of spent Li-ion batteries, but battery production and recycling systems have critical effects on material flow that leads to the timing changes in resource circulation. Particularly, rebound effect will occur due to the cost changes from the subsidy and technology development in production and recycling. These analyses provide a comprehensive perspective in the way of solving the dilemma during promoting EVs, also help in quantitatively pre-evaluating the combined effects from policies in resource circulation.

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A MULTI-LAYER LIFETIME SIMULATION MODEL FOR DESIGNING A CIRCULAR SUPPLY CHAIN FOR TRACTION LITHIUM-ION BATTERIES

JINGWEI ZHOU* [1], HAJIME OHNO [1], YASUHIRO FUKUSHIMA [1]

Nowadays, electric vehicles (EVs) are booming globally toward mitigating greenhouse gas emissions, which corresponds to a flourishing demand for high-performance traction batteries for powertrains, mainly lithium-ion battery (LIB). International Energy Agency (IEA) predicts that EVs' sales will be 245 million in 2030. It leads to increased lithium and cobalt demands for producing fresh LIBs up to more than 350 kt and 360 kt, respectively.

In this research, for managing the value chain of LIBs and related resource consumptions, we develop a tool to design a circular supply chain (CSC) of LIBs by simulating the life of a LIB dissecting into five layers: packs, modules, cells, cathodes, and elements, by utilizing a dynamic material flow analysis (dMFA). The multi-layer consideration is a novel concept for simulating LIBs' life, with the comprehensive information of when and how LIB packs and their components move in society. The CSC includes suppliers (for elements input), manufacturing firms (cells, modules, and packs), cathode recycling firms (for recovering elements from cathodes), and next-generation distribution sectors (EV or solar photovoltaics (PV)).

We simulated the CSC under our assumptions from the year 2005 to 2030, found that in the conventional model without layering, there will be recycled elements equivalent to at least 1.5 times more than that in the layered model, implying a longer average using period of products in sub-layers in the layered model. Up to 20% of the initial LIB packs were re-manufactured using recycled elements from collected cathodes in the layered model and then installed back into EVs, avoiding virgin materials use for manufacturing fresh LIBs. Figuring out each layer's inter-sector flows of materials, parts, and products allows for locating the CSC's weak point, thereby assists working out a guideline to improve material use efficiency.

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Organized session 1: Roles of Metal Refining in Sustainable Circular Economy

Base, rare and precious metals are important for the human society. However, the process of metal production causes heavy environmental impact and health hazard like mercury pollution or tailings dam failures. In addition, the demand of metals will increase by the economic development of the developing countries, and more "sustainable" metal production or recycling are required. With the aim of discussing the impact of metal refining or recycling, we call for studies addressing, but not limited to, technologies/environmental impacts/a convention or system related to metal refining or recycling.

Organizer Dr. Akihiro Yoshimura (Chiba University, Japan)

223: Session Keynote

ALTERNATIVES TO CURB MERCURY IN ARTISANAL GOLD MINING

MARCELLO M. VEIGA* [1] OMOTAYO FADINA* [1] PARIYA TORKAMAN* [1] AKIHIRO YOSHIMURA* [2]

Worldwide, artisanal gold mining (AGM) involves approximately 20 million people producing as much as 450 tonne/a of gold, but it is currently responsible for the main man-made mercury pollution. Millions of dollars have been spent to find a solution to reduce or eliminate mercury from this sector. Three typical types of approaches have been used by projects in the last 40 years: 1) environmental & health monitoring campaigns, stressing intoxication of miners and family members; these have not been working as miners do not believe in scientific papers or news, 2) technical-educational methods, demonstrating cleaner techniques to miners; it is partially working but most miners do not have technical assistance, skills or capital to adopt "new" techniques, 3) formalization-legal approach to prohibit the use of mercury in AGM, expecting that the miners follow regulations when there is no enforcement. Not any of these approaches have been effective and mercury use in AGM is increasing. The only approach to eliminate gold amalgamation that has been working and witnessed in the field is when organized companies buy the ores from artisanal miners for a fair price and provide technical assistance in the mining step. These companies process the ores using mercury-free technologies but usually with cyanide. Some environmentally-friendly techniques (e.g. gold concentration followed by leaching with bitter cassava or DMSO, etc) can be used by these companies. These techniques open opportunities to small, medium or large-scale companies to co-exist with AGM in their mineral titles and be more accepted by the local communities.

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ESTIMATION OF MERCURY USE AND LOST IN ARTISANAL AND SMALL-SCALE GOLD MINING (ASGM)

KOYO SUEMASU* [2] , AKIHIRO YOSHIMURA [2] , MARCELLO M. VEIGA [3]

Artisanal and small-scale gold mining (ASGM) is currently the largest emission and release source of mercury (Hg) to the environment. The UNEP Minamata Convention on Mercury, an international agreement to control Hg trades trying to curb Hg use in ASGM, entered in force on Sept 22, 2017 with 128 signatory countries and 125 ratifications. Previous studies of the amount of Hg annually used in ASGM, which is supposed to be the same as the amount lost, are fraught with uncertainties and with a large range from 1,400 to 2,000 tonnes/a. In this study, authors have estimated the gold production from ASGM using the difference between total production published from GFMS and production from large-scale gold mining (LSGM) published from Wood Mackenzie. As a result, the world Au production from ASGM in 2015, excluding countries lacking reliable data was estimated at 412 tonnes/a. with the use of 901 to 2,540 tonnes/a. of Hg. The estimated Hg emissions to air and releases to soil and water depend on the amalgamation method. African countries mainly amalgamate concentrates, therefore the ratio of Hglost to Au produced might range from 1.5 to 4.8. On the other hand,

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in Latin American and Asian countries, where mainly whole ore amalgamation is conducted, the estimate ratio ranged from 2.7 to 8.3, while in countries where both types of amalgamation is used the ratio ranged from 1.0 to 3.4.

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NOVEL REFINING PROCESS OF GOLD FROM ORE USING "ORGANIC AQUA REGIA" AS AN ALTERNATIVE PROCEDURE OF THE AMALGAMATION IN ARTISANAL AND SMALL-SCALE GOLD MINING (ASGM)

AKIHIRO YOSHIMURA* [1], TAKUMASA SUZUKI [1], OMOTAYO FADINA [2], PARIYA TORKAMAN [2], YASUNARI MATSUNO [1], MARCELLO M. VEIGA [2]

Artisanal and small-scale gold mining (ASGM) is currently the largest source of mercury (Hg) pollution, with over 2000 tonnes of Hg/a emitted and released to the environment worldwide. Such pollution has been causing outstanding health hazards in the developing countries. An alternative procedure of extracting gold from high grade ores or gravity + flotation concentrates is required to replace amalgamation. The authors have developed the "organic aqua regia" (OAR) method which uses dimethyl sulfoxide (DMSO) containing copper halide (CuX2, X = Br, Cl) to dissolve gold and silver and precipitate them by the addition of acidic solution. The authors had previously confirmed the recovery of gold from electronic wastes using this method. In this study, the authors applied the OAR to extract gold from a high grade Colombian artisanal mining ore, with 48 ppm Au. The ore was treated for 4-24 h at ambient temperature or 40 ° C. As a result, gold recoveries ranged from 94 to 100% within 24 h. The use of higher temperature reduces drastically the dissolution time. The process does not require activated carbon or electrowinning but filtration is still necessary. The DMSO, with a world production of about 100,000 tonnes, is a common solvent used in the cosmetic industry and it can be recycled reducing the costs of importation by developing countries. The OAR method, by its simplicity and low costs, can be a non-toxic alternative to amalgamation.

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THE ENVIRONMENTAL PERFORMANCE OF ENHANCED METAL RECOVERY FROM DRY MUNICIPAL SOLID WASTE INCINERATION BOTTOM ASH

JONAS MEHR [3], MELANIE HAUPT* [3], STEFAN SKUTAN [4], LEO MORF [5], LUGAS RAKA ADRIANTO [3], GISELA WEIBEL [6], STEFANIE HELLWEG [3]

This study assesses the environmental performance of the municipal solid waste (MSW) incineration bottom ash (IBA) treatment plant in Hinwil, Switzerland, a large-scale industrial plant, which also serves as a full-scale laboratory for new technologies and aims at an optimal recovery of metals in terms of quantity and quality. Based on new mass-flow data, we perform a life cycle assessment that includes the recovery of iron, stainless steel, aluminium, copper, lead, silver and gold. Fraction-specific modelling allows for investigating the effect of the metal fraction quality on the subsequent secondary metal production as well as examining further metal recycling potentials in the residual IBA. In addition, the implications on the landfill emissions of IBA residues to water were quantified. The impact assessment considered climate change, eco- and human toxicity and abiotic resource depletion as indicators.

Results indicate large environmental savings for every impact category, due to primary metal substitution and reduction of long-term emissions from landfills. Metal product substitution contributes between 75% and 99% to these savings in a base scenario (1' 000-year time horizon), depending on the impact category. Reductions in landfill emissions become important only when a much longer time horizon was adopted. The metal-based analysis further illustrates that recovering heavy non-ferrous metals – especially copper and gold – leads to large environmental benefits. Compared to the total net savings of energy recovery (215 kg CO_2-eq per tonne of treated waste, average Swiss plant), enhanced metal recovery may save up to 140 kg CO_2-eq per tonne of treated waste.

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ABIOTIC DEPLETION POTENTIALS FROM DIFFERENT TIME PERSPECTIVES BASED ON FUTURE DEMAND PROJECTIONS

RYOSUKE YOKOI* [1] , TAKUMA WATARI [2] , MASAHARU MOTOSHITA [1]

Depletion potential of metals is one of the main impact categories in life cycle impact assessment and the model for assessing it has been heavily debated. Although depletion potential depends on not only current status but also future status such as future demand and recycling, most existing models are based on only current status. In this study, we propose the extended ADP (abiotic depletion potential) to allow the assessment of depletion potential of metals from different time perspectives considering future metal demand and availability of secondary metals. ADP is one of the main characterization models for mineral resource depletion, quantifying the depletion potential by dividing the extraction rate by the square of a natural stock estimate. In the existing ADP, the current annual extraction is applied for the extraction rate.

We extend the ADP by applying the average extraction rate until the target year. The average extraction rates are estimated for 2010-2100 based on dynamic material flow analysis and logistic regression analysis. We calculate the extended ADPs for six major metals (aluminum, copper, iron, lead, nickel, and zinc) by five SSPs (shared socioeconomic pathways). The results show that ADPs for all five metals (aluminum, copper, lead, nickel, and zinc) increase relative to iron by considering the average extraction rate. It is due to the increase in extraction rate in the future for these five metals relative to iron. From the medium-term perspective (the target year is 2050), increase in ADP relative to iron is largest for copper for all SSPs (about 2 times larger relative to the existing ADP). On the other hand, from the longer-term perspective, increase in ADP relative to iron for lead and zinc exceeds that for copper.

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MINING LCA: THE FUNCTIONAL UNIT DILEMMA

JULIEN BONGONO* [3], BIROL ELEVLI [4], SEMRA CORUH [4] , BERTRAND LARATTE [3 4 5 6]

This work aims to review mining LCA-Life Cycle Assessment and especially the Functional Unit (FU) and identify the key points that could influence the final results. Also, our goal is to identify the missing points in the FU that could be consider avoiding some parameters that can be used to compare different mining processes. To constitute a database of studies which makes it possible to identify what is common beyond the contextual variations of the methodology in LCA, an intercontextual database of 15 publications was built, from which 7 studies were extracted to carry out transversal analysis of the FU. The criteria used for the selection of studies are: the exhaustiveness of the contexts, the timeliness of the studies and the operational realism. The critical analysis suggested that while there is a significant number of guidelines for certain difficulties encountered in selecting FU, such as the choice to include all of the functions or only part of the functions of the system, the consideration of both quantitative and qualitative functions, and the avoidance of bias and generalization, other difficulties, on the other hand, such as the prioritization of functions, uncertainty about the end use of the product or considering the interests of stakeholders are almost not found guidance. The lack of guidance on how to consider the final utility of the product and the interests of the stakeholders in the statement of FU, largely makes it difficult to compare, for instance, copper or alumina production from two regions of the world, as this does not only require considering the production process, but the whole environment around production as well as the humam aspects (e.g. environmental, human health; economic with employee income, working conditions, human rights, demographic variations and migration due to the presence of the mine).

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Organized session 2: Challenges and Opportunities of Sustainable Consumption and Production

Sustainable consumption and production (SCP) is key to transform the conventional linkage between consumers and producers in order to decouple economic growth from environmental impact while creating new values and bringing a better quality of life. This session will bring together researchers and practitioners to share the state-of-the-art research related to SCP. Speakers from different countries and diverse disciplines are welcome to join to exchange various approaches in addressing SCP issues, thereby deepening our understanding of challenges and opportunities in SCP context. Relevant topics include, but are not limited to, circular economy, sustainable design, consumer lifestyle, behavioral design, sharing service, product service system, policy design, and ecolabelling.

Organizer Dr. Yusuke Kishita and Dr. Eri Amasawa (The University of Tokyo, Japan)

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Transitions to sharing? Barriers and enablers for collaborative consumption in Southeast Asian cities

Monique Retamal* [1]

Collaborative consumption (CC) businesses offering shared-access to goods and services provide an opportunity to develop less resource intensive modes of consumption. The emergence of these businesses in rapidly growing economies in Asia therefore presents a potential contribution to sustainable consumption and production goals. Understanding the barriers and enablers for these emerging business types can provide important information for policymakers on how to support transitions to more sustainable consumption. In this study, we use the multi-level perspective framework to examine the socio-technical regimes influencing CC businesses in Hanoi and Bangkok, by drawing on document analysis and over sixty semi-structured interviews with policymakers, SCP experts, business owners and managers. In both countries, we found high-level policy support for sustainable consumption and production activities with many new laws and strategies being developed. However, so far there has been a lack of specific support for collaborative consumption style businesses that offer consumers the option to share and rent. The most significant barriers appear to be social norms regarding ownership, commercial norms, and business concerns such as a lack of access to finance. In both countries, there are a lack of legal definitions and appropriate business permits for collaborative consumption businesses, particularly with regards to transport sharing. For policymakers in Asia interested in supporting these business types, it will be important to establish appropriate legal frameworks and to undertake awareness raising campaigns to shift consumer perceptions.

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Sustainable Consumption and Production in Cities: Niches of Internet Biking and Circular Urban Agriculture

Jaco Quist* [2], Wenbo Yang [2], Graham Browning [2]

SCP in cities contributes hugely to the environmental footprint of cities, to a large extent due to importing products that are produced elsewhere. In Sustainability Transitions, novelty is assumed to emerge in niches, which can evolve around new sustainable and social innovations, including new sustainable and alternative consumption practices. This paper presents two cases using a niche-transitions framework. This paper presents two cases using a niche-transitions framework combining a transition multi-level perspective analysis with a Strategic Niche Management evaluation of the emerging sustainable consumption niches. Two cases in two different continents are presented. The first case consists of Circular Urban Agriculture in the Dutch city of The Hague consisting of three initiatives: (i) the Edible Park, a local permaculture initiative, (ii) Urban Farmers, a vertical farming business, and (iii) Haagse Zwam, a micro-firm that collects coffee waste locally, which is used to grow

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mushrooms. The second case consists of internet biking in the Chinese city of Hangzhou. The case describes the rise of internet biking initially leading to a quick increase of both internet biking firms competing among each other and issues on the streets and other public places, which were successfully addressed. These two cases illustrate opportunities and relevance for SCP in cities and also show that SCP in cities is a matter of addressing different domains of consumption, while local production and prosumers are important, as well as that it requires social innovation. A final point is that more attention and research is needed on how SCP and CE in cities relate one another and what possible synergies and pitfalls can be.

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Sustainable Consumption and Production (SCP) Initiative for Sustainable Solid Waste Management in Malaysia

Ahmad Fariz Mohamed* [1] , Eri Amasawa [2], Kishita Yusuke [2], Kojima Michikazu [3] , Benjamin Craig McLellan [4]

Malaysia experiencing rapid development growth for the past six decades, has learned managing solid wastes is a critical problem. With increasing development process through economic and social activities, solid wastes generation in Malaysia increased every year. The daily solid wastes generation reported was 13,000 ton/day in 1996 increased to 31,089 ton/day in 2019. Thus, the challenges of managing solid wastes in Malaysia is massive and complex. There is a need to change from end-of-pipe approach to a cyclic approach, where wastes treated as a valuable resource. However, the approach for sustainable waste management, must not base on wastes itself, must also focus at the products before it become a waste. Hence sustainable consumption and production (SCP) is the approach for sustainable solid wastes management in Malaysia. Government of Malaysia aware and concern about the need of SCP for its industry and consumers. Hence the initiatives have been taken and were driven by policies, strategies and action plan. These initiatives target not only on industry however it encompasses the consumers, and other key stakeholders. The implementation of SCP ideas has been determined since 2005, applying the "Zero Waste" concept and prioritizing the waste reduction, re-use and recovery approach. Later in 2016 the National Sustainable Consumption Production Blueprint was layout with comprehensive policy and strategies for SCP implementation in Malaysia. Current achievement could be seen in increasing recycling rate for solid wastes from 5% in 2005 increased to 28.1% in in 2019. SCP for solid waste management in Malaysia is a long-term commitment. With SCP approaches in place and practice by all the key stakeholders, the target of 40% recycling rate for solid waste by 2025 could be achieve. SCP as a concept must be translated through strategies and action plan which is important for a sustainable solid waste management in Malaysia.

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From the Asia Pacific SCP network to the National SCP networks: A case study of Thailand

Thumrongrut Mungcharoen* [5 6 7], Chaiyod Bunyagidj [5,6], Peeraporn Palapleevalaya [56]

During the APRSCP Board of Trustees Meeting in Melaka, Malaysia on 25 October 2017, it was proposed to encourage the establishment of national SCP networks in the region. So, the three representatives from Thailand returned home and started to make the arrangement. With the previous experiences in establishing Thailand Network on Eco-efficiency and Cleaner production (TNEC) which operated from 2001-2004, we organized several consultation meetings with the 26 SCP key players from various sectors in Thailand. They finally had joined hands to establish the "Thai Sustainable Consumption and Production Network" or "Thai SCP Network" on 25 September 2018 with the vision to drive Thailand SCP Roadmap 2017-2036. The network comprises of 11 key sectors, such as industry, agri-food, tourism and services, policy and planning, education and research, with the secretariat team from the four key organizations, i.e., Department of Environmental Quality Promotion, National Science and Technology Development Agency, Thailand Environmental Institute, and Thai SCP Association. Since its establishment, the network has more than 200 individual members and 7 organizational members, set up a website, published 2 SCP annual status reports, produced Thai SCP-experts database, and recently published monthly newsletters (since January 2021). The network has also organized more than 14 seminars, 2 training workshops, and 2 annual conferences. During the second annual conference on 15 September 2020, the

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network has signed the memorandum of collaboration with four partnership networks, i.e., GAP-net, PPP Plastics, UN Global Compact Network Thailand, and Thailand General Education Network. For international partners, the network has worked with APRSCP, UNEP, Switch-Asia SCP Facility, and PECoP-Asia research group, etc. In conclusion, Thai SCP network, established according to the encouragement of APRSCP, has grown up solidly during the past two years. However, there are still many challenging missions ahead towards "Sustainable consumption and production" of Thailand and the region.

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Sustainable Consumption and Production in Response to the Pandemic: Building Forward Together

Anthony SF Chiu* [1]

The 2030 Agenda for Sustainable Development presents a blueprint for addressing global challenges to achieve an inclusive and sustainable future. With this comes the recognition of the need for sustainable growth models supported by responsible consumption and production patterns. The emergence of the coronavirus disease (COVID-19) pandemic has challenged socioeconomic systems, public health, and environment. On the environmental aspects, the disease has pressured waste management systems from increasing municipal and biomedical wastes. Preventing future emergence of infectious diseases will need better management of resources to lessen environmental degradation, and stronger emphasis on resource efficiency, circularity and 3R to provide products with less inputs and waste. As authorities learn from and refine ongoing responses to the pandemic, the question remains on what economic recovery will look like following a pandemic that has roots on unsustainable consumption and production, and natural resource use. Regional cooperation and commitment to green recovery and natural resource management among others will be needed. On the national level, these responses can be translated to supporting measures related to SDGs like access to water and sanitation, and building resilient and sustainable infrastructure, and promoting public and private partnerships in sustainability initiatives. On the local level, responses can involve rethinking urban and rural development, redesigning business models and strengthening governance and social services. In all these responses, the essence of building back better needs to take on a sustainable approach, one that promotes green sectors, supports resiliency and climate goals, adopts circularity in growth, and creates localized responses tailored to the unique settings of communities and societies.

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A Resource Paradox Problem of Green Innovations

Eiji Yamasue* [2], Shoki Kosai [2], Shunsuke Kashiwakura [2]

Although green innovation is one of the important driving forces for building a sustainable society, it is apparent that many green innovations specifically focus on low-carbon technology. However, such innovation is often seen to induce additional resource demand. For instance, it is well-known that new generation vehicles with higher fuel economy require rare earth elements, lithium, cobalt, and nickel that were not used in such large quantities in conventional vehicles. This situation can be seen as a "resource paradox". Less attention has been paid to this resource paradox because of the lack of quantifiable indicators or insufficient databases on resource intensity. Total material requirement (TMR), is an indicator that quantifies the degree of mining activities required to supply direct material flows, in terms of hidden flows. The authors have been developing a database of TMR for various goods. The purpose of this study is to quantitatively reveal the resource paradox problem using TMR. In the presentation, we will introduce some of the more remarkable examples by comparing the TMR and lifecycle CO_2 emissions (LC-CO_2) or direct material input at the economy-wide, product, and metallic element levels.

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Consumer Behavior of Laundry-Machine Sharing Towards Sustainable Pathways

Dami Moon* [3], Eri Amasawa [3], Hirao Masahiko [3]

This study aims to clarify the characteristics of consumer behaviors that appear in applying the sharing economy to real life by using an example of laundry-machine sharing to examine the feasibility of achieving sustainable household consumption. The sharing economy is supposed an alternative for achieving sustainable consumption and production because it emphasizes consumer behavior of shifting from traditional consumption by ownership-based to new consumption by usability-based value. To

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confirm the feasibility of sustainability through the sharing economy, we used the example of laundry-machine sharing. We analyzed the laundry behavior differences and their environmental impact between private laundry machine (PW) users and coin-operated laundry machine (CL) users. Furthermore, we investigated the laundry behavior by country as part of generalizing consumer behavioral characteristics through laundry-machine sharing. As for a method, a web-based questionnaire survey was conducted with residents in Japan and Thailand having different PW ownership rates. The survey respondents were classified into groups according to the survey answers for PW ownership and the use of CL. Laundry behaviors and their greenhouse gas (GHG) emissions among the respondent groups in each region were analyzed and compared. As a result, Firstly, with the introduction of laundry-machine sharing, PW and CL mixed users appear not only PW-only users and CL-only users. Secondly, consumers who use CLs tend to use dryers, in addition to the basic use of a washer in the CLs to save time and laundry effort. Thirdly, CL has been used for different purposes in Japan and Thailand. These results provide a basis for assuming the possible environmental impacts of the sharing economy's proliferation by clarifying the consumer behavior differences between sharers and non-sharers. Further analysis of consumption-value for transforming consumer behavior would be needed to secure consumer behavioral changes towards a new consumption pattern in the future.

Organized session 3: Can we use a life cycle inventory analysis for material selection? - allocation methodology for the burden avoided by recycling among multiple products' life cycles

Energy transition from fossil fuels to renewable resources contributes to reduction of greenhouse gas (GHG) emissions, mitigation of climate change, and sustainability. This transition is relying on the material use for new technologies, and in turn causes environmental burdens such as GHG emissions. Although energy sources can replace each other at an equivalent calorific value, materials alternatives are more diversified. Particularly in transportation sector, lightweight materials can contribute to the reduction of energy consumption during operation. Furthermore, the differences in recyclability of candidate materials have to be taken into consideration. In a general life cycle inventory analysis, secondary resources consumed for production and recovered at end-of-life treatment do not tend to carry and avoid any environmental burden, respectively. This approach is called a "cut-off approach." However, in conducting a life cycle inventory analysis for material selection, the analysis should consider the consumption of secondary resources, use phase, and material recovery at the end of product lifetime. In the cut-off approach, the avoided burdens from the avoided natural resources and disposal are always allocated to the processes consuming and supplying the secondary resources, respectively. So far, several allocation approaches have been proposed, e.g., end-of-life recycling approach and waste mining approach. Amidst the theoretical developments of these methodologies, the time has come to apply those allocation methodologies to the actual cases. One of the major topics of this session becomes the material selection in automotive sector. In this session, we would like to have theoretical and empirical discussions about the evaluation of the environmental burdens associated with the use of different materials.

Organizer Dr. Ichiro Daigo, Dr. Daryna Panasiuk (The University of Tokyo), Dr. Kiyotaka Tahara (AIST, Japan)

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INFLUENCE OF DIFFERENT ALLOCATION APPROACHES FOR RECYCLING AND DYNAMIC INVENTORY ON CO_2 PAYBACK TIMES OF LIGHT WEIGHTED VEHICLES COMPUTED UNDER PRODUCT- AND FLEET-BASED ANALYSES: A CASE OF INTERNAL COMBUSTION ENGINE VEHICLES

PASAN DUNUWILA* [1], KO HAMADA [1], KENTARO TAKEYAMA [1], DARYNA PANASIUK [1], ICHIRO DAIGO [1], TAKEO HOSHINO [1], SHINICHIRO MORIMOTO [2], KIYOTAKA TAHARA [2]

Light weighting by material substitution is key strategy to uplift fuel efficiency and reduce CO_2 emissions during vehicle operation. The CO_2 benefits are a salient factor in selecting lightweight materials for vehicles, and are determined by conducting life cycle inventory (LCI) analyses centering the entire life cycles of the light weighted – and baseline vehicles. Though product-and fleet (multiple units of vehicles)-based LCIs have been conducted to determine these CO_2 benefits, none of them have investigated the influence of temporal variations of LCI parameters (dynamic inventory (DI)) and allocation approaches for recycling (approaches required to allocate environmental loads avoided by recycling, for instance, by consuming the scrap from the previous life cycle in the current life cycle) on CO_2 benefit evaluations, for the sake of accurate material selections. Therefore, this study aims at investigating aforesaid influences as a case of light weighting a steel- intensive internal combustion engine vehicle (ICEV) using lightweight materials, aluminum and magnesium. CO_2 payback time (CO_2-PbT; time required to achieve life cycle equivalence with steel-intensive vehicle) was used as an indicator for CO_2 benefits. Four allocation approaches for recycling were selected. Three LCI analyses; a-1) single-ICEV LCI analyses without DI; a-2) single-ICEV dynamic LCI analyses with and without DI; and a-3) fleet-based LCI analyses with and without DI, were conducted. Under a-3 without DI, all CO_2-PbTs for both light weighted ICEVs had delayed than those under a-2 at without DI; further gaps between CO_2-PbTs of aluminum-intensive ICEV remained larger than those of magnesium-intensive ICEV. Former can derive from the nature of the fleet model whilst the latter can be attributed to the influence of allocation approaches. Further DI had

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shortened the CO_2-PbTs of magnesium-intensive car highlighting its influence on CO_2-PbTs. The Implications of these findings are further discussed.

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MFA-BASED ESTIMATION OF RECYCLING INDICATORS FOR LCA RECYCLING

DARYNA PANASIUK* [1], KENTARO TAKEYAMA [1], PASAN DUNUWILA [1], ICHIRO DAIGO [1], TAKEO HOSHINO [1]

The modelling of recycling is one of the challenges related to the inventory aspects of Life Cycle Assessment (LCA). It includes the choice of allocation approach for recycling, consideration of co-products generation and use, as well as appropriate selection of parameters values. Recycling allocation is one of key sources of uncertaintity because different approaches lead to different results of the environmental impact. Allocation approaches, in their turn, are sensitive to the estimation of recycling parameters like metallic yield, recycled content and EoL recycling rate (RR).

Sensitivity of recycling parameters is particularly crusial for material selection. The estimation of these parameters requires the understanding of material cycle and recycling technologies. The values of these parameters in current LW models are varying greatly and are missing justification. Manufacturing yield is not systematically applied neither. It results in the lack of understanding of the recycling efficiency and misleading results when selecting materials.

Material Flow Analysis (MFA) provides an overview of material lifecycle and represents a reference tool for the estimation of recycling indicators. MFA can be used to for LCA, but not straightforward. To improve the comprehensiveness of the application of recycling parameters for LCA, the study defines recycling parameters, estimates them on the base of MFA and disscusses associated challenges. The focus is on metals used in automotive sector: steel, cast iron, AHSS, wrought/cast aluminium and magnesium.

The main difference identified between LCA and MFA definitions of parameters is the boundary between interrelated processes of production, leading to higher values of LCA parameters, compared to MFA. MFA represents a trustable source for calculation of recycling parameters for LCA, when consistency is ensured between LCA objectives, MFA scale, process boundaries and careful selection of flows for assessment.

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CONDITIONS FOR SELECTING AN ALLOCATION APPROACH OF THE AVOIDED BURDEN BY MATERIAL RECYCLING IN LIFE CYCLE INVENTORY ANALYSIS

ICHIRO DAIGO* [1], KO HAMADA [1], KENTARO TAKEYAMA [1], PASAN DUNUWILA [1], DARYNA PANASIUK [1], TAKEO HOSHINO [1]

During material selection, the producer has to concern about the environmental impacts associated with the use of the material. Thus, the differences in the recyclability of candidate materials have to be taken into consideration. In a general life cycle inventory analysis, secondary resources consumed for production and recovered at end-of-life treatment do not tend to carry and avoid GHG emissions, respectively. This approach excludes the recyclability from the comparison. We aim to address the selection of allocation approaches for the avoided emissions. Possible allocation approaches have been sufficiently discussed. The former articles select an allocation approach by defining whether the recycling is restricted by a supply or demand side. The domination of demand or supply is approximated to the market equilibrium problem and formulated by economic indices, such as price elasticity. Although the proposed procedure seems to be fair, it is hard to be applied in terms of practicality due to data availability and rapid fluctuation of prices. The basic concept of our methodology is that the additional effort to reduce GHG emission after the allocation has to contribute to GHG emission reduction in the whole system. The methodology helps to make a justifying selection of allocation approach among end-of-life recycling approach, waste mining approach, and 50/50 approach. The conditions for the selection include positive or negative change of GHG emissions by the recycling; the same or a different primary resource which the recycling can substitute; techno-economic factors, legislative factors, or supply-demand imbalance factor of constraining the recycling; fulfilling or not fulfilling required properties by the recycled material consuming additional secondary resource; and/or technology to avoid failing to fulfill required properties. Those conditions can be identified by LCA, MFA, and metallurgical knowledge.

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Organized session 4: Opportunities and Challenges for Plastics Recycling

Plastic production and consumption are increasing worldwide. Plastic products, in particular single-use plastics, impact the environment over their life cycles not only by entering the ocean but also by influencing climate change through greenhouse gas emissions from production to waste treatment. There have been wide-ranging discussions regarding approaches to solve and alleviate such problems, including the reduction and recycling of plastics. To reduce plastic usage and increase the amount of recycling, it is essential to quantitatively identify who uses and discards what types of plastics. Moreover, as the demand for recycled resin produced by mechanical (or material) recycling is constrained by quality deterioration and contamination by foreign substances such as plastic additives, recently chemical (or feedstock) recycling is attracting attention around the world. In this organized session, three topics including seven studies will be presented. First, emerging technologies and environmental implications of chemical recycling are discussed. Second, input-output modeling is applied to reveal material flows and environmental impacts of plastic packaging as typical single-use plastics. Furthermore, a substance flow study and a comprehensive database are presented for plastic additives including brominated flame retardants.

Organizer Dr. Jun Nakatani (The University of Tokyo), Dr. Hajime Ohno (Tohoku University, Japan)

224: Session Keynote

CHEMICAL RECYCLING: LCA APPLICATIONS AND IMPLICATIONS FROM EU PERSPECTIVE

MARTIN BAITZ* [1] MARTIJN GIPMANS [1] HANNES PARTL [1] CHRISTOPH KOFFLER [1] FABIAN LOSKE [1] MAIKE HORLACHER [1] STEFAN HORLACHER [1] THILO KUPFER [1] SOPHIE KIESELBACH [1] ULRIKE BOS [1]

In this session keynote speech, some insights concerning chemical recycling of plastics and LCA are presented. Firstly, we look into chemical recycling and LCA with some pioneer examples from industry. In detail, we present three scenarios of a complex LCA case study of a pyrolysis technology of BASF that was recently finished. We focus on consistent and efficient models, tools, and data solutions, as well as company/sector overarching harmonization of calculation rules to understand these complex supply chain. Then, we discuss application and implications of the mass balance approach to LCA of chemical recycling, especially focusing on engineering/marketing approaches, combined/separate systems, comparative LCA and footprinting, and balanced/bold communications. Furthermore, we explain the Circular Footprint Formula (CFF), an approach provided by European Commission, and its application in chemical recycling. We discuss how to share benefits/burdens of recycled material between primary and secondary product systems, how to select the avoided primary material and/or energy, how to handle downcycling, and how to avoid double counting or gaps of benefits and burdens. Overall, we conclude that we have to differentiate LCA study results and footprint figure communication, to define system expansion and upstream burden of waste input carefully, to consider multi-functionality of recycling, to define biogenic carbon modeling, and to be transparent about assumptions.

225: Invited

LATEST TRENDS AND CHALLENGES IN FEEDSTOCK RECYCLING TECHNOLOGIES FOR WASTE PLASTICS

SHOGO KUMAGAI* [2] JUN NAKATANI [3] YUKO SAITO [2] TOMOHITO KAMEDA [2] HAJIME OHNO [2] YASUHIRO FUKUSHIMA [2] TOSHIAKI YOSHIOKA [2]

Recent focus on ocean plastics pollution, and the decision to ban waste plastic import by China have significantly impacted several industrial sectors around the world. Yet, the global waste plastic generation is steadily growing, which has driven substantial and rapid growth in worlds' plastics recycling capacity to meet the needs for sustainable plastics use. Thus, immediate and substantial promotion of research and development of technologies for plastic waste recycling and creation of social and legislative frameworks for accelerating plastic recycling are in high demand. To enable substantial enhancement in the world's recycling capacity, we believe that feedstock recycling via pyrolysis technologies is of considerable importance. We have published a review article "Latest Trends and Challenges in Feedstock Recycling of Polyolefinic Plastics" [4], which summarizes

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global trends in waste plastics recycling and examines the trends and challenges regarding pyrolysis technologies, such as reactor design and effective catalytic pyrolysis, toward chemical feedstock recovery from polyolefinic plastics. In this presentation, we introduce the recent trends of catalytic pyrolysis of polyolefinic plastics for liquefaction, gasification, and carbon nanotubes recovery. Also, polyvinyl chloride (PVC) and poly(ethylene terephthalate) (PET) are well-known plastics causing corrosion of treatment facilities and deterioration of product quality. Therefore, I'd like to introduce our challenges for overcoming those PVC and PET issues in this talk.

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PLASTIC PACKAGING IN THE EU FROM PRODUCTION TO WASTE MANAGEMENT AND BACK AGAIN

CIPRIAN CIMPAN* [1], ANDERS STRØMMAN [1]

In the last years, the environmental and economic costs to society brought by the linear plastics economy, have gained substantial attention. While policy has made important steps, such as with the 2018 European Strategy for Plastics in a Circular Economy, the scientific understanding of this issue is still fragmented. Given the complexity of plastic use throughout the framework of our socio-economic systems, developing and implementing effective solutions cannot be done without a better understanding of various dimensions, including more comprehensive mapping of flows and how these are linked to final consumption, and the state and conditions determining management and reintegration of post-use materials back into production cycles.

Packaging is the largest plastic application globally and in Europe it accounts for 40% of plastic demand and constitutes 60% of the total generated plastic waste. In this work we study the material flows of plastics related to packaging in Europe (EU-28) and 2014 with the objective of gaining insight into interindustry flows and, wider, to look at the complete process chain in relation to circular economy. We construct a mixed-unit model, which combines mass flow data and the EXIOBASE 3 tables aggregated at 2-region level, denoting EU28 and the Rest-of-World (RoW).

Results include aspects of packaging use and waste generation intensity and analysis of circularity for the sector. We found food, beverage and chemicals manufacture as most packaging intensive sectors, while commerce, hotels and restaurants, and healthcare sectors generated significant waste amounts. Circularity within the packaging sector appeared overall limited, although substantial quantities of recovered plastics constituted input to other manufacturing sectors or was exported outside the EU.

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GREENHOUSE GAS EMISSIONS REDUCTION POTENTIAL OF TAIWAN'S PLASTIC PACKAGING CIRCULATION GOALS: SCENARIO ANALYSIS BASED ON WASTE INPUT - OUTPUT MODELING

JUI-HAO CHANG CHIEN* [2], PI-CHENG CHEN [2], KUANG-LY CHENG [2]

Transitioning toward a more circular economy might lead to significant carbon reductions. A society closing the loop of materials can reduce the demand for goods and the associated supply chains' embodied carbon footprints. Also, the circulation of resources reduces the greenhouse gases generated from the waste management system. Taiwan EPA has set the goals for better resource circulation of plastic packaging. However, the carbon reduction potential of these goals is still not clear. A whole life-cycle systems approach is needed to quantify the greenhouse gas (GHG) emissions of different circular policies' scenarios. We established a waste input-output (WIO) model of Taiwan to calculate GHG emission of a circular economy. The WIO model is derived from a WIO table of Taiwan, which comprises an intermedia transaction matrix (including 68 general and 40 waste treatment sectors), waste generation, and input matrix (685×108). An allocation matrix was compiled based on the waste treatment matrix (685×40). The GHG emissions coefficients of 108 sectors were constructed based on Taiwan's energy balance sheet and report of GHG emissions. The scenario of this research used Taiwan's plastic packaging reduction goals. Scenario 1 reduces the amount of disposable plastic packaging by 25%; Scenario 2 has the 50% recycling rate of recyclable plastic packaging achieves; Scenario 3 sets the proportion of recycled plastic as raw materials of plastic packaging to be 25%. The results show that scenario 2 is the best, reducing 425.8 $ktCO_2$-eq. GHG emissions, followed by scenario 3 with 275.5 $ktCO_2$-eq. Scenario1 only reduces 52.9 $ktCO_2$-eq. Compared with scenario 1, scenario 2 and 3 have more potential due to the lower demand for plastic raw materials and lower embodied carbon emissions. In the future, the developed WIO model will be applied in other materials' circular scenarios.

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Revealing Bromine Flame Retardants Flow in Japan with Input-Output Approach

Mayu Sasaki* [1], Hajime Ohno [2], Yuko Saito [3], Shogo Kumagai [3], Toshiaki Yoshioka [3], Jun Nakatani [4], Yasuhiro Fukushima [2]

Flame retardants are added to plastics, rubber, fibers, paint, and adhesive to prevent or slow the ignition of the materials. Among several types of flame retardants, brominated flame retardants (BFRs) have a large share due to its high performance even in a small amount by combining antimony trioxide. However, in waste treatment such as incineration, BFRs can be converted into dioxins and furans that are toxic to the environment and humans. Therefore, the use of some BFRs has been banned by RoHs directive and the Stockholm Convention on Persistent Organic Pollutants. Despite establishing the regulation on using the BFRs for the newly produced products, products containing the BFRs produced before the regulation remain in-use. These products will be discarded after the enforcement of the regulations. For that reason, we need to understand which products contain BFRs and consider appropriate disposal and recycling systems for the products. To identify the products containing BFRs, we quantified the BFRs' usage in the Japanese economy in 2015 using an Input-Output-based Material Flow Analysis (IO-MFA) approach. In this study, 11 types of BFRs are considered, including regulated BFRs, decabromodiphenyl ether (DecaBDE). BFRs spread across the economy via the abovementioned materials. The result reveals that the total of BFRs use induced by domestic demand for products is about 6,000 tons, of which 140 tons are DecaBDE. The top 10 sectors producing DecaBDE containing products account for about 52% of the total; the top 3 sectors were "Knitted apparel," "Plastic tableware, kitchenware, and miscellaneous household articles," and "Passenger motor cars," whose usages are about 15, 13, and 11 tons respectively. Based on the results, we can discuss appropriate disposal and recycling systems for products containing BFRs.

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A comprehensive plastics additives database and its potential application for plastics recycling scenario investigation

Magdalena Klotz* [5], Helene Wiesinger [5], Zhanyun Wang [5], Melanie Haupt [5], Stefanie Hellweg [5]

Plastics are ubiquitous in our lives and can provide advantages over other materials in terms of convenience as well as environmental impacts. Numerous plastics applications are enabled by the immense variety of additives used to tailor the plastic properties. While additives enable high performance in the use phase, their presence can complicate plastic recycling. In our research project, we aim to predict potential problems in recycling scenarios based on a combination of material flow analysis and a database of plastics additives. In a first step, a material flow analysis for plastic products used in Switzerland is conducted, focusing on their disposal and recycling as well as the applications of gained secondary materials. A distinction between the main plastics application segments, further divided into a total of 54 subsegments, is made. For each segment, the most frequently used plastic types are included, in total eleven plastic types. Based on the material flow analysis, and taking several incentives and barriers besides plastics additives in consideration, product streams suitable for increased recycling are identified. In a second step, a database containing information on more than 9,000 (potential) plastic additives is developed based on publicly available information. The database contains, inter alia, information on plastic types and plastic application segments, in which each additive may be used. To predict potential accumulation of plastics additives in secondary materials and environmental releases for future scenarios involving increased recycling, the developed database is integrated with the material flow analysis. The integrated assessment based on the plastics additives database and the plastics material flow provides a useful tool for designing future plastic products and their material flows, towards creating a more sustainable circular plastics economy, despite many remaining information gaps. Future work may focus on addressing specific data gaps as highlighted in this study.

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INPUT – OUTPUT MODELING FOR THE INTERSECTORAL MATERIAL FLOW OF PLASTIC PACKAGING IN JAPAN

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In 2019, the Japanese government developed a strategy for plastics and laid out ambitious targets including the reduction of 25% for single-use plastic waste and the reuse/recycling of 60% for plastic packaging by 2030. However, the current usage situation of single-use plastics including plastic packaging, which should be a basis of the strategy, is unclear. It is essential to quantitatively identify who uses plastic packaging to supply products, and who purchases these products and discards their packaging. Against this backdrop, we develop a model for material flow analysis using input – output tables that specifies the intersectoral flow of plastic packaging. We apply the model to the nationwide material flow of plastics in Japan (2000, 2005, 2011, and 2015) and discuss which types of plastics should be collected from what sources to achieve the recycling target set by the government. Of the domestic plastic demand of 8.4 Mt in 2015, 1.6 Mt and 2.5 Mt were estimated to be for plastic packaging comprising household and industry inflows, respectively, through the purchase/procurement of products, services, and raw materials. Considering the current amount of recycling collected from households (1.0 Mt) and industries (0.3 – 0.4 Mt), the reuse/recycling target has already been achieved if the goal is limited to household plastic packaging waste, as is the focus of Japan' s recycling law. Conversely, the results indicate that it will be extremely difficult to reach the target collectively with industries. Therefore, it is essential that efforts be made throughout the entire supply chain. Food packaging that flowed into the food-processing and food-service sectors accounted for 15% of the inflow of plastic packaging into industries. Thus, the key to achieving the reuse/recycling target will comprise the collection of plastic food packaging from not only households but also the food industry.

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A LCA OF BIO-H_2 THROUGH THE BIOMASS CO-GASIFICATION OF SEWAGE SLUDGE EQUIPPED WITH BECCS

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The Intergovernmental Panel on Climate Change (IPCC) has pointed out that we need to achieve a negative emission (carbon fixation and/or removal technologies) scenario, in which CO_2 emissions are negative globally in the second half of this century. To achieve the goal, mainly, the promotion of the low carbon fuel effective uses and/or the removal technologies would be better.

We have developed the synthetization technology of hydrogen from the biomass resources which have a characteristic of carbon neutral and the H_2 purification system of 2-step PSA in which almost CO_2 gas in the syngas would be separated. In addition, it is known that the removal technology of carbon capture and storage (CCS) has a potential to lower emission aspect. In particular, in the case of the combination with biomass energy systems, which is called bio-energy with carbon capture and storage (BECCS), the emission level can be a negative status.

In this study, the H_2 production system through the indirect gasification process including 2 step-PSA in use of sewage sludge was discussed. In the critical issue of gasification process, the production rate of H_2 cannot be improved due to the lower heating value of feedstock.

Therefore, the additional heat resource of charcoal, that is, the co-gasification process was considered to enhance the production performance, and the sequestration effect of CO_2 from syngas was argued. That is, the first idea is to abate the eco-burden by increasing the production volume per 1kg feedstock of H_2, the second is to reduce the emissions. Here, through the process design in use of the process simulator (ASPEN-Plus ver.11), we investigated the H_2 production performance including the auxiliary power of entire system. Based on the estimation, we analyzed the impact intensity in use of LCA on the combination of co-gasification and/or BECCS.

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PROCESS SIMULATION AIDED CRADLE-TO-GATE GREENHOUSE GASES EMISSION ACCOUNTING ON A NOVEL CO_2 CONVERSION PROCESS: DIRECT DIMETHYL CARBONATE SYNTHESIS FROM CO_2 AND METHANOL

HAJIME OHNO* [3] , YASUHIRO FUKUSHIMA [3]

The direct synthesis of dimethyl carbonate (DMC) from CO_2 and methanol is an attractive alternative route utilizing CO_2 instead of toxic phosgene as a carbonate source. The route is thermodynamically difficult because of the equilibrium limitation of the reaction $2\,CH_3OH + CO_2 \rightleftharpoons (CH_3O)_2CO + H_2O$. In addition, the azeotrope formed by DMC and methanol makes the separation of DMC from unreacted methanol complex and energy intensive. The use of CeO_2 and 2-cyanopyridine as a catalyst and dehydration agent solved both the equilibrium constraint and the separation challenge. In this study, the direct DMC synthesis from CO_2 and methanol over CeO_2 with 2-cyanopyridine was evaluated in terms of greenhouse gas (GHG) emission with the aid of process simulation. It was validated that the cradle-to-gate greenhouse gas emission attributed to the product of this system (0.39 kg-CO_2-eq/kg-DMC) becomes much lower than that of conventional commercialized processes. The heat exchange in the process reduced the emission further to 0.34 kg-CO_2-eq/kg-DMC. Among the items associated with emissions, methanol consumption shared the largest part (0.63 kg-CO_2-eq/kg-DMC), while the converted CO_2 was regarded as an important offset (-0.49 kg-CO_2-eq/kg-DMC). It is due to the use of the typical methanol production from natural gas (0.88 kg-CO_2-eq/kg-methanol). It suggests that if the methanol production with its associated GHG emission accounting for less than 0.41 or 0.34 kg-CO_2-eq/kg-methanol could be applicable for with or without heat-exchanging cases, the presenting process achieves negative emission. Furthermore, based on the results, the requirements for the practical process implementation are discussed by comparing the lifecycle GHG emission results with other DMC synthesis routes.

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TECHNO-ECONOMIC AND ENVIRONMENTAL ASPECTS OF THERMOCHEMICAL ENERGY STORAGE SYSTEM TO UTILIZE UNUSED ENERGY OF SUGARCANE: A CASE STUDY AT SUGAR MILL

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Local unused renewables should be utilized effectively to achieve sustainability goals. This study focuses on sugarcane which is one of the most productive biomass sources. The solid residue of sugarcane after the milling process (termed "bagasse") is supplied as a fuel to boilers at sugar mills. The post combustion flue gas of bagasse has untapped energy which should be harvested. Our thermochemical energy storage system can store the unused heat derived from bagasse combustion into heat storage materials (i.e., zeolite) that can be transported to nearby industrial heat demands that currently consume fossil fuel. A zeolite steam ad/desorption cycle was employed as the heat storage method for this study. A heat charging device and heat discharging device employing a moving bed reactor were proposed. Numerical simulations of process performance were validated by bench-scale testing. Additionally, a process simulation to quantify the material and heat flow within a sugar mill was developed and merged with the heat storage process simulation. A drying process to increase the heating value of bagasse was proposed and the alteration to the heat charging potential and power generation was predicted.

All performance predictions for the various systems were merged into a techno-economic and environmental analyses to clarify the effects of altering the sugar mill processes. From the economic analysis, the electricity cost due to the blower, which injects hot air into the zeolite bed of the heat charging device, has a large impact on operating expenses. Additional power generation was expected by applying the bagasse drying process and can compensate for the electricity consumption of the blower; this leads to a decrease in the heat charging cost. The system is financially viable when a sufficient subsidy rate is provided. Around 70 t-CO_2/y is expected to be avoided by the system.

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DESIGNING TECHNOLOGY ROADMAPS OF THERMOELECTRIC GENERATORS TOWARDS A CARBON-NEUTRAL SOCIETY

SHUN KASHIMA* [1], YUSUKE KISHITA [1], KOTARO KAWAJIRI [3] , YUKIHIRO ISODA [4], YOSHIKAZU SHINOHARA [4]

Thermoelectric generators (TEGs) have the potential to contribute to the realization of a carbon-neutral society by recovering electrical energy from various types of waste heat. However, TEGs have not yet been marketed due to high cost and low energy conversion efficiency. In order to clarify the gap between market needs and technological developments and discuss how to fill the gap, this paper designs technology roadmaps to clarify the conditions (e.g., technology development goals) for the future diffusion of TEGs. Here, a technology roadmap refers to a diagram showing how the environment surrounding the technology should change toward a future vision, drawn along a timeline. The roadmap consists of 3 layers, that is, Market, Product/Service, and Technology layer.

Aiming to prototype the roadmap design process, we developed technology roadmaps of TEGs using online interviews with two companies. Based on the results, we hypothesized that the entire technology roadmap design process consists of 5 steps, that is, (1) problem setting, (2) preparation and research, (3) information gathering and idea generation, (4) organizing, structuring and analyzing the results, and (5) feedback. In addition, we defined three types of links to distinguish the different relationships between events, i.e., causal relation, detailing, and competing.

To verify the applicability of the proposed method, we conducted an online workshop, in which three experts from different companies working in the thermoelectric generation business were invited to design a TEG roadmap. Through the roadmap design process, it was discussed how TEGs could be diffused in society to meet social needs.

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DETERMINING THE PERFORMANCE REQUIREMENT FOR RECYCLING TECHNOLOGIES FOR CARBON-CONTAINING PRODUCTS BASED ON THE ICEBERG APPROACH

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For deep carbon emission reductions beyond decarbonization of the energy supply, among reduction streams, recycling-induced elimination of materially retained carbon (MRC) releases to the atmosphere have a great direct reduction potential. Moreover, the use of recycled materials indirectly avoids the manifestation of cradle-to-gate carbon footprints of virgin materials that would otherwise enter anthropogenic cycles. These facts have been individually revealed by preceding studies on lifecycle assessment of recycling technologies and carbon footprint accounting. However, the limited focus on specific waste and recycling technologies might narrow the range for the future development of recycling activities. This study comprehensively quantifies the carbon emission reduction potential of recycling activities through an input-output based material flow analysis. Here, we reveal the Japanese economy-wide potential emission savings, both direct (12.8 Mt-CO_2) and indirect (17.5 Mt-CO_2), that could have been achieved through maximal MRC recycling from households (i.e. post-consumer recycling) in 2011, outweighing potential energy recovery through waste incineration (3.1 Mt-CO_2). Further, we found that incineration of plastic-containing products currently not covered by recycling laws is likely to cause 3.9 Mt-CO_2 emissions. These are first-order estimates of reduction potentials of post-consumer recycling encompassing the entire national economic structure by regarding the potential emission savings as an iceberg, i.e., the direct saving is the "tip," and the indirect saving is the hidden "bottom" of the iceberg. Energy-induced carbon emissions in recycling activities are excluded from these estimates, allowing for the deduction of acceptable energy usage for recycling activities. The identified structures of direct and indirect reductions on value chains allow for efficiently directing the advancement of recycling technologies and policies toward the deep decarbonization of society.

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ASSESSING CARBON FOOTPRINT REDUCTION POTENTIAL OF LIFESTYLE CHANGES IN CITIES: ILLUSTRATIVE PATHWAYS OF 52 JAPANESE CITIES TOWARDS 1.5 ℃ TARGET

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Lifestyle change has been recognized as an essential element of climate change mitigation actions by governments and research communities. Cities are expected to play a major role in enabling and facilitating the decarbonization of consumer lifestyles, considering its large direct and indirect climate change impacts through consumption of products and services. Although existing studies identified the hotspots of urban consumption and variation of carbon footprints between cities, most studies are focusing on the current status rather than future transitions. In this study, city-specific carbon footprint reduction potentials of more than 60 lifestyle changes were quantified and illustrative pathways towards decarbonization target are proposed with cases of 52 major Japanese cities. The city-level per-capita carbon footprints of household consumption were estimated using household expenditure statistics and input-output method. The units of consumption are hybridized with the price and physical consumption data, and total carbon footprints were adjusted to the national inventory. Lifestyle change options related to mobility, housing, food, goods, and leisure were identified by the literature review, and their mitigation potentials for specific cities were modelled using the city-level footprint database. The results of the analysis revealed a large variation in the impacts of lifestyle changes between cities, even within the same country, and the necessity of ambitious actions in all cities but with different levels and priorities. The scenario analysis suggested that both types of lifestyle changes, efficiency (e.g., end-use technology introduction, improving the efficiency of similar products) and sufficiency (e.g., consumption amount, shifting modes, be-

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havioural changes) approaches are necessary to reduce the footprints to the 1.5-degree target of the Paris Agreement. The approach in this study is useful to evaluate city-specific carbon footprint reduction potential by lifestyle changes considering the local context and to incorporate lifestyle changes in cities' mitigation strategies with fully considering the life cycle impacts.

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THE SCALE AND DRIVERS OF CARBON FOOTPRINTS IN HOUSEHOLDS, CITIES AND REGIONS ACROSS INDIA

JEMYUNG LEE* [1], TAHERZADEH OLIVER [1], KEIICHIRO KANEMOTO [1]

The carbon footprint (CF) has emerged as an important yardstick to understand the total contribution of countries, sectors and individuals to climate change. In contrast to conventional emissions accounting which captures only territorial or local production activities, a CF includes the emissions imposed by consumption across global supply chains for goods and services. Recent interest has grown in the application of CF assessment for municipalities owing to their large contribution to global carbon emissions and the limited coverage of existing data to monitor their climate pledges. By linking household-level consumer surveys to a global supply chain database, spatially-explicit CF assessment is possible at a district and household scale. To date, such technique has exposed otherwise unforeseen differences in consumer carbon footprints in developed countries. Within this study we calculate and compare the household carbon footprints 623 districts in India, based on micro consumption data from 203,313 households and explain their variation by economic, cultural and demographic factors. We show the eradication of extreme poverty does not contradict with climate change mitigation in India. However, our analysis suggests CF reduction policies within India need to target high-expenditure households which are responsible for nearly seven times the carbon emissions than low-expenditure households (living on $1.9 consumption a day). These vast disparities between the carbon footprint of citizens in India highlights the need to differentiate individual responsibilities for climate change in national and global climate policy.

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URBANIZATION AND CARBON DIOXIDE EMISSIONS: INDEX DECOMPOSITION ANALYSIS FOR 30 PROVINCES IN CHINA

YUZHUO HUANG* [2], KEN'ICHI MATSUMOTO [2]

China's extensive and growing CO_2 emissions are linked to rapid economic development and advancing urbanization, posing serious concerns in the context of climate change. Decomposition analysis has been widely performed to identify drivers of China's CO_2 emissions. However, to date, no studies have examined the impacts of urbanization on CO_2 emissions across all of its provinces. Using provincial statistical data and six key factors influencing CO_2 emissions (carbon and energy intensity, residential consumption and consumption inhibition, and population urbanization and size), we applied the logarithmic mean Divisia index (LMDI) decomposition method to examine how urbanization affected CO_2 emission changes across 30 provinces between 1990 and 2016. Our results indicated that while urbanization's impacts on CO_2 emissions increased in China as a whole during this period, they were regionally differentiated. The energy intensity effect was the main driver of reduced CO_2 emissions, with carbon intensity exerting weaker effects in the 30 provinces, differentiated by their energy structures. The residential consumption effect, which is strongly linked to advancing urbanization, was the primary driver of increased CO_2 emissions in all of the provinces. While the consumption inhibition and population urbanization effects were positive at the national level, they were negative in highly urbanized provinces and in highly industrial provinces. These findings highlight the need to promote environmentally friendly consumption and to design regionally differentiated policies and optimized energy structures tailored to particular urbanization contexts. Moreover, they can provide valuable inputs for other developing countries undergoing continuous urbanization, contributing to efforts to balance economic development and environmental sustainability.

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LIFE CYCLE CARBON EMISSIONS OF WOOD-BASED PRODUCTS: A CASE STUDY FROM DIFFERENT LAND CONVERSION SCENARIOS IN INDONESIA

RIO ARYAPRATAMA* [1], STEFAN PAULIUK [1]

Wood-based materials could contribute to climate change mitigation by prolonging the carbon storage in the anthroposphere. Despite the abundant forest resources, there is a possibility that wood-based products produced in Indonesia may originate from unsustainable sources due to wide-spread land-use changes since the past decades. Therefore, a comprehensive assessment covering biospheric and technospheric woody carbon flows and emissions over time is needed. In this study, we combined dynamic material flow analysis, stock modeling, and life cycle assessment to estimate life cycle carbon emissions over time of wood products from different land conversion types in Indonesia on a hectare (ha) basis. Our results show that the wood production from clear-cut primary forest conversions to oil palm and timber plantations and secondary forest lead to net carbon emissions between 429 – 1290 t-CO_2-eq/ha at the end of the 200-year time horizon (TH). The counter-use scenarios of using non-renewable materials or energy while leaving the primary forest untouched display 43 – 88% lower global warming potentials at the end of the TH than converting the primary forest to oil palm plantation and secondary forest for wood products. Meanwhile, wood products produced through forest plantation from restored degraded land (DL_FP) and reduced-impact logging (RIL) of primary forest went beyond carbon neutrality, displaying carbon removal potentials of up to around 407 and 62 t-CO_2-eq/ha, respectively. At one ha-scale, our results indicate it would be preferable to keep the primary forest intact, even when emissions from the counter-use of non-renewable materials or energy are factored in. Utilizing wood products would be only favourable from a climate point of view if produced through DL_FP or RIL scenarios. Our results could help screening of policy options regarding preferable land-use strategies to produce wood products in Indonesia. They can also inform further national-scale prospective analyses of wood products' climate mitigation potential.

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THE CARBON FOOTPRINT OF GLOBAL MATERIAL PRODUCTION

EDGAR HERTWICH* [2]

The production of materials is widely recognized to be an important source of greenhouse gas (GHG) emissions and a range of policy processes now aim at enhancing material efficiency and circular economy. Yet, our understanding of the dynamics and drivers of material-related GHG emissions is limited. Previous analyses did not cover all materials and neither did they address the use of the materials nor their enabling of final consumption. Here, the hypothetical extraction method is used to quantify the GHG emissions from material production in EXIOBASE, a multiregional input-output model of the global economy, and to trace the carbon footprint of materials from production through their first use to final consumption. GHG emissions from material production increased by 120% in the period 1995 – 2015 to 11 Gt CO_2e, rising from 15 to 23% of global emissions. China accounted for 75% of the growth. Capital formation drives two thirds of emissions. Two fifths of materials in terms of GHG are used in construction, and two fifths are used in the manufacturing of machinery, vehicles, and other durable products. Policies addressing the rapidly growing capital stocks in emerging economies hence offer the best prospect for emission reductions from material efficiency.

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DYNAMIC MATERIAL FLOW ANALYSIS OF MOTORCYCLES UNDER CARBON REDUCTION GOAL IN TAIWAN

PIN-YEN FANG* [3], HSIN-TIEN LIN [3]

Motorcycle is a major means of transportation in many Asian economies, including Taiwan. However, motorcycles are significant contributors of air pollution and carbon emission in cities. Modal shift into electric motorcycle (or e-scooters) is a potential solution to pollution problems. CO_2 emission mitigation may be expected when e-scooters replacing conventional motorcycles, but corresponding End-of-Life motorcycle generation and resource requirement in motorcycle production cannot be neglected. This work presents the dynamic material flow analysis of modal-related resources from motorcycles under the carbon reduction goal in Taiwan in 2050. We calculated the required e-scooter numbers to achieve the carbon reduction goal under three scenarios: current energy mix, renewable energy

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20%, and renewable energy 50%. Our results showed that it required approximately 50% ownership rate of e-scooters to reach the goal in 2050, which will lead to considerable amount resource requirement and waste flow. The different material composition of conventional motorcycle and e-scooter is causing the variation of waste flow materials. The system developed in this work can be applied to the prediction of waste flow in detail and planning of the recycling policies.

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Multiple Linear Regression Analysis of Agricultural Inputs and Greenhouse gas(GHG): A Case Study of Sugarcane Cultivation in Thailand

Natsuda Yokshoo [1], Wanwisa Thanungkano [1], Ruthairat Wisansuwannakorn [1], Jitti Mungkalasiri* [1]

Correlations of agricultural inputs and global warming potential are the starting point of this research. the Multiple Linear Regression Analysis (MLRA), a causal relationship analysis technique, was employed to determine relationship and predicted the value of one dependent variable based on two or more independent variables. In general, the analysis of such a relationship should be reasonable, accurate and as consistent as possible. This research was carried out on production data by sample survey from sugarcane farmers in Thailand. By considering the agricultural inputs as follows: (1) chemical fertilizers consist of urea, nitrogen (N), phosphorus (P) and potassium (K) fertilizers, (2) water resource consist of irrigation water, ground water and reservoir, (3) pesticides consist of Paraquat, Ametryn, Atrazine and 2,4 dichloraphonol and (4) energy consist of diesel and gasoline for preparation, plantation and maintenance. The climate change impact is considered as it is a major global environmental problem, and the agricultural sector generated greenhouse gas emissions that are the root cause of the problem. The results found that the urea was the most related to climate change impact with a 95% confidence interval, followed by nitrogen (N), Ametryn, and diesel oil for sugarcane maintenance, respectively. The research has answered the question of the relationship of variables. The findings can be applied to the preparation of Life Cycle Inventory which can benefit to reduce budget constraints and time consuming by using primary data collection approaches.

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How to achieve carbon neutral in consumer goods industry: Case of oil palm production in Indonesia

Joni Jupesta* [2]

Since 2019 several global consumer goods industries have set their target to become carbon neutral. The carbon neutral from consumer goods is dependent to the greenhouse gasses (GHG) emissions from their major ingredients i.e.: oil palm. This crop has nonetheless become one of the most controversial today because, despite its high productivity, high applicability and ability to alleviate poverty, the palm-oil development is most often at the cost of deforestation, which causes greenhouse gas (GHG) emissions and biodiversity loss. This study aims to assess the possibility for the palm oil towards carbon neutral to achieve Sustainable Development Goals (SDGs); in particular SDG 13 (climate action). The methodology of this study is by explore the mitigation pathway to reduce the GHG emissions from oil palm in its current state based on Roundtable Sustainable Palm Oil (RSPO)' study. The current Business as Usual (BAU) the greenhouse gasses (GHG) emissions from palm oil is 0.6-ton CO2eq./ ton Crude Palm Oil (CPO). The study shows that four scenarios: Land, POME utilization technology, new planting materials and nutrient (fertilizer) management could contribute to the GHG emissions reduction at value -0.36-ton CO2eq./ ton CPO, 0.15 tonCO2eq./ton CPO, 0.3-ton CO2eq./ ton CPO, and 0.06-ton CO2eq./ ton CPO respectively. Altogether, those four scenarios contribute -0.37-ton CO2eq./ ton CPO. It is expected that the result become reference guidelines to accelerate the carbon neutral for the final consumer goods products. With 47.4 million-ton CPO produces in 2018 hence the potential for negative GHG emissions is 301.94 million-ton CO2eq; 20.7% of Indonesian GHG emissions in 2016 (1,457 million-ton CO2eq.).

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