The 15th Biennial International Conference on EcoBalance

EcoBalance 2022

Shifting Paradigms with Life Cycle Thinking

Abstract

October 30 -
November 2, 2022

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Plenary sessions

Plenary session (1): Shifting Paradigms with Investment

[Plenary talk] Trends and expectations in the investment industry for carbon neutrality

Hiroshi Ozeki
Nissay Asset Management Corporation, Japan

Nissay Asset Management was founded in 1995 as an asset management company of the Nippon Life Group. We signed the United Nations Principles for Responsible Investment (UN-PRI) in 2006 when it was launched, and have been involved in ESG management for more than a decade. The issue of climate change is a topic that the world must work together to address, but there are both risks and opportunities in addressing carbon neutrality, and the role of the asset management industry is becoming increasingly important. As a member of the Net Zero Asset Managers Initiatives (NZAMI), Nissay Asset is striving to achieve net zero CO2 emissions from assets under management by 2050.

Investments related to "ESG" and "carbon neutrality" are now commonplace. In the past, investments in companies that excelled in ESG initiatives were called "ESG investments. However, in order for society as a whole to move toward carbon neutrality, it is important to invest not only in "good investments" that actively address ESG issues, but also in "bad investments. We must promote a paradigm shift. We believe that it is extremely important to provide transition finance to companies with large carbon footprints that are willing to make the transition to net zero, including business restructuring, or to make impact investments that contribute to net zero through innovation and other means.

In order to achieve carbon neutrality, for example, it is important to optimize the entire cycle of electricity generation, storage, transmission, use, and reuse, rather than partial optimization. Such efforts require technological innovation and infrastructure development in each of these areas, which in turn require a great deal of capital, and as an asset management company, our role in supporting such efforts in the form of transition finance and impact investment is now increasing.

Our corporate slogan is "A Good Investment for the Future" to help realize a sustainable society. As an asset management professional, we hope to play a role in the realization of a sustainable society by identifying and investing in good investment opportunities that will enable us to achieve both a good return and contribute to improving environmental and social sustainability over the medium to long term.

[Plenary talk] Corporate biodiversity impact assessment using biodiversity footprinting – bridging the gap between nature and business

Justine Bolton
FirstRand Limited, South Africa

Biodiversity and functioning ecosystems are essential for livelihoods and economies. Biodiversity is important to business in terms of providing inputs, but also in terms of preventing ecosystem collapse and loss of GDP. In addition, nature provides key life support systems in terms of climate change mitigation and adaptation, but poor ecosystem health can also exacerbate these climate risks.

Globally, as awareness and action on climate change grows, there has been a shift in focus towards nature related risks and impacts, and a rapidly growing discourse on natural capital and biodiversity in the business sector.
But time is running out. To achieve the Convention on Biological Diversity's global of protecting and restoring the Earth's biodiversity, and transforming society's relationship with biodiversity and nature over the next decade through post-2020 framework process – businesses, governments and communities need to support each other and take action now.

Businesses have a role to play by engaging with emerging frameworks such as the Task Force on Nature Related financial disclosures; participating in implementation projects; conducting biodiversity footprints (for example using the PBAF guidance) to understand impacts of their business, as well as the dependencies of their business, on nature; and integrating these considerations into business strategy so as to drivee change through core business. Systemic thinking is needed to address challenges and enhance opportunities, including those of a Just Transition that integrates people, planet and the economy.

Plenary session (2): Shifting Paradigms in Industrial Sustainability

[Plenary talk] Achieving ESG and Growing Sustainability

Nuttavut Intarode
The Siam Cement PLC (SCG), Thailand

Achieving ESG – Environmental, Social, and Governance dimensions and growing sustainability helps the corporate establish the resiliency and drive long-term value for the businesses. Thus, ESG has become a must have and huge opportunities to satisfy customers, employees, and other stakeholders. To become a sustainable business, listed companies are required to do thing differently while not enough to turn just a profit. As the world has changed drastically and is facing challenges all around, I do believe that ESG is not just a framework to create a business growth, rather, it is the way to help all sectors including government sector, private sector, and public sector to collectively come together to build the right balance circumstances and deliver a better world for our next generation.

Presentation list: VOD spotlight

V-1

How IoT helps to achieve sustainable supply chain management——A study based on two supply chains

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As a representative Industry 4.0 technology, the Internet of Things (IoT) brings new opportunities for the intelligent and flat transformation of supply chain organizations, and could help to improve its environmental, economic and social performance under fierce competition. In order to explore the specific effect of IoT in improving the performance of green supply chain. This paper establishes the operation and competition mechanism of a IoT supported two-tier and a traditional three-tier supply chain mode based on system dynamics and agent-based modelling. The demand for products is regarded as a driving force. Three-tier supply chain is modelled with several active agents (retailers, wholesalers, and manufacturers), and runs as the products go from manufacturer to wholesaler, then flows to retailer, and finally are delivered to the consumers in market. Each agents has a specific manufacturing, inventory and delivery strategy. IoT supported supply chain has much radical zero-inventory and shipment strategies due to punctual and accurate information transmission, and wholesaler has been replaced by manufacturers directly connecting with retailers. Taking a hypothetical logistics scenario as an example, the two modes are simulated and compared within carbon emissions, profitability and market share dimensions. The results show that by pursuing zero inventory and more aggressive scheduling and transportation strategies, IoT technology can significantly reduce overall inventory levels and transportation emissions from different logistics nodes, with average daily emissions drop of 31%. In contrast, the overall profitability of the IoT supply chain increased by 37.1%, while the market share gap between two products is relatively small, normal supply chain has 6% higher value.

V-2

Oil price pressure on the Japanese economy: An unit structure analysis

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[1]School of Economics, Kyushu University, Japan; [2]School of Economics, Kyushu University, Japan; [3]Faculty of Economics, Kyushu University, Japan

Crude oil prices have increased by 40% during the period between 2015 and 2022. Thus, the Japanese economy has clearly experienced a rapid increase in the crude oil prices due to the global oil supply insecurity caused by the Russian aggression against Ukraine. It is important to note that the rapid oil price increase has a significant impact on the production cost of industries because they directly and indirectly use crude oil via supply chains. This study focuses on cost pass-through describing that a business entity changes the price of goods or services in response to a change in the energy cost of producing them. To model the cost pass-through via product supply chains, we develop a new cost-pushed unit structure approach that is capable of describing an adjacency

matrix by weighting the energy cost increases embedded in transactions between each sector. We then applied cluster analysis to the adjacency matrix to find industry groups with overconcentrated energy cost increased in the supply chain network. From the results based on the 2005, 2011, and 2015-linked input-output tables, we found that the pressure on Japanese economy due to rising oil prices decreased considerably. Furthermore, we observed that fishing-related cluster had the highest effect of the pressure caused by increase in oil prices during the study period. Based on the cluster results identified in this study, policy makers should define a priority for aiding supply chain groups with higher oil price pressure.

V-3

Comparative life cycle assessment of fired clay bricks and alternative concrete blocks used in Bangladesh

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Fired clay bricks are widely used as a construction material in Bangladesh. Use of top fertile soil for clay brick production and burning of those bricks are associated with detrimental environmental impacts (e.g., air pollution, loss of land, CO2 emission) in Bangladesh. At present various commercial and experimental concrete blocks are being used in the country as alternatives to fired clay bricks, which have potentially less environmental impacts. However, comprehensive studies on comparing the environmental impacts of burnt clay brick and its alternatives are still lacking. This study aims to measure the environmental footprints of concrete blocks and compare them with traditional fired clay bricks to assess the sustainability of alternative materials to minimize the environmental impact of fired clay bricks. Life cycle assessment (LCA) has been carried out to estimate environmental impacts of fired clay brick and nine different concrete blocks following the ReCiPe midpoint method, with a “Cradle-to-Gate” system boundary for three different functional units (single block or brick, 1 m2 interior wall and 1 m2 exterior wall). The results of this study show that, when impacts are measured for single unit blocks, larger dimension bricks or blocks leave more environmental footprints. However, when the functional unit is one square meter wall, clay brick walls leave much more environmental footprints than concrete block walls in most of the impact categories (e.g., climate change, fossil depletion, human toxicity, particulate matter formation). Additionally, the largest burden for clay brick production comes from coal burning; whereas cement production is the most significant contributor for concrete block production. In summary, the findings point out that concrete blocks can be a sustainable alternative to fired clay bricks.

V-4

Digitalization of sustainable value roadmapping in engineering education

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Sustainability is a complex and paradoxical concept which can be challenging to teach. Education for sustainable development (ESD) in higher education has been researched since the early 2000s and identified challenges in designing teaching activities, such as critical thinking, transformative learning, and conflicting schools of thought for sustainable development. Gamification lends itself well to these challenges as it creates an engaging environment for students to explore the concept of sustainability for themselves. Gamification in education is the use of game design elements and mechanics as vehicles for teaching. In industrial engineering education, this active learning approach has commonly been applied in supply chain management, production planning and project management. Research suggests that digitalization and web-based education could further enhance student motivation and engagement. Accordingly, this study aimed to test a gamified workshop about sustainable value roadmapping using varying levels of digitalization. Digitalization was applied to two aspects of the workshop: the material and the delivery media. The workshop material could be physical (poster template, stick notes and markers) or digital (virtual template and stick notes in Mural, a web-based app). The delivery could be face-to-face (facilitators and students together in a classroom), virtual (via Zoom, an online communication platform), or mixed (facilitators online but students physically together in small groups). For face-to-face workshops, either physical or digital material can be used. When online communication is involved (virtual and mixed delivery), only the digital workshop material can be used effectively. This presentation discusses the preliminary findings about the potential effects of digitalization on cognitive and affective learning outcomes. Finally, the authors suggest ways in which digitalization can enhance or hinder the students’ learning experience.

V-5

A data-driven approach for evaluating the occupant behavior influence on electricity consumption in Taipei City

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Occupant behavior is essential to city electricity management. Overestimate electricity savings potential often occurs when the occupant behavior is ignored. However, there is a lack of information on the electricity consumption behavior of urban residents because of a few studies on building electricity usage on a city scale. To predict occupant behavior on electricity consumption, empirical materials from Taipei City and machine learning were used to establish a framework. This study used k-means clustering with socioeconomic factors and building data to understand the regional electricity consumption characteristics. Then, the historical socio-economic factors were applied to assess the potential of electricity consumption pattern transformation. 773 surveys of occupants in residential buildings were conducted, and 33 rules of occupant behavior were clarified using decision trees. The quantities of occupant behavior influences and the possibilities of behavior adoption were calculated by the rules at last. The results show that the electricity consumption in Taipei City can be classified into four clusters, excluding the outliers. Cluster 2 and 3 are commercial areas with high electricity consumption. The average monthly household electricity consumption of cluster 2 and 3 are higher than in Taipei City. The average monthly household electricity consumption of cluster 1 and cluster 4 are near the average value in Taipei City. Cluster 1 has the highest potential with 49% to transfer into cluster 4 because of the similar trend in the number of enterprise units. 38.8% of occupant behavior influence in rule 1 of cluster 2&3 is the highest, with 4.4% for occupants to adopt it. The highest possible rule to follow is rule 3 of cluster 4, with a probability of 54.7% and an occupant behavior influence of 4.1%. The information on occupant behavior provided by this study can fill the gap between measured and simulated electricity consumption in the household.

V-6

How to build sustainable cities: Research on the local energy governance in Taiwan

Ying-Da Wang, Li-Ting Huang, Ching-Chun Chang, Ting-Hung Wang, Hsiu-Chuan Lin
Industrial Technology Research Institute, Taiwan

Since Taiwan launched its energy transition policy in 2016, local governments cooperated with the central government in various power-saving programs and renewable energy subsidies initiatives for local governments. Local governments drafted local energy policies according to regionally-specific conditions, including the replacement of energy-efficient equipment, the expansion of renewable energy installations, power-saving, energy inventory, and framing of energy citizenship. Preliminary results of the energy transition policies are achieved, indicating that local governments formed partnership with the central government in the process of the energy transformation.
Recognizing the urgency of global net-zero emissions and climate governance initiatives, more than 130 countries and regions around the world announced the goal of 2050 Net Zero Emissions. Taiwan also adopted the “2050 Net Zero Transition” policy goal in 2021. Therefore, many countries helped local governments in order to build sustainable cities or communities to achieve the goal of net-zero, such as “Regional Decarbonization Pilot Zones” in Japan and carbon neutrality cities in South Korea.
To achieve Taiwan’s Net Zero Vision, it is necessary to re-examine the strategies and mechanisms of local energy governance to build sustainable cities. First, we reviewed how sustainable cities or communities were built successfully around the world. Second, sustainable development goals have been adopted by many cities in Taiwan gradually, yet local governments often faced challenges during communication processes with the central government, environmental groups, stakeholders, and local citizen groups. After analyzing the problems that local governments confronted with, we provided suggestions about the framework of local energy governance to achieve sustainable cities.

V-7

The emergy footprint of a city: comparing supply- and use-extended input-output models for the case of Vienna, Austria.

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EPFL, Switzerland

The design of environmental extensions in the input-output analysis is based on the user side perspective and only focuses on commercial energy supply and use, which implies that its spatial and temporal boundaries are limited to technical energy extraction and use. Moreover, the literature that discusses donor side perspective to supply and use-extended footprint models is in its infancy. This study introduces an emergy-evaluated supply-extended and use-extended carbon footprint models for the city of Vienna and then compares and assesses differences in results for their empirical and conceptual implications. Our results show that the ranking of footprints of final products categories is sensitive to the evaluation method and that products of extractive and manufacturing industries (agricultural and chemical products) differ by more than 10% depending on whether emergy or carbon evaluation is chosen. The emergy-based comparison further reveals that for products of extractive industries difference between use and supply extension results can be more than 20% as opposed to carbon-based comparison with the difference between supply and use extension results for services not even amounting to 5%. We, then discuss conceptual differences between emergy and traditional carbon-evaluated extension designs and conclude that more accurate estimation of the total environmental burden of each sector in an urban economy can be archived the first step of allocation procedure used in emergy-evaluated used -extension design (allocation

direct energy use of fuels to final consumption to households, government, capital formation, and exports) is added to emergy-evaluated supply-extension results. Such use of these models provides a basis for a comprehensive understanding of environmental support to production

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V-8

Extraregional dependence of municipal / industrial plastic waste treatment based on material flow analysis in the 47 prefectures of Japan

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This study estimated and organized flow data for municipal waste plastics (MWP) and industrial waste plastics (IWP) by prefecture based on data from various surveys on plastics and waste by the Ministry of the Environment, prefectural governments, and industry groups.
The intra- and inter-regional flow structures of waste plastics (WP) by prefecture are analyzed by aggregating both MWP and IWP flows. Prefectures were classified by their degree of extraregional dependence for WP treatment.
The results suggested that geographically independent prefectures such as Hokkaido and Okinawa have low extraregional dependence. On the other hand, metropolitan areas such as Tokyo and Osaka and exchange areas such as Saitama showed high extraregional dependence. This study clarified the geographical characteristics of WP management by identification of the inter-regional and inter-regional flow structure of IWP and MWP by prefecture and the classification of extraregional dependence of WP treatment. This result contributes to optimizing the regional WP management system considering geographical factors.

V-9

Evaluation of greenhouse gas reduction effect through the silver recycling

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As the global consumption of resources increases rapidly, environmental problems caused by exhaustion of natural resources and an increase in waste are expanding; thus, the importance of the recycling industry is increasing.
This study analyzed the greenhouse gas reduction effect of the silver improvement process from the plated waste liquid generated in the metal industry by applying the Life Cycle Assessment (LCA). The functional unit was applied as 1 kg of treated from recycled silver.
As a result, the recycling rate increased from 75% to 83% according to the improvement process, and the purity rate increased from 99.99% to 99.999%. In addition, greenhouse gas reduction compared to the current process is about 50% reduction effect, which had 5.36E+02 kg CO2 eq./kg.
Substances in greenhouse gases of the current process are mainly generated from waste liquid(77%), electricity(18%), and reduced to waste liquid(40%), electricity(98%) in the process of improvement. In addition, electricity was found to be significantly reduced to comparing to the current process. Therefore, high-efficiency improvement processes contribute to significant energy savings.
However, the main substance affected by major greenhouse gas emissions has the highest in waste liquid treatment at about 77 to 93%. Therefore, it is necessary to establish a treatment plan for waste liquid in the future.

V-10

Heuristic analysis of scale mining: The balance between safety, environmental and social impact and operational performance

Tatiane Marin, Jacopo Seccatore

University Adolfo Ibañez, Chile

Achieving a Mercury-free Small Scale Mining would achieve also its sustainability? Is mercury the only obstacole for sustainable small-scale mining?
A successful approach for sustainable mining operations is associated to the efficiency of the recovery of the ore contained in the mineral deposit. The best practices in mining take into account rigorous mine planning processes to ensure the maximum recovery. However, that is not always the case in small-scale mining, where the limitations of the managerial, economic and strategic conditions

of this sector tend to constrain the implementation of proper mine planning procedures.
The base problems of small-scale mining in are: lack of planning, high costs, high variability of income and reduction of spaces. Small and medium-sized producers are more vulnerable to price variability of the mineral, which supports a research initiative to adapt the mine planning cycle process to the reality of small-scale mining within a context of sustainability.
The main objective is to develop a methodology to make small mining operations a sustainable activity.
In the first phase of the project, we applied the minimum reserve methodology in a Gold Small Scale Mining at Chile. The preliminary results demonstrated that it is possible to transform the operation into a sustainable mercury-free way.

V-11

Building an AI-based automatic ESG evaluation estimation model and its application

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With the spread of global sustainable development goals (SDGs), environmental, social, and governance (ESG)-driven investing is becoming increasingly important; hence, there is a growing need for research on ESG disclosure. However, extant ESG evaluation and rating processes are often black box in terms of how ratings are applied (Borial et al., 2021). Therefore, despite the growing importance of corporate ESG investing, there is a risk that information disclosure may be distorted to influence evaluations and ratings. To offer mitigation to this risk, this study discusses an artificial intelligence (AI)-based ESG evaluation model that intakes a variety of disclosed data for corporate evaluation without relying on rating agencies. The purpose is to make it easier for companies to disclose appropriate and realistic ESG information. Additionally, the framework of the analysis model is provided.
ESG reports can be found on the internet without restriction, making assessment quite easy. However, if ESG rating agencies were to monopolize their use while also providing consulting services, then ESG reporting would be overly influenced by those agencies, which is opposite the intended situation.
A related study was conducted by Aiba et al. (2019); however, they only addressed information found in the Global Reporting Initiative (GRI) comparative table. Therefore, this study aims to construct a model that extends it to the entire ESG report.
The aim of this study was to present the notional capability of a machine learning AI automatically ingesting corporate ESG data to automatically estimate RobecoSAM ESG scores, which emphasize a variety of industrial perspectives. The experimental results of the automatic estimation model of ESG valuation based on AI and the application analysis utilizing the data will be reported at this conference.

V-12

Assessing the social dimension in strategic network design for a sustainable development: The case of bioethanol production in the EU

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University of Augsburg, Germany

Unlike site-specific assessments, corporate or political Greenfield decision-making on a strategic and multi-regional level relies on aggregated ex-ante data. In contrast to environmental LCA, the complexity of social indicators, their subjective and often qualitative nature, and a lack of data render the inclusion of SLCA indicators into quantitative optimization models for strategic supply chain decision-making difficult. This work presents a structured process for including a comprehensive set of social aspects by selecting applicable quantitative and regionalized social indicators. This approach is applied to the case of lignocellulosic, second-generation bioethanol (2G EtOH) production in the EU, which is a promising substitute for fossil and food crop-based fuels. Based on i.a. the Guidelines for Social Life Cycle Assessment of Products and Organizations (GSLCAPO), the Social Hotspots Database (SHDB), state-of-the-art literature, as well as previous work, we compile 9 social objective functions, 25 functions for social hotspot identification. They are evaluated alongside economic and 21 environmental LCA-based objective functions in a mixed-integer linear programming (MILP) model. We identify optimal strategic decisions (regional biorefinery locations and capacities in the EU, feedstock collection, EtOH transportation, and substitution of either fossil petrol or first-generation EtOH) and resulting optimal objective values for each of the social, environmental, and economic objectives. Key results show that social optimization either leads to large, labor-intensive or regionally focused, indicator-driven networks. ‘Injuries and fatalities’ in the feedstock sectors of Central and Eastern European countries is the primary social hotspot. We determine conflicts and congruencies between the different objectives, identify Pareto-optimal trade-offs between them, and assess the network’s impact on the level of the Sustainable Development Goals (SDGs). The approach in the study at hand is novel in both the fields strategic network design and the European bioeconomy, and contributes to a more holistic life cycle sustainability optimization.

V-13

Evaluating resource use reduction effects of residence-related 3R behaviors

Teppei Kan, Seiji Hashimoto
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A need exists to shift from a linear economy of mass production, mass consumption, and mass disposal to a circular economy based on 3R behaviors, with the aim of improved resource efficiency. As methods of doing so, 3R behaviors include reducing the use of products, sharing products, reusing and using products for long periods, conserving resources used for products, conserving resources used for containers and packaging, saving resources during production process, and utilizing recycled resources. For this study, we evaluated how residence-related 3R behaviors have affected residence-related resource usage. Additionally, we estimated the potential for reducing resource use when anticipated future 3R actions are taken. Findings indicate that (1) the residence-related resource use for house construction decreased by an estimated 68 million tons, whereas resource use for energy consumption of houses increased by about 18 million tons during 1973–2013. (2) During the period examined above, the lifetime extension of houses reduced resource usage, although the increased housing floor area per person, the decreased occupancy rate of the houses (increased number of vacant houses), and the increased energy consumption per person contributed to increased resource usage. (3) The potential for reducing resource use is estimated as approximately 52 million tons for house construction through the reduction of housing floor area per person, utilization of recycled resources, etc., and approximately 35 million tons for energy consumption of houses through decarbonization achieved by the spreading use of renewable energy.

V-14

The environmental footprint methods: history, state of the art, future developments

Ugo Pretato[1], Elia Rillo[1], Irene Cropanise[1], Alicia Boyano Larriba[2], Michael Knaute[3]
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A company wishing to market its product as environmentally friendly in several EU Member States faces a confusing range of choices of methods and initiatives for counting and communicating its environmental performance.
The European Commission proposed the Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF) methods as a common way of measuring the environmental performance of products and organizations, adopting in December 2021 the revised Recommendation on the use of Environmental Footprint methods [1].
The methods were tested between 2013-2018 and the European Commission is now implementing a transition phase to include new methodological developments, to monitor and further develop Product Environmental Footprint Category Rules (PEFCRs) as well as to explore how to incorporate them in upcoming policies and initiatives.
The 2020 Circular Economy Action Plan already foresees that “the Commission will also propose that companies substantiate their environmental claims using PEF and OEF methods”. It is part of a set of interrelated initiatives to establish a strong and coherent product policy framework that will make sustainable products, services and business models the norm, and not the exception [2].
The adoption of the Green Claims initiative is planned for the first half of 2022.
This presentation is part of a set of EF capacity building events that the Directorate-General for the Environment of the European Commission is implementing to raise awareness on the principles, characteristics and opportunities underlying the EF methods.
The following topics will be discussed:
- Brief history of the Environmental Footprint project (from pilot phase to transition phase);
- Overview of the current implementation (e.g. PEFCR development and update);
- Ongoing policy initiatives (e.g. Green Claim Initiative);
- Future development.
The meeting is intended as an online presentation of 30 minutes.
[1] Recommendation on the use of Environmental Footprint methods:
https://ec.europa.eu/environment/publications/recommendation-use-environmental-footprint-methods_en
[2] European Commission Environmental Footprint:
https://ec.europa.eu/environment/eussd/smgp/index.htm

V-15

Analysis of approaches to quantifying environmental benefits of reuse in the IT sector

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Extending the lifetime of electronic products through circular economy strategies, such as reuse, is an effective way to reduce environmental burden associated with the manufacturing of new products. In the space of IT and ICT devices, reuse has become increasingly common, with companies and individuals making their devices available for reuse and businesses re-introducing pre-owned, refurbished and remanufactured equipment into the market.
The quantification of environmental effects of reuse is relevant as a basis for communicating benefits to a target audience as well as

for potential applications in carbon accounting and offsetting that incentivize organisational engagement in circular economy practices. However, to date, there is no consensus on a 'best practice' approach to suitably estimate environmental benefits. Insights into the status quo reveal a considerable variance in approaches and communicated data, highlighting the lack of a harmonized method.
This contribution investigates existing approaches and illustrates the effects of different allocation methods to distribute embedded carbon of a laptop to multiple users in reuse scenarios as a study case. Common allocation methods include the 'cut-off' approach, which allocates embodied carbon to the first user, while subsequent users receive used products free of burden, and the 'shared burden' approach, in which allocation keys are used to distribute embedded carbon among multiple users. The different approaches are evaluated in terms of their practical applicability and the setting of incentives for users to employ circular economy strategies.
The contribution aims to highlight the need for a harmonized approach that can be applied uniformly in frameworks such as life cycle assessment and carbon accounting in the absence of an objectively 'right' or 'wrong' solution. This long-standing challenge requires ongoing dialogue among LCA experts and organisations involved in the practical implementation of circular economy business models to work towards future standardization.

Presentation list: Oral sessions

1-1A: Carbon management for neutrality

1-1A-1

Using CO2 as feedstock to decarbonize the global chemical industry: A feasible reality or an urban myth?

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Carbon capture has been projected to play a vital role in many roadmaps of power and industrial sectors towards net-zero greenhouse gas emissions. Recent advancement of CO2 utilization as chemical feedstock shows the possibility of a win-win situation by simultaneously valorizing CO2 as a waste and enabling feedstock decarbonization of the chemical industry. In this study, we aim to explore the feasibility of a future defossilized chemical industry that fully relies on CO2 as its carbon source in 2050. With the assessment of the future global and regional CO2 supply-demand balance, we find the global CO2 demand as chemical feedstock to be 2.2-3.1 Gt/year, which is well within the technical limit of its supply volume from power, cement, steel, and kraft pulp sectors of 5.2-13.9 Gt. Nonetheless, certain regions, such as Middle East, would face local supply shortage. With Life Cycle Assessment, we also examine the savings on greenhouse gas emissions and the trade-offs of other induced environmental impacts of capturing 1 kilogram CO2 in different regions and from different sectors. We conclude that CO2 captured from solid biomass-fired power plants and kraft pulp mills in Europe would have the smallest environmental impacts. India and China should prioritize low-impact regional electricity grid to maximize the environmental benefits from carbon capture. Finally, a CO2 sourcing strategy developed based on regional supply capacity and environmental impacts from carbon capture is demonstrated in two bottom-up case studies of China and Middle East, which illustrate how the total regional environmental impacts from carbon capture can be minimized by optimizing its supply sources. Our findings support the strategic planning of the sustainable transition of the chemical industry, especially regarding site selection and supply chain optimization. They also provide insights for governments and international organizations regarding the prioritization to reach the climate targets by 2050.

1-1A-2

Detecting insecure supply chains lacking carbon neutral commitments

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Achieving a carbon-neutral society in 2050 is a highly ambitious greenhouse gas (GHG) reduction target. Currently, major Japanese companies have prepared their schemes for achieving the target, but it is still unknown how much of the national GHG emissions in Japan are covered by such schemes. Here, we analyse the link between corporate climate change efforts and GHG emissions associated with commodity production for household consumption. Specifically, we combined an assessment of corporate climate change measures published by CDP, an NGO headquartered in the UK, with Japan's Environmental Input-Output Table called 3EID. As a result, supply chains with a weak commitment to carbon neutrality were detected among carbon-based supply chains generated by household consumption.

1-1A-3

Life cycle assessment on forest resource utilization considering long-term carbon balance

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Towards carbon neutral society, forest resources have different roles in energy systems from variable renewable energy, e.g., solar and wind, due to its storability and adjustability. Thanks to the forestation conducted in the 1960s in Japan, a large amount of trees is available in Japan although the demand for wood is not necessarily high. It resulted in the tree age distribution being unbalanced in the older side. Harvesting and forestation should be redesigned to meet the demand in the society to be carbon neutral for reactivating the carbon absorption by forest and utilizing the resources substituted for fossil resources.
In this study, a life cycle assessment (LCA) was conducted to analyze the prospective forest resource utilization considering long-term carbon balance attributable to forest. Harvesting and no-harvesting scenarios were defined to clarify the changes in the carbon balances. In the harvesting scenario, forests are harvested in a 50-year cycle followed by new forestation and wood is used for energy and construction. In the no-harvesting scenario, forests are left once planted without cutting, which necessitates the production of products replaceable with the same functions as the wood-derived products in harvesting scenario. Life cycle greenhouse gas (LC-GHG) emissions with carbon absorption were analyzed on forestry operations annually and for 200 years.
The results demonstrated that harvesting, reforestation, and effective use of resources can reduce LC-GHG in the long term of this calculation. Also, it can be effective for the reduction in LC-GHG to consider the harvested wood products in markets as construction materials to be utilized as energy. Considering the other social trends towards carbon neutrality, e.g., decarbonization in power sources, the background inventories of non-wooden products could also be changed. A mechanism to take into account such conditions is strongly needed for sustainable forest management.

1-1A-4

Matching post-combustion carbon capture technologies in power and industrial sectors based on emission reduction potentials

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The power and industrial sectors, accounting for ~65% of Japanese CO2 emissions, need to mitigate their emission. Carbon capture, utilization, and storage (CCUS) would be one of the mitigating options to be retrofitted to existing indispensable power and industrial processes. However, reduced emissions are not equal to captured CO2 amounts since CCUS can be energy-intensive for capturing CO2. Furthermore, the energy intensity and suitability of carbon-capturing technologies depend on the flue gas properties such as CO2 concentration and emission factors of utilities. Regarding this backdrop, this study evaluated the energy consumption for capturing CO2 by post-combustion carbon-capturing technologies retrofitted to power and industrial processes such as amine-based chemical absorption and membrane separation. Process simulation-aided life cycle assessment was performed to quantify energy consumption, utilities, and cradle-to-gate greenhouse gas (GHG) emissions for capturing CO2 generated by existing power and industrial processes under the criteria of CO2 capture rate (90%) at 150 bar and purity (>95%). This study investigated the effect of the membrane properties such as selectivity and thickness on the net GHG emissions for capturing CO2 compared to the amine-based absorption. According to the simulation, the amine-based absorption and membrane separation needed 3.6 – 4.0 MJ/kg-CO2 and 0.77 – 3.4 MJ/kg-CO2 for the CO2 separation, respectively. In addition, sensitivity analysis was performed to quantify the net GHG emissions at varying emission factors of utilities and degradation of components such as amine solvent and membrane. Although the membrane separation indicated lower energy consumption than the amine-based absorption, the net GHG emissions could vary with the emission inventories of utilities and the level of degradation of components. Consequently, the availability of low-emission utilities and operating environment would also be an important factor in implementing post-combustion technologies.

1-1B: Technology application in local system

1-1B-1

Modeling the effect of improving sewage disposal rate on ecological health for aquatic organism: A case study Gunma prefecture, Japan

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Sewage disposal rate in watershed boundary of Gunma prefecture is 70.5% in FY2015 due to two factors: (1) households unconnected to sewage line are remained in a sewage system area. (2) households using singular type of onsite water-purifier tank focused on treatment of only toilet water are remained even now. It leads to direct emission of gray water into river, and its

improvement is an important issue related to SDGs' indicator 6.3.1 "Proportion of domestic and industrial wastewater flows safely treated". The purpose of this study is to estimate the effect of improving sewage disposal rate on ecological health for aquatic organism.
Loading amounts of biological oxygen demand (BOD) were estimated for four scenarios: Present scenario in FY2015; Scenario A, the sewage disposal rate is improved to 75.2% in FY2030 by partially progression of connection to sewage line; Scenario B, the rate becomes 88.2% in FY2030 by adding to partially progression of update to combined type of onsite water-purifier tank; and Scenario C, the rate achieves 100% in FY2040. Loading amounts of BOD at resolution of 1×1 km2 is inputted to the river water quality simulation model, the National Institute of Advanced Industrial Science and Technology - Standardized Hydrology-based AssessmeNt tool for chemical Exposure Load (AIST-SHANEL), customized for BOD estimation.
River ecological health is evaluated by treating EPT richness as substitution indicator, total taxon richness of Ephemeroptera, Plecoptera, and Trichoptera. The correlation equation between BOD concentration and EPT richness was applied, and improvement effects were visualized based on EPT richness. Potentially disappeared fraction of aquatic species (PDF) is regularly adopted in the field of life cycle impact assessment for ecological effect, whereas, similarities and availability of EPT richness were discussed in this study.

1-1B-2

Life cycle assessment of sustainable organic waste treatment in Cimahi Indonesia

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Solid waste management is a complex municipal problem that should be adequately treated. In Cimahi City, the organic fraction of municipal solid waste (MSW) has the highest portion compared to other types of waste. Approximately 50.6% of the total waste, about 226 tons/day, is generated from the domestic sector, while most are transported to the landfill without an effective treatment and management system. Therefore, a proper intervention should be addressed to solve this problem appropriately. The use of black soldier fly (BSF) hypothetically can reduce the number of organic wastes in a rapid processing system. This study aims to analyze the impact of BSF as a pre-processing waste treatment before sending it to a landfill compared to other waste treatments such as windrow composting and direct landfilling. This study used life cycle assessment and cost-benefit analysis (CBA) to determine the right management system for treating organic waste in Cimahi City. A pilot study in a neighborhood association (NA-which is locally called Rukun Warga/RW) was used to analyze the life cycle assessment of the waste treatment. Then, the assessment result is generalized on a municipal scale to analyze the treatment's potential as municipal organic waste treatment. The results showed that the BSF treatment has the lowest total emission (in CO2 equivalent) compared to another treatment system. Besides, BSF produces a high-quality and saleable product, increasing the benefit value. Thus, implementing and multiplying the BSF management system can reduce the number of wastes sent to landfills and provide economic incentives to the communities in Cimahi City.

1-1B-3

Analysis on environmental compatibility and economic feasibility of the ground source heat pump in tropical Asia regarding the lifecycle aspects: a case study in Bangkok, Thailand

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Ground source heat pumps (GSHPs) in the tropical regions require a large-scale ground heat exchanger (GHE) owing to the excessive cooling load and high subsurface temperature, resulting in increased initial costs and greenhouse gas (GHG) emissions in the phase except for operation. However, the compatibility of GSHP in tropical regions was limited to evaluation based on energy consumption in the operation phase, leading to unclearness in the contribution of increased initial cost and GHG emissions in the except for operation to the compatibility based on lifecycle aspect. Thus, this study aimed to evaluate the GHG emissions over the entire life cycle and cost payback time of the GSHP with the capacity of 20 kW in Bangkok, Thailand, designed with a predicted 50-year heat sink temperature. The results confirm that the scale of GHEs is twice as large in tropical regions as in mid-high latitude regions; nevertheless, the energy-saving effect of GSHP resulted in an 8.8% reduction in GHG emissions over the entire life cycle compared to air source heat pump (ASHP). This indicates that the reduction in GHG emission owing to the energy savings in the operation phase can offset the increment of GHG emission regarding the installation of GHEs. However, the initial cost of the GSHP could not recover within the lifetime, requiring initial cost subsidies in the range of 50 – 67% and the initial cost reduction induced by the growth of the GSHP market. These findings elucidated that GSHP in Bangkok, Thailand, is compatible in combating global warming, even under climatic and geological conditions unique to tropical regions. However, owing to the increase in initial costs associated with the large scale heat exchanger, further discussion with the analysis on the deployment scenario is desirable to judge whether the system is economically feasible.

1-1B-4

Comprehensive evaluation of the utilization of bamboo biomass In Kitakyushu city considering the nexus structure of SDGs

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The Sustainable Development Goals (SDGs) are international goals from 2016 to 2030. Although efforts to achieve the SDGs are regarded as important worldwide, but there are synergies between the goals of implementation, and mutual trade-offs must be taken into consider. At present, it has been pointed out that the bamboo grove in Kitakyushu City is expanding. Unmanaged bamboo forests are more reproduced than artificial forests and broad-leaved forests. At the same time, due to the continuous expansion, other species of trees around are expelled, which in turn leads to problems such as single vegetation, low biodiversity and cultivating water sources. Due to the loss of functions and landslide prevention functions, not only the risk of disasters but also social problems exist.

This research focuses on the construction of a carbon-free society and the promotion of the use of regional bamboo resources by utilizing regional bamboo biomass resources for bamboo resources in Kitakyushu City and trades off with the synergies that arise when achieving the SDGs at the same time. We will try to clarify the possibility of achieving the SDGs and the regional circulation symbiotic sphere at the same time for sustainable resources by quantitatively comprehensively evaluating each region.

1-1C: Metallic resources: now and future (1)

1-1C-1

Closed-loop recycling of steel products

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Steel products are highly recyclable, and in fact, almost all of them are recovered as scrap after the end of their product life, and all of them are recycled. This excellent recyclability can be attributed to the following characteristics of steel. (1) Easy sorting: Steel is virtually the only major industrial material that can be magnetically sorted, and magnetism allows for easy and reliable sorting of only steel. (2) Easy recycling: Steel can be recycled into other steel products basically only by remelting. (3) Valuable: Steel scrap has economic value, and there has been a worldwide recovery system based on market economy, without relying on subsidies or supports. (4) Easy removal of impurities: Since the alloy elements used in steel products are not so much compared to other metal materials and steel is less susceptible to oxidation than most of them, most alloying elements and contaminants are oxidized and removed as slag and steel can be refined to clean steel through oxidation refining.

Thus, steel recycling is unique not only in its high recovery and recycling rate, but also the fact that almost all of them can be recycled to almost any steel products over and over again especially due to the properties described in (4) above, forming closed-loop recycling. However, recycling of steel products are sometimes interpreted as open-loop recycling or cascading recycling. In this presentation, we will analyze the factors that cause such differences in interpretation based on the ISO 14044 standard, which provides the basic principles and guidelines of LCA studies.

Moreover, we will discuss the LCI calculation methodology for steel products as described in ISO 20915 and JIS Q 20915 standards, which allows to calculate the LCI of steel products including the closed-loop recycling potential.

1-1C-2

A new approach for modelling primary mineral supply scenarios and associated environmental impacts

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The mining sector is broadly recognised as a major contributor to local environmental degradation and a potential disruptor of social cohesion. At the same time, there can also be substantial contributions to the development of economic opportunity and industry in the regions where mining operates. Many of the trade-offs and complexities surrounding mine sites can only fully be appreciated on a case-by-case basis and require understanding of the context of specific regions and supply chains in which they operate. Despite this, most prospective material flow analysis and scenario modelling approaches used to understand long-term sustainable development and decarbonisation trajectories place a ‘black box’ around primary mineral supply, aggregating data to a point where potential outcomes at local scales can no longer be interrogated. In doing so, we lose information on the uncertainties and diversity of

potential outcomes across the full cohort of mining operations required to meet future mineral demand. This presentation will provide an overview of the Primary Exploration, Mining and Metal Supply Scenario (PEMMSS) model that has been developed to translate scenarios for aggregated mineral demand into a more nuanced and disaggregated understanding of how primary mineral supply may evolve to meet this. Some key advantages of the model include the ability to incorporate detailed information for known mineral deposits, simultaneous scenario modelling of co-product commodities, as well as the ability to stochastically model uncertain mineral exploration and mine development outcomes. We will present a series of preliminary scenarios for major co-product commodity groups, alongside an approach for improving prospective life cycle analysis through combination of the scenario results with rich datasets for the natural resource requirements of mining and mineral processing operations.

1-1C-3

Future projections of global life-cycle mercury emissions under CO2 reduction target toward 2050

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The Minamata Convention entered into force in 2017 to prevent health hazards from anthropogenic mercury emissions into the environment. The steel industry has not been listed in Annex D because iron/steel factories themselves have relatively low mercury emissions. However, crude steel production requires large amounts of coal as a reductant, a significant source of mercury, but these are not accounted for in the Global Mercury Assessment framework. Therefore, it is essential to evaluate mercury emissions per unit production of crude steel on a life cycle basis. The steel industry is also known as a significant source of CO2 emissions, and a shift to iron/steelmaking methods with lower CO2, such as electric arc furnaces or direct reduction by hydrogen gas, is considered inevitable. This implies a significant life-cycle decrease in coal consumption in crude steel production. Thus, the objective of this study is to estimate life-cycle mercury emissions up to 2050 due to changes in the crude steel production structure to reduce CO2.
Mercury emissions in the steel industry were estimated by multiplying crude steel production and its ratio for each steelmaking method by the amount of mercury emitted per production unit. Crude steel production estimates were obtained from the World Steel Association. The crude steel production ratio scenarios were obtained from the Iron and Steel Technology Roadmap by the International Energy Agency (IEA).
As a result, the global life-cycle mercury emissions were projected to decrease by about three-fourths. China is the primary producer of crude steel today, mainly using a blast furnace. Thus, changes in crude steel production methods in China in line with the IEA scenario can be considered a significant contributor to the reduction in life-cycle mercury emissions. Detail of data collection, scenario setting, and the quantitative results will be discussed in the session.

1-1C-4

Production process improvements for niobium-based products

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The primary raw materials sector is often badly perceived due to the environmental impacts resulting from the extraction and refining of ores into metals or semi-finished products. However, several of these primary raw materials are essential for the so-called environmentally friendly technologies, such as wind turbines and batteries that enable the use of renewable energy. Therefore, it is important to look into the production process of these raw materials and reduce the environmental impacts wherever it is possible. This study quantified the environmental impacts of the production of two niobium-based materials, both of which being potential contributors to the energy transition. Niobium is mostly known for its use as ferroniobium (FeNb) in the steel industry, as pure niobium in special alloys and as niobium oxides (e.g. Nb2O5) in piezoelectric materials, lenses and capacitors. However, both FeNb and Nb2O5 have demonstrated a good performance in renewable-based technologies such as wind turbines, solar panels and storage systems. The environmental impacts in the production of these two materials were assessed through a cradle-to-gate life cycle assessment, making use of production data, provided by CBMM, the niobium producer responsible for roughly 75% of the global market. A comparative assessment for the production in 2017 and in 2019 was performed to quantify the reduction in impacts as a result of production process optimizations implemented in the company. Results for 2019 indicate a Global warming impact of 5.09 kg CO2 eq./kg FeNb and 4.70 kg CO2 eq./kg Nb2O5. Aluminum supply is the main source of impacts for FeNb, whereas the processing chemicals of Nb2O5 have the main contribution for the high purity oxides. Production process improvements in 2019 resulted in significant impact reductions compared to the 2017 levels, with impacts on Stratospheric ozone depletion reduced by 55.8% for FeNb and 65.6% for Nb2O5.

1-1C-5

Evaluation of secondary aluminum cycles under automotive changes in China

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Because of the penetration of next-generation vehicle and vehicle-lightweight trends, automotive demand for aluminum, especially wrought aluminum alloys, is increasing significantly. Secondary aluminum recycled from aluminum scrap can save 95% of the energy and reduce the environmental impacts compared with the primary aluminum production (Ding et al, 2012). However, the recycling potential of aluminum and the artificial flows of secondary aluminum have not been quantified in China due to the prolonged neglect and complex aluminum scraps. The impacts of the vehicle-lightweight trends on aluminum cycles are not estimated. In this study, we expanded the diagram of secondary aluminum flows in China to estimate the stocks, flows, and metal dissipation of aluminum within its life cycle in 2019 and 2050. This diagram distinguishes wrought and cast alloys so that the chemical composition of each flow is considered. In addition, through introducing the improvement in collection system, dismantling, and sorting for end-of-life vehicles, the recycling potential of aluminum and the reduction in primary aluminum requirement are estimated, with considering the penetration of next-generation vehicle and vehicle-lightweight trends.
Findings include the following: (1) Share of wrought alloys in secondary aluminum production will decrease from 31% in 2019 to 4% in 2050. (2) Total loss rate of secondary aluminum cycles will increase from 21% in 2019 to 30% in 2050. The biggest loss occurs in the end-of-life product collection process due to the underdeveloped waste management system and the lack of legislation in China. (3) Automotive demand for cast and wrought alloys will increase by 2 and 15 times compared with 2019, respectively, vehicle-lightweight trends are more attributable to aluminum demand than penetration of next-generation vehicle. (3) Improving collection system and applying dismantling and sorting for end-of-life vehicles can reduce primary aluminum requirement by 4%-8% in 2019 and 12%-26% in 2050.

1-1D: [OS] Doing more with less - Transitioning to circular economy through business model innovation (1)

1-1D-1

How will service-oriented circular economy businesses contribute to environmental sustainability? – An introduction

Yusuke Kishita, Koji Kimita, Eri Amasawa
The University of Tokyo, Japan

A number of service-oriented circular economy (CE) businesses, such as bike sharing and clothing rental, is becoming more popular than ever. One question is how such businesses contribute to environmental sustainability while maintaining or increasing customer satisfaction. In this presentation, we present our research project that aims to develop a method for assessing environmental impact reductions of service-oriented CE businesses. For this purpose, we develop a customer behavior model to evaluate customer acceptance. By describing and comparing scenarios assuming different services and business models, we will gain insights into designing sustainable resource circulation.

1-1D-2

[Keynote talk] Circular fashion by airCloset

Satoshi Amanuma
airCloset, Inc., Japan

airCloset is a fashion subscription service based in Japan with more than 700,000 users as of 2022.
Renting fashion as an alternative to the mass-produced, mass-consumed fashion consumption of the past has led to less wasteful consumption and the purchase of clothes that suit the individual.
airCloset has cleared the difficulties of cost management in the subscription business by optimising logistics through the construction of its own systems and improving operational efficiency through the use of AI and data utilization.
In addition, the system whereby fashion stylists select clothes through personal styling, rather than users selecting clothes, maintains the freshness of the subscription service and is supported by many users.
In the session, founder of airCloset will share the story of how a monthly fashion rental service was launched to establish circular fashion for a sustainable society.

1-1D-3

Designing sustainable fashion rentals based on environmental benefit and consumer preference

Eri Amasawa, Tatsuki Yoshida, Koji Kimita, Masahiko Hirao
The University of Tokyo, Japan

This study presents a design of sustainable fashion rental services, which has environmental benefit from rentals while maintaining the consumer preference. To reduce the environmental impact led by the mass production and disposal of garments, fashion rental services have been attracting attention. Rental services provide a consumption pattern alternative to purchasing, which could reduce the material demand in the society. While the environmental impact mitigation is theoretically possible, consumer preference on fashion rentals have yet to be discussed together with the environmental impact. Specifically, there is a need to clarify the type of products, services, and the consumers that would reduce the environmental impact when consumers shift from owning of garments to rentals. In our study, the research objective was to design a sustainable fashion rental service that the environmental benefit and consumer preference are met, where we clarify the type of products, services, and target consumer groups suitable for rentals. We first analyzed the type of clothing and services that consumers prefer in fashion rentals using a questionnaire survey. Based on the consumer analysis, we characterized a fashion rental service that meets consumer preference for 15 distinct clothing types, and performed a life cycle assessment. The consumer behavior and preferences for associated services (i.e., access to variety of styles, free cleaning fee) were collected from the survey. As a result, we identified a group of garments that are more preferred to realize a sustainable fashion rental service. Additionally, the associated services that consumers preferred induced negligible environmental impact; thus, services play a key role in ensuring consumer preference and reduce the environmental impact in rentals. Our study characterized the combination of products, services, and consumer groups for sustainable fashion rentals, which may help in development of a general guideline in designing a sustainable rental service.

1-1D-4

Circular business models for plastics in India

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Circular business models (CBMs) are expected to play an important role in the transition to a circular economy. CBMs are being investigated in the context of plastics in India as part of the India-Australia Industry and Research Collaboration for Reducing Plastic Waste. In this study, an interdisciplinary team has examined the international and Indian literature regarding circular business models and have investigated their uptake in India. The team have refined a circular business model typology based on the literature for application in the Indian context in relation to plastic supply chains. The four circular business model strategies that have been considered are: 1) substituting; 2) extending; 3) intensifying; and 4) cycling. In the first phase of the study, the team identified 55 businesses currently using a circular business model in relation to plastics in India. More than half of those identified were focused on recycling. Overall, the most common types of CBMs being used for plastics in India related to recycling and technology platforms to facilitate extended producer responsibility (EPR) schemes and the substitution of plastic materials. The least common CBMs in the review of practice related to 'intensifying' (sharing models, rental/leasing/access models, user cooperatives, creative commons, pooling models).
Businesses employing circular strategies often face challenges in implementation and there are gaps in understanding which measures might facilitate greater uptake of CBMs. In the second phase of the project, the research team is interviewing a number of businesses using CBMs to discuss the challenges to employing a circular approach in India and to identify pathways to facilitate broader uptake of circular business models and practices. These interviews are being qualitatively analysed and the results will be presented at Ecobalance.

1-1E: Mobility and energy storage

1-1E-1

Comparing approaches to certification and sustainability assessments of minerals used in batteries

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In response to climate change, there is a global imperative to swiftly decarbonise transport and energy systems via electrification powered by low-carbon technologies. In addition to increased electricity generation from solar and wind, decarbonisation pathways give rise to a much greater use of batteries for energy storage in homes, businesses, at grid-scale and above all, in electric vehicles. Given the vast increase in the scale of minerals used in batteries, including lithium, nickel and cobalt, the environmental and social impacts associated with their extraction and processing are being closely examined by both end-users such as electric vehicle

manufacturers and also by investors in mining projects.
This research, undertaken as part of Australia's Future Battery Industries Cooperative Research Centre (FBICRC), compares the drivers for certification of responsibly sourced minerals in battery supply chains. With a view to then understanding what is required for implementation of both certification and other sustainability assessments, a comprehensive review and document analysis is undertaken. The result is a mapping of data requirements across environmental, social and governance dimensions for prevailing approaches to sustainability assessment which span formal certification schemes (Initiative for Responsible Mining Assurance; Certification of Raw Materials) through to reporting and assurance standards (Towards Sustainable Mining; Global Reporting Initiative; Carbon Disclosure Project; Dow Jones Sustainability Index; Responsible Mining Index; OECD Due Diligence Guidance for stakeholder engagement in the extractives sector).
Significantly, we identify areas of commonality and divergence in data reporting requirements. This informs barriers and opportunities for the dual uptake of certification and sustainability assessments by industry. Finally, the findings provide insights for a companion FBICRC research project which is seeking to utilise blockchain for evidencing environmental claims in trusted supply chains.

1-1E-2

Qualifying CO2 emissions reduction of vehicle to X using life-cycle assessment.

Hironobu Kiuchi[1], Kensuke Murai[1], Kenta Suzuki[1], Maki Hoshino[1], Keigo Ikezoe[1], Isoshi Mukai[2], Shumpei Nakada[2], Tomoyo Saito[2], Yusuke Udagawa[2], Yumiko Iwafune[3], Kazuhiko Ogimoto[3]

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For realization of sustainable society, renewable energy such as solar and wind power, and electric vehicles (EVs) are expected to become popular.
Private vehicles are parked in almost 95% of their lifetime. Vehicle to X (X means, home, building, grid etc.) for utilizing EV battery during parked time to supply power from EVs to power infrastructure are being demonstrated worldwide.
V2X is expected to contribute for reduction of CO2 emissions from fossil fuel for power supply by stabilizing grid from fluctuation of variable power such as solar and wind power and suppressing thermal power plants.
However, not many of previous studies achieved to quantify the CO2 emissions from not only fossil fuel but also manufacturing power supply system.
Therefore, aim of this study is to evaluate CO2 emissions reduction of manufacturing and operating power supply system by introducing V2X using life-cycle assessment(LCA).
The scope of assessment expands from conventional system boundary estimating CO2 emissions of vehicle, with annual power consumption of power supply system in Kyusyu as functional unit.
Annual CO2 emissions by manufacturing power supply system were quantified by calculating CO2 emissions of manufacturing power plants in Kyushu, chargers, EVs divided by their life-time. Then, annual CO2 emissions by operating power supply system were quantified using power supply and demand simulation. Specifically, power plant operating model of Kyushu and EV model created from actual usage data were applied for simulation of V2X.
Moreover, the capacity of stationary battery was estimated to have equal amount of CO2 emission reduction from V2X. Then, CO2 emission reduction by V2X was evaluated comparing to stationary battery by not only operating but also manufacturing power supply system

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1-1E-3

Estimation for vehicle LCA considering another way to use

Mayumi Isobe, Maki Hoshino
Nissan Motor Co., Ltd., Japan

In order to realize a sustainable society, it is required to cut GHG emissions in the life cycle to zero from the company activities and products. To do so, companies do research, and development, and put on new technologies and products on the market. Many car manufactures have published the LCA result for their products in sustainability reports and so on. The calculation method was established when the almost vehicles have an internal combustion engine. However, since the launch of an electric vehicle (EV) with in-vehicle battery as products that leads to reduction of CO2 emissions at the stage of use, the EV become no longer limited to have the function of traveling. After using as the mobility, it is able to rebuild the used one for other stationary storage batteries or for batteries driven of the machine except vehicles. Farther more it is able to be used as a renewable energy storage battery when it is mounted as an in-vehicle battery, at that time vehicle has stopped, not traveled, and it is expected to contribute to the management of renewable energy in the area. In order to evaluate their effects, we examined several evaluation methods and compared the effects of their ideas.

1-1E-4

Relationship between profitability of recycling business of the lithium-ion battery from electric vehicles and decision-making of dismantling companies

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In recent years, demand for electric vehicles (EVs) has been increasing in order to reduce CO2 emissions, and demand for lithium-ion batteries (LIBs) to be used in EVs is also increasing. Automobile manufacturers need to secure a stable supply of rare metals used as materials for LIBs. However, rare metals are scarce and unevenly distributed in mines in certain countries, and their supply can be unstable due to mining stoppages caused by conflicts and other factors. Therefore, it is necessary to secure a supply source that is not affected by international conditions through recycling.
On the other hand, waste LIB is recycled as roadbed material because recycling costs are currently high relative to the price of extracted metals. This recycling cannot compete with export restrictions on rare metals. Therefore, it is necessary to subsidize and nurture the recycling industry until the business generates revenue through higher resource prices and lower costs due to technological innovation. Furthermore, the lack of visibility of business profits due to uncertainties such as fluctuating resource prices is another reason why the private sector has not entered the recycling business.
Previous studies have clarified the relationship between the recycling rate and the profitability of the business, they have not been able to clarify the relationship between the decision-making process of the dismantlers involved in determining the recycling rate and the profitability of the business. There is an interaction between the two: a higher purchase price offered by the operator increases the recycling rate, and a higher recycling rate decreases the cost.
In this study, we represent the dismantler's decision-making as an engineering model and integrate this model with the recycler's profit model. In addition, numerical experiments will reveal the impact of the interaction on the profitability of the recycling business.

1-1F: Construction

1-1F-1

Environmental impact assessment of PEMFC for residential use considering regionality and performance drop

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Recently, the use of fuel cell combined heat and power systems (FC-CGSs) for residential applications has been expanding. Based on the increased use of these systems, in International Electrotechnical Commission (IEC)/ Technical Committee 105, the technical specification of the impact assessment procedure regarding general FC-CGS using the life cycle assessment methodology have been released. As for proton exchange membrane fuel cell (PEMFC), the amount of platinum (Pt), which largely contributes to abiotic depletion potential (ADP), used as the catalyst has a trade-off relationship with durability and power generation performance. Therefore, it is important to consider the interrelationship between the Pt consumption and the durability including performance degradation to evaluate the environmental impact over the life cycle.
However, although the environmental impact of FC-CGS varies depending on the regionality and the degradation, previous studies have not considered the effects of them. In this study, we conducted comprehensive evaluation of 700W-scale PEMFC-CGS including PEMFC degradation, the mass and heat balance in the reformer, energy demands and global warming potential (GWP) values considering regional characteristics of such as Japan and Europe. The evaluation was based on the idea of the above technical specification and considered GWP and ADP values for 10 years of use. Through the Pt dissolution model, the electrochemical surface area (ECSA) transition was calculated. Note that GWP is related to the operating condition and that ADP is attributed to the manufacturing stage.
As a result, the efficiency of conversion of methane to available hydrogen in the reformer was 0.77, and the use of PEMFC-CGS in Japan contributed more to the reduction of GWP than in Europe because of regional characteristics. Finally, it was suggested that the appropriate amount of Pt to reduce ADP and GWP for a particular region and energy demand.

1-1F-2

Thinking the future – End-of-life life cycle assessment of fiber reinforced concrete

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This work aims to identify the current, possible methods for recycling carbon- (CRC) and glass fiber-reinforced concrete (GFRC) to enable environmental assessments of different End-of-Life (EoL) scenarios for comparison with the EoL of traditional steel-reinforced

concrete (SRC).
Fiber-reinforced concrete is an innovative alternative in the construction sector as significant material savings can be made since no corrosion protection is required compared to conventional steel-reinforced concrete. With Life Cycle Assessment (LCA), the environmental impacts occurring in the EoL and thus in the recycling process of building materials are quantified.
For CRC, transportation to the stationary processing plant represents the driver of Global Warming Potential (GWP) and highlights the need for processing plants near the demolition sites. It is emphasized that although mechanical recycling of CRC shows a lower GWP, the inferior quality of the recycled carbon fibers and the resulting lower range of recycling options into new products are clear disadvantages compared to pyrolysis. Therefore, the importance of the closed material loop and the associated processing of the recycled carbon fibers into new carbon reinforcement is highlighted in this work. This relevance stems from both the high energy input and the dependence on petroleum, a non-renewable raw material, to produce primary carbon fibers. The concrete fraction separated from steel and fiber concrete can be successfully used as recycled concrete.
Moreover, we show detailed comparisons between GFRC and SRC. The explicit consideration of the EoL of reinforced concrete is highly relevant, allowing an early determination of the environmental impact of the recycling processes. Furthermore, the question of whether fiber-reinforced concrete has the potential to play a decisive role in improving the environmental performance of the built environment is addressed.

1-1F-3

Carbon footprint analysis of construction technologies in Japan

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To mitigate climate change, the residential building sector needs to reduce not only CO2 emissions caused by direct energy use phase at home but CO2 emissions triggered by construction supply chains. In 2020, 820000 units of houses were newly built in Japan. In the same year, the number of new wooden houses was 470000 units, accounting for approximately 60% of the new housing starts and thus the demand for wood-frame housing is higher in Japan. This study focuses on three types of technologies of wood-frame construction, steel-framed reinforced concrete (SRC) construction, and reinforced concrete (RC) construction and determines a functional unit of total floor area of an 'average' house constructed by the specific technology. Based on the Construction Input-Output Table (CIOT) provided by the Ministry of Land, Infrastructure, Transport and Tourism and the Embodied Energy and Emission Intensity Data (3EID) for Japan Using Input-Output Tables provided by the National Institute for Environmental Studies of Japan, we estimated the carbon footprint from supply chains formed by constructing an average house with 106 square meters by the specific construction technology (i.e., wood-frame technology, SRC technology, and RC technology). Subsequently, we used a unit structure model with a focus on the specific construction technology and identified CO2 hotspots in the construction supply chains. We found that the wood-frame technology contributed to increasing the carbon footprint during the study period between 2005 and 2015 due to growth of CO2 hotspots for material sectors. It is crucial to implement a policy to reduce supply chain emissions with a focus on the CO2 hotspots identified in this study.

1-1F-4

Carbon handprint for assessing the positive impacts of constructing low carbon buildings in evolving economies

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To meet the Paris climate goals of limiting global warming below 1.5 C, rapid implementation and incentivizing the innovation of low/decarbonization technologies are of high importance. Various sustainability assessments have been developed and utilized for decision making, such as the GHG Protocol Scope 3 Emissions for green / ESG investments. However, most of the assessment methodologies focus on the negative impacts that the industrial activities cause, instead of evaluating the created positive impact. One of the assessment methodologies to assess such impact the companies create is called "handprint" methodology.
The study conducted a case study for creating and establishing a simplified carbon handprint method for a building with high impact, high replication potential typology for supporting low carbon transition in evolving economies.
The reference building as a baseline for quantifying the handprint was defined based on local stakeholder consultations, and literature reviews. Due to the issue on availability of data for conducting the assessment, the study also conducted an app-based digital building data collection approach (CAPSA) and stored in Building Passport, a whole life cycle repository of building information being developed under UNEP Global Alliance for Building and Construction (GABC) program in Work Area 5 on Building Data, Measurement and Information. The study further investigated the hotspots for maximizing the handprint of the high impact buildings to arrive at a simple and therefore scalable checklist for the construction industry in selected evolving economies.

1-2A-1

Environmental impacts of global offshore wind energy development until 2040

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The continuing reduction in levelized cost of energy is driving the rapid development of offshore wind energy (OWE). It is thus important to evaluate, from an environmental perspective, the implications of expanding OWE capacity on a global scale. Nevertheless, this assessment must take into account various scenarios for the growth of different OWE technologies in the near future. To evaluate the environmental impacts of future OWE development, this paper conducts a dynamic life cycle assessment (LCA) including parameterized supply chains with high technology resolution. Results show that OWE related environmental impacts, including climate change, marine ecotoxicity, marine eutrophication, and metal depletion, are reduced by ~20% per MWh from 2020 to 2040 due to various development including size expanding, lifetime extension, and technology innovation. At the global scale, 0.3-0.5 Gt CO2-eq of greenhouse gas emissions are emitted cumulatively due to OWE deployment from 2020 to 2040. However, this compares to 12.4-20.7 Gt CO2-eq emissions (31-52 times more) that would be generated when producing the same quantity of electricity with the global electricity mix of 2020. Manufacturing of primary materials, such as steel and fibers, is the dominant contributor to impacts. 6-9% of the cumulative OWE related environmental impacts could be reduced by end of life (EoL) recycling and the substitution of raw materials.

1-2A-2

Life cycle CO2 emissions from ammonia power generation

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Since ammonia combustion does not accompany any CO2 emissions, the use of ammonia as fuel is expected to play an important role in realising the future carbon neutrality. However, their low-carbon potential should be evaluated from a life cycle point of view. We conducted a life cycle inventory analysis to understand the low-carbon potential of using ammonia as a power generation fuel. We considered two options for ammonia production: blue and green ammonia. Blue ammonia was produced from natural gas (with and without carbon capture and storage (CCS) option), and green ammonia was produced from solar photovoltaics. Both were produced overseas, imported to Japan and then used in NH3 co-firing with coal and NH3 mono-firing power plants. The CO2 emissions from the operation and the capital goods related to the NH3 value chain and power generation were calculated. The results indicated the life CO2 emissions from the NH3 mono-firing power plant with a low-carbon NH3 value chain could be lower than those from the coal power with CCS. The results also revealed that the CO2 emissions attributed to the capital goods of the fuel value chain may have an enormous impact on the whole life cycle emissions, especially when utilising variable renewable energy with low capacity factor.

1-2A-3

Decarbonization by green electricity: The challenges of double counting

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Electricity consumption constitutes a significant contribution to global, organizational and product greenhouse gas emissions. The same holds true for many other environmental impacts. Emissions related to electricity production strongly depend on its energy source, i.e. fossil fuel or renewable energy. Thus, double counting electricity generated from specific energy sources can lead to an underestimation of electricity related emission and consequently overall emissions. The aim of this research is to identify challenges of double counting electricity from specific energy sources in LCA and propose potential solutions.
Different electricity accounting methods are currently applied. Location-based electricity accounting uses average emission factors for all grid electricity consumers in a certain region, whereas market-based accounting is based on contractual agreements and residual electricity mixes. If applied consistently, both methods can avoid double counting. However, a parallel application of location-based and market-based electricity accounting is susceptible to double counting. For location-based accounting, the main challenge of double counting lies in the application of different temporal and spatial resolutions. Nevertheless, location-based electricity accounting is relatively straight forward. However, it precludes electricity consumers from accounting for a specific energy sources, such as renewable energy. For market-based accounting, the main challenge for the avoidance of double counting is its consistent application the whole life cycle, since generic life cycle inventory processes are often used to fill data gaps. These processes usually include location-based electricity mixes, rather than market-based mixes. Consistently integrating market-based electricity mixes into life cycle inventory processes would require a recalculation of existing databases.
In order to avoid double counting, there is an urgent need for the LCA and GHG accounting community to agree on consistent

electricity accounting rules. Our research provides a basis for this agreement.

1-2A-4

Co-benefit / trade-off assessment of NH3 energy carrier and NOx recovery

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Nitrogen economy is a proposed future in which nitrogen compounds play a critical role for our society. Ammonia is a representative among others. Its applications can be traced back to 1850s used for refrigerant, and then for fertilizer in 1900s and synthetic resin 1950s. In the 21st century, it was proposed as a potential energy carrier due to the merits regarding affordability, safety, flexibility, and versatility. On the other hand, burning of fossil fuels generate huge amount of nitrogen oxides, which are mainly treated by dinitration currently. To increase the resource efficiency, nitrogen oxides were recovered to produce ammonia as high value-added product. When those new industrial technologies are implemented into our society to reduce the target risk, the ancillary risk can be affected which causes co-benefits or trade-offs. This study evaluated new industrial technologies of ammonia energy carrier and nitrogen oxide recovery to support their social implementation. We explored the optimum supply chain, identified the environmental hotspots, and illustrated the co-benefits/trade-offs, which provide insights into introduction of emerging nitrogen technologies promoting sustainability.

1-2B: Technology assessment

1-2B-1

Life cycle assessment of recycling of polymer-bonded magnets in supercritical hydrothermal reactor

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Recycling of magnets containing critical raw materials (CRMs) has received considerable attention due to the importance of CRMs, which is linked to all industries across all supply chain stages, and closely linked to clean technology. Polymer-bonded magnets (PBMs), one type of these kind of magnets, consist of Nd-Fe-B (neodymium-iron-boron) magnetic particles bonded in a polymer matrix and its recycling can be achieved by a hydrothermal solvolysis process.
This study aims to evaluate the environmental impacts of PBMs recycling by a hydrothermal solvolysis process in comparison with landfill and incineration treatment using life cycle assessment (LCA) method to provide the environmental performance of this technology. The results point to sodium hydroxide and heat as the main contributors to the environmental impacts arising in different materials used and processes applied in hydrothermal solvolysis. Impact assessment results associated with hydrothermal recycling show that impacts of the recycling process are important in most impact categories. Nevertheless, the results of comparison with the primary production suggest considerably lower environmental impacts of secondary PBM rout overall for all the categories and particularly toxicity-related impacts. Overall, we can show that the global warming potential and the cumulative energy demand are approximately 70% lower than the primary production route.
The findings of this study are that the recycling by the hydrothermal solvolysis process is relatively green in comparison with the virgin alternative and that the hotspot analysis serves to show where further improvements may have the most meaningful effect on reducing environmental impacts. It scientifically supports that the process design optimization should be directed to reducing the impacts of chemicals and energy, as well as in a better preservation of magnetic properties.

1-2B-2

A system analysis of the impurity removal on a bio-hydrogen production system using granulated neutralized sediment as adsorbent

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Biomass, which is carbon neutral, is one of the most environmentally friendly hydrogen fuels. However, during the production of biomass-derived hydrogen (biohydrogen), hydrogen sulfide (H2S) contained in the gasified biomass contributes to the performance degradation of fuel cells. Generally, H2S is removed by impurity adsorption. However, metal oxide, which is a common adsorbent, has a large eco-burden, and adsorbents with a smaller eco-burden are needed. In our previous study, we proposed the use of a powdered waste material, neutralized sediment (Ns), including iron as an adsorbent for H2S in the viewpoint of circular economy for improving metal depletion, and showed that eco-burden of the impurity adsorption system using Ns had a GWP 95% lower than that using metal

oxide. However, the powdered adsorbent has a large pressure drop (about 20kPa in previous experiments), requiring additional pressure to be applied to the entrance side, which is expected to require additional energy. Therefore, in this study, we granulated the Ns to confirm the decrease in pressure loss and to investigate the change in the sulfur capture capacity due to granulation. In addition, considering the additional energy and cost of granulation, we designed a biohydrogen production system from sewage sludge that utilizes the granulated Ns as an impurity adsorbent, and analyzed it from the viewpoints of energy, eco-burden, and cost. As a result, at adsorption temperature 40℃, while sulfur capture capacity of granulated Ns was 30% smaller than that of powdered one, pressure drop of granulated Ns was 80% smaller than that of powdered one. In addition, at same adsorption temperature, compared to the biohydrogen production system using metal oxide which is conventional adsorbent, the energy efficiency of biohydrogen production system using granulated Ns was about the same, but the eco-burden (GWP) and cost of it was reduced by 30% and 40%, respectively.

1-2B-3

A life cycle design for FC systems in consideration of Pt catalyst degradation in practical small applications

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In recent years, fuel cell systems have been become increasingly popular to their use in large applications such as fuel cell vehicles and the stationary fuel cell power system for residential application. In the future, the spread of fuel cell systems in smaller applications, such as electrically power assisted bicycles and drones, is expected to expand. Fuel cells are well known for their low environmental impact during operation, but in considering the future expansion of fuel cell use, it is important to consider reducing the environmental impact not only during the use phase, but also during the manufacturing phase. This is because there is a concern that the sale of products may be restricted if they fail to meet legal standards such as the LCA regulations in EU countries. For instance, in TC 105 of IEC, the technical specification of LCA methodology for a stationery fuel cell (FC) co-generation system was issued. In this document, the abiotic depletion potential (ADP) in the manufacturing phase besides global warming potential (GWP) in the using are evaluated. That is, in this study, since FC has a large environmental impact due to the platinum (Pt) used as a catalyst, which is larger than that of lithium and cobalt used in conventional lithium-ion batteries, it is important to design each FC application in consideration of the entire life cycle stages including optimal performance and product life.
For instance, we analyze the performance drop caused by Pt degradation in the using phase for the assisted bicycle in which FC application and the supplementally power source of Li-ion battery were launched. Based on the analysis, suggestions on the how to optimize the use of Pt in fuel cell systems for each device will be presented through an evaluation based on a LCA thinking.

1-2B-4

Identification of high-environmental impact processes in oil and gas upstream industry through life cycle assessment: Case of Borneo, Indonesia

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The oil and gas sector's GHG emissions in Indonesia have a significant potential to be further lowered. This study investigates the processes that potentially cause significant environmental impacts (so-called hotspots) in the oil and gas upstream sector, based on a life cycle assessment (LCA) conducted on five different oil and gas fields in Borneo, Indonesia. The LCA conducted has a functional unit of 1 GJ of oil and gas produced. The scope of the LCA is cradle-to-gate, which involves processes such as drilling, workover & well intervention, separation, compression, well injection, transportation of products to customers, and utilities. A system expansion approach was utilized to separate the oil and gas production system. The life cycle inventories included chemicals, fuels, transportation of materials, water use, infrastructures, land use, wastes, and emissions. The data quality rating (DQR; ILCD-based) showed that all fields complied with the basic quality level (DQR <= 2).
Life cycle impact assessment (LCIA) was performed using IPCC 100a, CML IA (Baseline and non-Baseline), ReCiPe, AWARE, and cumulative energy demand. The potential environmental impact categories assessed are global warming potential (GWP), ozone depletion potential (ODP), acidification potential (AP), eutrophication potential (EP), photochemical oxidant formation (POF), abiotic depletion – fossil (ADF), and non-fossil (ADP), ecotoxicity (ETP), human toxicity – carcinogenic (HTC) and non-carcinogenic (HTN), water footprint (WSF), and cumulative energy demand. The LCIA results indicated that GWP was mainly produced from well operation, flaring, and gas compression processes. The extracted crude oil and gas had a major impact in ADF, while the production of infrastructures and supporting materials primarily contributed to ADP and ETP. This highlights the importance of utilizing the materials at their end of life stage. Emission from the diesel combustion in various machinery showed a significant impact on other categories such as ODP and EP.

1-2C: Metallic resources: now and future (2)

1-2C-1

Boron mining in Turkey: An overview of the environmental impacts using MFA, LCA and abiotic depletion indicator adaptation

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Boron is a fairly widespread mineral but its deposits are very localized and nearly 70% of this resource is found in Turkey. Since 2017, boron has been considered a critical mineral by European authorities and better management of this mineral should be considered, especially since there is no boron recycling system. The ore is generally used in various sectors of activity (eg glass industry, fertilizer) and its miscibility characteristics mean that it is no longer separable after use and therefore cannot be recycled. It is also important to note that the term boron actually compiles several ores, namely tincal (or borax), colemanite and ulexite.
Using methods such as material flow analysis and life cycle analysis, our project aims to identify the deposits of each mineral and their uses, to assess the potential environmental impacts specific to each of these minerals and finally to adapt the parameters used to calculate the abiotic depletion indicator in the life cycle analysis.
Our research has therefore shown a great disparity in exploitation between the different ores (because it depends on their uses) and that Europe is totally dependent on Turkey for its boron supply. The life cycle analysis also shows us that the potential environmental impacts between the different minerals are very different. Finally, we were able to observe that the indicator of abiotic depletion in the life cycle analysis was based solely on boron without distinction of ore, which can generate certain errors of interpretation, this is why we propose differentiated characterization factors for tincal, colemanite and ulexite.

1-2C-2

Life cycle assessment and carbon footprint for deep sea mining of polymetallic nodules

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Polymetallic nodules in the deep sea are a widely discussed deposit of battery metals. Irrespective of biodiversity impact issues, it has been argued that polymetallic nodule extraction has a better carbon footprint than extraction of equivalent metals from mines on land. This is used as a major argument in favor of deep-sea mining, as climate protection is a global priority.
Together with the German Federal Institute for Geosciences and Natural Resources, an LCA was performed, in which the extraction of the metals nickel, copper, cobalt and ferromanganese from polymetallic nodules was compared with extraction from mines on land. Mines from Australia and Finland, which are comparable in terms of metal composition, were selected for this purpose. For the extraction of polymetallic nodules from the Clarion Clipperton Zone in the Pacific Ocean, technical feasibility studies were used, since no industrial extraction has taken place to date.
The production of metals from one kg of wet manganese nodule (containing 9g nickel, 7g copper, 1g cobalt and 200g ferromanganese) results in approx. 1.2 kg CO2e and a CED of approx. 15 MJ. The comparison with mines on land shows that polymetallic nodules from the deep sea – even with optimistic assumptions – do not provide a decisive advantage in terms of energy demand and greenhouse gas emissions. However, the results depend on many assumptions e.g., when compiling metallurgical process inventories, or defining the functional unit, multifunctionality handling, allocation and reference scenarios. These artifacts of LCA calculation are comprehensible to LCA experts, but not to investors and policymakers. This makes transparent presentation of assumptions and a careful critical review process very important. The results of the present study indicate that the carbon footprint of polymetallic nodules is not a strong argument for deep-sea-mining.

1-2C-3

Gold production and mercury consumption from artisanal and small-scale mining

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Gold production has increased greatly since 1900 (705 tonnes) and achieved record new highs each year from 2011 through 2015 due to its unique role in central bank reserve, investment, jewelry production, and as a key component in many electronic products.

As an important part of gold production, although often overlooked or underestimated by the public, artisanal and small-scale gold mining (ASGM) may increase and play a more important role in global gold production, given that the large, low-cost mines and older ones are nearing exhaustion.
In this study, we investigated the methods of estimating the amount of gold production from ASGM in the literature from different perspectives. According to our review of papers, the proportion of ASGM businesses to large-scale mines, and the subtraction of conventional gold mining companies from total global gold production were the main factors in estimating ASGM production. Although the methods for estimating gold production vary and data uncertainties are often difficult to eliminate, the estimates of global gold production are roughly equal across methods.
Globally, ASGM produces 379.4–871.2 tonnes of gold each year. At the regional level, the newest estimate shows a significant increase in Asia from 120 tonnes in 2011 to 304.1–479.4 tonnes in 2015, with extreme increases existing in China and Indonesia, and a slight increase in Africa from 85–90.4 tonnes to 126.5–178.4 tonnes. ASGM production in Central and South America is relatively stable with an estimate of 184.7–213.4 tonnes in 2015. The mercury consumption, therefore, may exceed 417.3–958.3 tonnes at its lowest estimate using the Hg: Au ratio as 1.1.

1-2C-4

Life cycle assessment of copper tailings reprocessing: Collaborative, prospective approach

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Sustainable transitions and economic development have driven demands for minerals and materials in recent years. Innovation for all mining life-cycle operations, including waste management, can significantly contribute. With the right implementation, tailings and mine waste streams could be a solution to growing resource demand. Recoverable materials from mine waste stocks include base metals and construction materials, e.g., alternative cement. Researchers have found that some tailings have elevated concentrations of metals and minerals, which are promising for resource recovery. Herein we focus on copper mining and processing, which are known as a dominant contributor to tailings generation globally. While tailings can be deposited in a dam, careful monitoring is required to prevent the risk of contamination or major collapses. Poor management could lead to environmental threats for the surrounding area, especially in the long term after mine closures. In this study, we validate the environmental performances of tailings reprocessing through systems-thinking approaches. More specifically, the potential environmental impacts of emerging technologies for copper tailings are evaluated using the prospective life cycle assessment (LCA) method. Process-based life cycle inventories are built from continuous interactions with experts in a research cluster, ensuring compatibility of material processing in a series of technology flowsheets. We employed prospective LCA concepts by combining bottom-up modeling of foreground systems based on lab-scale research and future background data, such as energy supply. The results indicate that both metal recoveries and valorization of bulk residues as building materials are necessary together to gain overall environmental benefits in all studied reprocessing flowsheets. Toxicity impacts originally arising from tailings deposits are minimized compared to the default landfill practice. Overall, we are able to identify the environmental impacts of early-stage innovation, thus helping informed decision-making for process optimizations and eventually sustainable waste management in the mining/mineral industry.

1-2C-5

Prospective life cycle assessment of mineral and metal recycling from waste incineration slag

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In municipal solid waste incineration (MSWI) plants waste is thermally treated for energy recovery and volume reduction. According to the state-of-the-art, iron and non-ferrous metals are recovered from the coarse fraction of the MSWI slag. However, recovering processes for the fine fraction (< 3 mm) of the slag are lacking. Recovering the metals and minerals is challenging because they are melted together due to the combustion process. Although, the fine fraction contains metals such as copper and important minerals for the cement industry such as calcium oxide and silicon dioxide. Therefore, it is the aim of our project to develop treatment technologies that make metals and minerals available from the fine fraction as secondary raw materials. The substitution of raw materials in the cement industry with the recovered minerals leads to a mitigation of environmental impacts like resource depletion and climate change. However, the high energy demand for the treatment technologies leads to additional environmental impacts.
To quantify the effects of the emerging technology of MSWI slag treatment on the environment, we apply the method of life cycle assessment (LCA) to the processing alternatives on a lab scale. By using upscaling methods, we make the treatment technologies comparable to state-of-the-art technologies. As it is the nature of emerging technologies, uncertainties must be faced appropriate. Besides the considered upscaling method, the influence of allocation factors applied to the network of participating industries (waste, cement, metal, and energy sector) influence the results. To face both, prospective scenarios are developed that represent different options of upscaling and allocation effects. In these scenarios the uncertainty of output products, like different metals and minerals, and input products e. g. different electricity generation scenarios are modeled. The study results indicate an important mitigation

potential in most categories provoked by the innovative treatment technology.

1-2D: [OS] Doing more with less - Transitioning to circular economy through business model innovation (2)

1-2D-1

Unlocking the sustainability potential of circular business models by design

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We stand at a tipping point in society, which calls for innovative and transformative solutions capable of addressing the global sustainability challenges (e.g. climate change, loss of biodiversity, resource depletion). Circular Economy is increasingly seen as a promising approach to decouple resource consumption from value creation through business and product innovation. But how to ensure that circular innovations are systematically more sustainable? In this keynote speech, Daniela will explore the potential of circular innovations to transform the world around us and lead to enhanced sustainability performance. The potential sustainability gains and rebound effects will be discussed through a number of provocative examples focusing on a diverse set of innovation strategies. Throughout the argumentation, the participants will be invited to reflect on how to ensure that circular business models will enable the decoupling of value creation from resource consumption.

1-2D-2

Toward the realization of circular economy business for home appliances and industrial equipment

Gaku Miyake
Panasonic Holdings Corporation, Japan

Environmental sustainability is currently a central issue in manufacturing. In particular, achieving both carbon neutrality and a circular economy is indispensable. Toward this end, it is necessary to change business models to circular economy-based business models . This study presents a design method for and the LCA results of circular economy business models at Panasonic.

1-2D-3

Development of an indicator system to measure the implementation of the SDG12 on sustainable production and consumption for enterprises in Vietnam

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Realizing the SDG targets at national and local levels requires monitoring systems to measure the implementation and achievement of each target. This study aims to provide insights from the development of an indicator system to measure and monitor the implementation of the SDG12 on sustainable production and consumption for enterprises in Vietnam, focusing on five business sectors (plastic, textile, steel, food processing, beer and beverage). We applied both top-down and bottom-up approaches, including a literature review of previous indicator systems, relevant scientific papers, and national policies, as well as 20 interviews and a consultation workshop with experts and entrepreneurs. The proposed indicator system contains 91 indicators classified into different patterns of sustainable production and consumption. The suitability of these indicators is rated differently by experts and entrepreneurs during the interviews and workshops, indicating divergences in the importance and relevance of each indicator for various actors. The lesson learned from the development of the indicator system includes the consideration of different business sectors and customers' perspectives in the indicator selection and various implementation roadmaps for business sectors. Adding social indicators and supplementing information from the application of the indicator system for an enterprise are also recommended to improve the quality of the developed indicator system.

1-2E: Food

1-2E-1

Predicting conservation risks of global agricultural production and consumption

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Despite efforts to promote sustainable agriculture, food and agricultural production remains the main driver of global biodiversity loss. However, it is still not clear where food production conflicts with biodiversity conservation, nor which products and countries contribute the most. This study provides the first mapping-based prediction of how production and consumption of 48 agricultural commodities driven by 197 countries conflict with conservation priorities for 8,428 species. Our analysis consists of two main steps to expose the location and drivers of potential conflict between conservation priority sites and agricultural products. First, we assess the level of co-occurrence between agricultural production activities and conservation priority sites. Second, we link agricultural commodity production in conservation priority sites to countries and sectors of final consumption using trade and sectoral use data. By spatially modelling the overlap between agricultural land use and species habitats we reveal how, where, and what products and countries threaten conservation priority areas. Globally, we find 39.5% of agricultural production occurs on sites of very high conservation priority. Cattle, maize, and soybean occupy the most abundant land use areas in those sites and pose the highest conservation risk of the commodities analysed. However, we also identify biodiversity-friendly products (e.g., sugar beet, pigeon pea and lentils) which avoid such risk hotspots. The conservation risk posed by national demand for agricultural commodities varies between countries based on consumption and sourcing patterns. Based on climate-induced shifts in future species distribution for 2070, we estimate the scale and location conflicts are likely to change in the future for most commodities analysed. By meeting the increasing scope and spatial resolution of assessments in other domains (e.g., water use, greenhouse gas emissions, and land use change), the analysis developed within this study can serve as part of a broader assessment of meeting human needs within planetary boundaries.

1-2E-2

Development of national baseline for food waste and use of LCA for conducting hot spot analysis of food waste reduction opportunities.

Tim Grant

Lifecycles, Australia

The United Nations have a target to halve global food waste per capita by 2030 which in turn has been adopted as a target in the Australian context.

To support this target, a National Food Waste Strategy Feasibility Study was undertaken in 2021 which included updating the National food waste baseline, undertaking a thorough hot spot analysis and testing a range of policy options.

The hotspot analysis consisted of an LCA of 18 major food categories across five supply chain stages. The LCA included climate change, water scarcity, and land occupations as well as net waste and economic value as indicators.

The LCA was largely based on the Australian National Inventory data, supplemented with studies on major protein production pathways in Australia including chicken, pork and eggs. Other data sources included EcoInvent and the World Food LCA Database.

The results show that the most significant impacts occur at waste at consumer (including households and hospitality), due to the compounding effect of waste along the supply chain, with the highest climate impacts being from meat, dairy, and bread. For water scarcity the highest impacts were dairy and vegetable production and for land use the highest impacts were from meat production, particularly beef, and lamb.

A range of strategies that were tested to reduce food waste showed that at the manufacturing stage waste can be diverted to beneficial uses, however, the main climate change benefits are found in strategies that reduce waste at the household level.

1-2E-3

A follow-up study of the attitudes of middle school students toward composting and food waste

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In Japan, approximately 6.12 million tons of food waste is generated annually. To solve this food waste problem, people can use home composting. This study has three objectives.

- How the composting experience changes junior high school students' attitudes toward composting
- How will awareness and behavior toward food recycling and food waste change?
- How they share composting experiences with their surrounding family and friends

This research was conducted with the cooperation of Dohoku Junior High School (total 570 students) located in Wakamatsu-ku, Kitakyushu City. The composting experience was led by the junior high school. Four composters with a volume of 0.14 m3 were placed in plastic containers, which were filled with a bamboo-based material “Takehime" produced by Hayashida Sangyo Co. We followed 16 students. On July 1, 2021, an interview was conducted with the students before the composting experience began, followed by three follow-up surveys. For each survey, we first asked each student to fill out a survey form and then proceeded to ask

for further details in group interviews.
The results of the study showed that the students were more excited by a curiosity about insects, mold, smells and changes in temperature in the hands-on compost. The final survey helped students understand the operation of the compost. In the final interview survey about food waste, the students' answers related to environmental conservation, such as reducing daily food waste, appreciating the living environment, understanding the criticality of food waste, and emphasizing 3R activities. Overall, a positive impact was seen via this environmental education for the students. Since they had talked to their families more than friends, the impact on their families was greater than the impact on their friends.

1-2E-4

Considering a practical approach that drives consumer behavior change by providing carbon footprint information of food

Hiroya Iwashita, Shoichiro Tsuruta
Sustainable Management Promotion Organization (SuMPO), Japan

To achieve a carbon neutral society by 2050, it is crucial that we all understand how much greenhouse gasses are emitted through human activities. There has been a global shift to sustainable development, and frameworks such as TCFD recommendations help many businesses to quantify their lifecycle influence on environment. As a result, thousands of enterprises now disclose climate-related information, most notably Scope 3 emissions, to stakeholders. On the other hand, there is still not much information that allows general consumers to know how much greenhouse gasses they emit in everyday life. More consumers have become environmentally conscious, but there is virtually no way for them to be sure if choices they make every day are really low-carbon. If more products and services are offered together with carbon footprint, it becomes easier for consumers to choose low-emitting options and a market for low-carbon offerings is more likely to expand. An increase in demand for green products is probable to make corporations' investment decisions easier, which should accelerate decarbonization transitions. Among many consumer goods, food is one of the most frequently consumed items, and greenhouse gas emissions from agriculture sector is not insignificant. Therefore, we are developing a tool that is easy to use and can visualize carbon footprint of food. In this tool, there are data for hundreds of ingredients and multiple cooking methods, so carbon footprint of thousands of recipes can be calculated. The dataset is developed by using publicized survey statistics as well as 3EID. In this presentation, a logic behind its calculation method and possible ways to utilize this tool are discussed.

1-2E-5

Results of a fact-finding survey on the sustainable diets and smart food services: a case of Japan

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Sustainable diets and smart food services can be effective solutions to achieving SDG 12.3. The establishment of a smart food system covering more regions is also essential to an aging society. Given such context, we conducted a questionnaire survey to investigate the impacts of sustainable diets and smart food services in Japan. The survey covers 6,000 households nationwide and collects the responses of dinners in 3 days. The questions include the number of menus, the number of all ingredients (22 types), the expenditure on such ingredients, the amount of discharged kitchen and plastic waste, the heating time of each meal, as well as the attitudes towards household cooking (13 questions) and acceptance to PCs and smartphones (10 questions).
Based on the survey results, we first developed indicators to characterize each meal. We quantified the indicator of cooking effort, the convenience food usage intensity, the average price specific weight, CO2 emission points (CO2 emissions per unit price), and the proximity score for each ingredient. Regarding the proximity score, for each ingredient, we quantified the degree of using processing of food based on the NOVA classification and the fresh/processed food classification formulated in the Food Labeling Law. Finally, based on these indicators for all meals from all respondent families, we investigated the impacts of the attitudes towards household cooking and the acceptance to PCs and smartphones on the following dimensions: cooking effort, convenience food usage intensity, expenditure, energy consumption for cooking, the amount of discharged waste, and CO2 emissions. The results provide important

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1-2F: EcoDesign

1-2F-1

Assessment of the environmental impact for OLED TV module using LCA

Jewon Yang, Byungkwun Kang, Byunghee Choi, Yongchae Jung
LG Display

Recently, the international community is demanding to reduce the emission of environmental pollutants such as carbon dioxide and greenhouse gases to prevent extreme weather events caused by economic growth. In response to these international demands, the electrical and electronic product industry is establishing and implementing environmental impact reduction plans through eco-friendly materials, technologies, and processes. In this study, the environmental impact was quantitatively analyzed using LCA on the OLED TV module. Based on the ISO 14040 series standard, the environmental impact of global warming was assessed and discussed across the whole life cycle including raw material extraction, manufacturing, product use, and end-of-life stages of OLED TV module.

1-2F-2

LCA as a tool for innovation: How to leverage LCA to accelerate a sustainable-Tech startup

Shinya Shimizu
Elephantech Inc, Japan

Life cycle assessment has become popular for most companies, but not for startups. LCA has been used as a tool for companies to assess their current business activities, identify the room for improvement, and improve it. While incremental improvements of current business activities are essential for a sustainable society, disruptive innovations are also necessary, where startups play an important role.
LCA is, however, rarely utilized by startups even if the technology of the startup has a great potential for carbon footprint reduction. There are mainly two reasons behind it: (1) Difficulty of assessment. Unlike just assessing current business activities, it is not straightforward to estimate technological potential of avoided emission; (2) Value of assessment. Unlike large, profitable companies, it is challenging for startups to justify the cost of assessment given the value of the assessment is limited.
In this paper, a case study on Elephantech is introduced. Elephantech is a startup who has a technology to manufacture circuit boards using metal nanoparticle inkjet printing and electroless copper plating. With this technology, manufacturers can eliminate all the subtractive processes including exposure, development, etching and stripping, which is estimated to reduce water consumption, carbon footprint, and manufacturing cost significantly.
It was challenging to conduct an apple-to-apple comparison between Elephantech method and conventional method because Elephantech has just started a small-scale mass-production, which is different from conventional factories in many ways, and circuit board manufacturing process is complicated to set clear system boundaries. We analyzed an existing LCA paper on circuit boards, built estimation logics and boundaries, and calculated the avoid emission potential based on LCA.
We also got feedback on LCA from potential clients and partners and identified its benefits.
We hope this case study shows the viability of LCA in the innovation sector and helps accelerate sustainable-tech innovations utilizing LCA.

1-2F-3

Integrating Ecodesign approach in high valued materials & processes TRL Referential: the experience of an aeronautical actor.

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When it comes to environmental approach, the Aviation's sector focuses on the reduction of noise and gaseous emissions during use phase. Virtuous environmental approach cannot avoid taking into account the specificities of the global life cycle of the product. Ecodesign has become a primary topic in such industry. Every upstream and downstream steps of the entire life cycle have to be accurately considered.
Among decarbonated aviation's levers, like disruptive materials and processes development, Eco-design is now identified as a compulsory path to accompany choices in order to avoid pollution transfer induction.
Safran has been developing since the last three years Ecodesign's integration within its materials and processes (M&P) TRL Referential. As equivalent approaches exist in other types of industrial sectors, such as automotive, the critical point is here to address strongly guided developed applications, within a specific market's characteristics such as long life cycle products.
Our research aims to present the referential logic and construction, leading to the developed strategy that connects each TRL step to environmental knowledge and completion.
Characterization of most of aeronautical M&P does not exist in Life Cycle Assessment databases, and one essential step is to collect these environmental data. One objective of this data extraction is to identify at the earliest development level (TRL1) the key indicators that can be set in order to define some raw improvement goals to begin with.
Ecodesign is not an integrated skill within technical teams' daily operations yet: we have to provide them with an optimized work frame while nurturing the arising of questions linked to the environmental challenges the industry faces. The present research is about methods and tools, but also about change management feedback loops. Ecodesign is no more than a big multifactorial optimization problem that have to be solved while involving the human factor.

1-2F-4

A life cycle assessment modelling approach: Identifying hotspots and improvement opportunities for a recyclable multi-material design of automotive lightweight structures

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Nowadays, environmental aspects play a significant role in the research, development, and application of technological solutions within the automotive sector. Thereby, automotive lightweight components, leading to less material consumption and, therefore, reduced manufacturing and operating environmental impacts, are considered a key factor for sustainable and resource-efficient mobility. Recently, a particular focus has been given to polymer multi-material lightweight structures. These have the potential to reduce environmental impacts throughout the entire life cycle of the materials compared to conventional monolithic aluminum or magnesium lightweight components. An example in this context is the construction and process development of functionalized multicomponent structures with complex-shaped hollow profiles (FuPro), combining fiber-reinforced thermoplastics, organic sheets, and injection molding. Furthermore, recyclability can be achieved using a single fiberglass-reinforced polymer (FRP) matrix and laser structuring processes for material bonding. However, to make an actual and measurable environmental contribution, potential hotspots of such lightweight structures and optimized manufacturing in terms of the lowest possible environmental impact must be assessed through a life cycle approach. Life Cycle Assessment (LCA) in the early stages of development has great potential to support decision-making processes. Yet, considering previous publications, it has only been carried out to a limited extent for automotive lightweight structures, posing new modeling challenges. Commonly, environmental impacts considering recyclability have not been clarified, and impact categories have mostly been limited to the Global Warming Potential (GWP). Thus, an LCA including the main phases of the process is contemplated following the ISO 14040/14044 standards. As a result, an LCA modeling framework for the recyclable multi-material lightweight structures, building on the FuPro process and determining the functional unit, the system boundaries, potential environmental impacts, and a broader range of impact categories, is proposed for assessing environmental hotspots and improvement potentials.

2-1A: Energy-material nexus for carbon neutrality

2-1A-1

Future metal production and associated greenhouse gas emissions with implication for climate goals

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Metals play an essential role in human life, while metal use is associated with not only metal depletion but also environmental concerns. To discuss strategies towards sustainable metal use with lower environmental impacts in line with climate goals, quantifying future environmental impacts from metal production and exploring effective measures for alleviating the environmental impacts are essential. Therefore, we estimated the global greenhouse gas (GHG) emissions from the future production of six typical metals (aluminum, copper, iron, lead, nickel, and zinc) under the five shared socioeconomic pathways (SSPs) for 2010-2100 and compared the results with a GHG emission reduction target (2°C target). In addition, we explored the influential parameters of metal cycles to reduce the environmental impacts by scenario analysis.

We show that trends for GHG emissions from metal production are significantly different among SSPs, while the 2°C target will not be achieved for the metal sector under any SSP, mainly due to the increase in GHG emissions in the early 21st century in middle-income countries. This suggests that substantial efforts to reduce GHG emissions are required in addition to the transition to the sustainable socioeconomic pathway. From a short-term perspective, lowering the per capita in-use metal stock level and GHG emission intensity of metal production is identified to be effective. From a long-term perspective, improving the recycling rate will also be an effective way. However, our analysis shows improving a single parameter is expected to be insufficient for achieving the 2°C target. Given that GHG emissions from metal production will increase mainly in the early century and improving parameters cannot be achieved promptly, implementing multiple measures immediately with international cooperation, as well as following the sustainable socioeconomic pathway, is essential for sustainable metal use in line with the climate goals.

2-1A-2

Study on medium- to long-term scenarios for achieving net zero greenhouse gas emissions by 2050 in the material cycles and waste management sector

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Medium- to long-term scenarios (draft) for achieving net zero GHG (Greenhouse Gas) emissions by 2050 in the material cycles and waste management sector were examined based on the estimation of the future waste generation and the decommissioning of current waste treatment facilities, as well as the scales and GHG reduction effects of the countermeasures that were selected and investigated for each of the three priority areas set in this study for reducing non-energy-related GHG and energy-related CO2 emissions. For future emission scenarios, we set and calculated the BaU scenario, four scenarios with different intensities of countermeasures in line with the priority areas, and two scenarios that take into account the amount of CCUS required to achieve net zero emissions. Major implications include: it is possible to achieve net zero or even negative emissions in 2050 in this sector; and implementation of measures that are extension of existing plans is insufficient.
This presentation is based on the results of the "FY2021 Study on Medium- to Long-term Scenarios for Achieving Net Zero GHG Emissions by 2050 in the Material Cycles and Waste Management Sector (Waste Management Division, Environmental Regeneration and Material Cycles Bureau, Ministry of the Environment)," and the basic contents have been publicized at the 38th meeting Recycling Society Committee of the Central Environmental Council in August 2021.

2-1A-3

Critical materials and decarbonization: The economic and policy context of 'appropriate' material availability

Roderick Eggert
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The demand for certain raw materials central to decarbonization will increase quickly and significantly for some materials, although at what rate and by how much is uncertain. Examples include certain rare earths for magnets in electric motors; lithium, cobalt, nickel and others for batteries and energy storage; and copper for all forms of electrification. A fear is that lack of "appropriate" material availability will become an obstacle to the clean energy transitions. "Appropriate" in this context refers to growth in supply that is sufficient, secure, affordable, environmentally sustainable, and socially responsible. This paper reviews material availability in all these dimensions - as well as opportunities for wasting less through improved manufacturing efficiency and increased re-use and recycling; and using less through the development of substitute materials.

2-1A-4

Just energy-resource transitions to clean energy - Engagement and evaluation

Benjamin Craig McLellan
Kyoto University, Japan

Energy transitions (and their linked resource transitions - water, land, minerals, etc.) are an important focus as the world looks to reduce global greenhouse gas emissions. It is important to reduce the environmental impact of these transitions, but it is also vital that the transitions do not leave part of the community behind. The communities that currently host power plants or mines that support the carbon-energy system may suffer due to a shift to carbon neutrality. This paper examines the impacts and potential mitigation of these impacts for promoting a just low-carbon transition, with a focus on Japan.

2-1B: [OS] Sustainability visualization software and its role toward 2050 net-zero carbon

2-1B-1

Increasing impact of LCA results through flexible visualization

Eric Mieras, PRé Sustainability, the Netherlands

2-1B-2

Introduction of questionnaire results for the development of LCA software MiLCA

Ken Yamagishi, Saki Sunaga, Masayuki Kanzaki
Sustainable Management Promotion Organization, Japan

2-1B-3

Fujitsu's Carbon-Neutral initiative and the trust service to cross-company data exchange in the

supply chain

Tomoko Konishi-Nagano, Mitsumasa Matsuike
Fujitsu Limited, Japan

2-1B-4

GHG emissions calculation and visualization cloud service “zeroboard”

Yoichi Sakamoto
Zeroboard Inc., Japan

2-1C: [OS] Chemical industries' challenge and contribution for carbon neutral and circular society with life cycle thinking

2-1C-1

[Invited talk] Linking decarbonization and resource circulation in the chemical industry through life cycle thinking

Jun Nakatani[1,2]
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Towards realization of the carbon neutral society in 2050, decarbonization is now one of the most concerned issues in any industry. On the other hand, being led by the EU circular economy policies, resource circulation including recycling also draws much attention worldwide Decarbonization and resource circulation have often been discussed independently, while it is sometimes postulated that an advance in resource circulation unconditionally contributes to decarbonization. However, their relationship needs to be carefully examined from the life cycle perspective.
The chemical industry is a major contributor to the national greenhouse gases emission in Japan, as is the case with other industrialized countries. It should be noted that the chemical industry is not only responsible for the process emissions but for emissions from other stages of the life cycle of its products. Recycling petrochemical products is expected to simultaneously alleviate emissions from the raw material (petroleum) procurement and end-of-life (waste incineration) stages. Circulation of plastics, which is mainly composed of fossil carbon, is specifically relevant to decarbonization of the chemical industry.
Recently, a lot of chemical makers are devoted to developing chemical recycling processes of waste plastics. According to the EU circular economy principle, mechanical recycling is given priority over chemical recycling, which is regarded as an outer loop. However, many life cycle assessment studies have shown that chemical recycling is potentially effective for reducing overall the climate change impacts, often rather than mechanical recycling.
In this presentation, the linkage between decarbonization and resource circulation in the chemical industry is conceptually and empirically discussed through life cycle thinking, with a special focus on chemical recycling of plastics. From the life cycle perspective, the yields and energy efficiencies of recycling processes, as well as the quality of recovered materials, are keys to decarbonizing plastics regardless of the size of recycling loop.

2-1C-2

Contribution to additional reduction of greenhouse gases by products through the implementation of LCA methodology

Hitomi Miura
Sekisui Chemical Co., Ltd., Japan

Sekisui Chemical applies the Life Cycle Assessment (LCA) methodology to Natural Capital assessment and evaluate the impact of environmental aspects of corporate activities that need to be managed, in order to solve environmental issues such as de-carbonization and resource circulation. LCA is also used to manage progress and the effectiveness of GHG reduction activities.
SEKISUI CHEMICAL is not at the top of the supply chain, but is a manufacturing company that mainly processes a variety of plastics and other raw chemical materials and provides solutions to many environmental and social solutions. In order to take part to a carbon-free society, the main strategy is to reduce the carbon footprint during the use of the products. In order to maximize the reduction levels effectively, the amount of emission is confirmed through an index using the LCA methodology.
In recent years, the amount of reduction contribution by products has increased. In the future, as declared in the resource recycling strategy announced in 2021, we plan to expand the contribution of CO2 reduction in the product life cycle by expanding the low-carbon or decarbonization of raw materials used in products.

2-1C-3

Sumitomo Chemical's challenge for carbon neutral society 1. ~Development of carbon footprint of products (CFP) calculation system~

Tomoyuki Izumi, Naoki Yokokawa, Saki Manabe, Mayumi Hayashi, Masaaki Toma
Sumitomo Chemical Co., Ltd., Japan

Sumitomo Chemical has formulated a grand design to achieve carbon neutrality by 2050, setting out a direction for its initiatives and goals for its activities. We will accelerate reductions in greenhouse gas emissions by approaching the issue from the perspectives of both obligations and contributions, implementing initiatives that are built on scientific, logical and quantitative foundations and leveraging the expertise and technological capabilities the Company has developed as a diversified chemical company.
As one specific initiative of contribution, we focus on Carbon Footprint of Products (CFP). CFP represents greenhouse gas (GHG) emissions throughout the product life cycle. CFP is an important indicator for developing products with low environmental impact. We have formulated CFP evaluation guidelines for its products and developed a proprietary calculation system (CFP-TOMO(TM)).
<CFP-TOMO(TM) features>
- CFP is calculated in accordance with ISO14040, 14044, 14067, etc. This system specializes in Cradle-to-Gate GHG emissions calculations and enables speedy and transparent calculation.
- This system can calculate a great number of CFPs at once considering material flow from upstream to downstream as well as the recycling process.
- This system supports the handling of byproducts that are not clearly regulated by ISO.
- This system runs on general-purpose software (Microsoft Access/Excel) and can be used by anyone thanks to its simple and user friendly interface.
We have evaluated the CFP of every Sumitomo Chemical product (about 20,000 items) by using this system. In addition to evaluate CFP at Group companies, we will promote the disclosure of CFP for our Group products.
We provides this system to other companies free of charge, and many companies have already started trial use. Through this initiative, Sumitomo Chemical will contribute to the reduction of GHG emissions via the enhancement of CFP evaluation throughout the entire supply chain.

2-1C-4

Sustainability in Teijin Group: History and future

Smitha Sundaram, Heidi Beers, Shuichi Osaki
Teijin Limited, Japan

Teijin Group relentlessly strives to be a company that supports the society of the future, by utilizing our diversity to create value for society's needs. Teijin Group intends to contribute to the sustainability of society by continuing to challenge issues around the clock in our effort to enhance the quality of life, which is our corporate philosophy.
In 2008, TG enacted long-term goals for environmental preservation, and Teijin Group Environment-Friendly Design Guidelines were formulated. That same year we presented the first LCA of our para-aramid fibre. Since 2008, we reduced the carbon footprint of this material more than 50%. For many other Teijin materials we have calculated the footprint or studies are ongoing.
Today, Teijin Group is a committed member of the Science-Based Targets Initiative, and has set ambitious climate change targets. This includes an absolute 30% reduction in Scope 1+2 emissions, and an absolute 15% reduction in Scope 3 emissions by 2030 (vs 2018). By 2050, TG aims to be net-zero in Scope 1+2. Moreover, Teijin Group is actively collaborating with customers as well as other actors in the value chain to because we believe that sustainability can truly be achieved only through collaboration. We are constantly looking for applications that help lower emissions through the life-cycle of our products, thus benefitting the entire value chain.
But how did we get here? Sustainability is a continuous process, where we have built on initiatives step by step, in Teijin group companies worldwide. In this presentation, we will trace the history of sustainability at TG, and how we plan to continue this into the near future.

2-1D: Input-output analysis

2-1D-1

Visualization of the uncertainty in CO2 emission intensity caused by the price homogeneity assumption in the input-output table.

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The 3EID database (i.e., Embodied Energy and Emission Intensity Data for Japan Using Input-Output Tables) provided by the National

Institute for Environmental Studies of Japan has been widely used in many hybrid LCA studies. Although researchers can use the embodied sectoral CO2 emission intensities in t- CO2 per million JPY in different years (e.g., 2005, 2011, and 2015) from the 3EID database, it is meaningless to evaluate temporal changes in the embodied CO2 emission intensities. In doing it, we firstly need to estimate input-output tables in constant prices using survey or non-survey method. Secondly, the embodied CO2 emission intensities at sector level are calculated by multiplying direct CO2 emission intensities vector by Leontief inverse matrix in constant prices. This study estimates time series input-output tables (IOTs) with 368 commodity sectors for 2005, 2011, and 2015 using double deflation (DD) method as a survey method and GRAS method as a non-survey method and provides time series datasets of embodied sectoral CO2 emission intensities in constant prices (i.e., 2015 prices). The GRAS method, unlike the DD method, allows us to deflate intermediate and final demand of a particular sector at different price indexes. A comparison in the embodied CO2 emission intensities in constant prices estimated by using the DD and GRAS approaches shows that the price homogeneity assumption in the DD approach brought about an underestimation of the embodied CO2 emission intensities in many sectors. Looking at aggregated industry groups, the price homogeneity assumption caused significant fluctuations in the embodied CO2 emission intensities in nonferrous metals sector. We suggest that physical input-output data of those sectors with higher uncertainty identified in this study should be incorporated into a mixed-units input-output approach.

2-1D-2

A marginal extraction analysis for green supply chain restructuring

Keitaro Maeno
Kyushu university, Japan

For climate change mitigation, industries need to establish green supply chains through an effective restructuring strategy. To identify effects of restructuring of the relevant global supply chains (GSCs) on the CO2 emissions at globe, I propose a new input-output framework with a focus on marginal restructuring of GSCs of a particular industry. Based on the latest world input-output database (WIOD) in 2014, I firstly estimate the global CO2 emissions from the GSCs of the particular sector (automobile sector in Japan, Germany and United States in this study). Secondly, I apply the expanded hypothetical extraction method, called the marginal extraction method (MEM) to the WIOD. The proposed MEM can describe the hypothetical GSC structure in which a unit of a trade coefficient (one percent in this study) of a relevant industry in a relevant country is extracted and substituted by the same industries in other countries (i.e., the marginal restructuring of the relevant GSC). Thirdly, I compare between the global CO2 emissions from the actual and restructured automobile GSCs and estimate the impacts of the marginal restructuring of the GSCs. The results show that the marginal restructuring of Chinese manufacturing sectors of Electrical equipment and Basic metals had a significant CO2 reduction effect in the Japanese automobile GSC. The case studies of Germany and US show that the Russian basic metals sector and the Chinese machinery and equipment sector are the key sectors to reduce the CO2 emissions through GSC restructuring, respectively. Based on the results, I discuss practical trade policies for CO2 mitigation through GSC restructuring and finally conclude that the MEM can help policy makers to design effective climate policies for green restructuring of GSCs.

2-1D-3

Drivers of greenhouse gas emissions in Kenyan industries by resource-consuming countries: An input-output model approach

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Global multiregional input-output (MRIO) models have been ubiquitously applied to quantitatively analyze the relationships between consuming and producing countries. A typical such relationship is where developed countries' consumption causes environmental burdens such as direct greenhouse gas (GHG) emissions through resource consuming from developing countries. Using the 2015 full Eora MRIO table, this paper assesses how GHG emissions in the Kenyan industries are induced by other countries' demands. The results show that a total of 63500 Gg CO2 of emissions were accounted for during the period. This results to close to 88% of Kenyan total GHGs emissions being induced by domestic final demand. The "Transport" and "Building and Construction" industries are the biggest contributors to GHG emissions in Kenya. The top developed countries contributing to agriculture-related emissions include the US, UK, and Germany. These three countries account for over 2.5% of GHG emissions in Kenyan agriculture; the most affected industries include "Cut flowers" and "Vegetables" for the UK and Germany and the "Tea" industry for the US. Contrastingly, developing countries impact the secondary industries, especially "Metals and Machinery" and "Non-metallic manufacture" as well as tertiary industries including "Trade". The East Africa region, mainly Uganda and Tanzania, dominates GHG emissions at 3% to Kenyan industries. The remaining close to 7% of emissions are contributed by the rest of the world (ROW). Most high-income countries, therefore, and the East African countries drive emissions in Kenyan primary and secondary industries respectively. Overall, the countries mentioned are substantially and comparably responsible for GHG emission in Kenya.

2-1D-4

Carbon footprint analysis considering production activities of informal sector: A case study of India

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Kyushu University Graduate school of economics, Japan

This study attempts to estimate how informal sector in India contributed to production- and consumption-based CO2 emissions in India. The informal sector is a set of activities that are imperfectly regulated by the government and it is hardly accounted on official statistics. In India, the third largest CO2 emitter in the world following China and the U.S., production activities of the informal sector accounts for about half of the GDP and employs about 90% of the population. In spite of the huge size of the informal economy, due to the unavailability of economic and emission accounts, it is not well identified how the production activity of the informal sector involves CO2 emissions in the whole supply chains in India. We first constructed an environmentally-extended input-output table in 2016 in India that distinguishes between formal and informal manufacturing activities in India by using the official data published by the Indian government and previous studies. We visualized the environmentally-important supply chains with higher CO2 emissions as networks. Our results showed the several informal sector is included in the supply chain which induced the largest CO2 emission in India and especially the informal sector in non-metallic mineral products contributed to huge CO2 emissions. The impact of informal sector in CO2 emission is not negligible and it is necessary to address the informal sector for a rapid reduction of CO2 emissions in India.

2-1D-5

The devil is in the details: Disaggregating agricultural trade in an existing input-output database for assessing water-related impacts

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In many regions of the world, freshwater consumption exceeds sustainable use boundaries. In theory, input-output analysis can be used to allocate this freshwater consumption to consumers worldwide. However, global input-output databases partially comprise aggregated data in a manageable amount of economic sectors. A limited sectoral resolution of an input-output database, however, can lead to inaccurate allocation patterns and thus misinformed decision making. Usually, aggregated agricultural primary production constitutes only a fraction of an input-output database's sectors. However, because circa 90% of freshwater consumption occurs in agricultural primary production, input-output analysis-based water-related assessments are particularly prone to inaccurate allocation as a result of aggregation and low sectoral resolution.
In our research, we explore how an existing input-output database can be disaggregated and refined to better account for externalities, e.g. water consumption, associated with agricultural primary production. For this, we seek to disaggregate an existing input-output database's agricultural production sectors based on FAOSTAT[1] crops' trade data. We complement these sectoral data sets with satellite accounts based on spatially explicit Spatial Production Allocation Model[2] crop production data.
The resulting database offers unprecedented sectoral detail concerning agricultural primary production. It maintains the integrity of the other sectors in the database and allows the approximation of the virtual flow of water through the global economy in high detail. Our work contributes to understanding and overcoming challenges in input-output-based water-related analyses and can easily be extended to other externalities associated with agricultural primary production, such as land use, eutrophication or others.
[1] https://www.fao.org/faostat/ (accessed 25.03.2022)
[2] https://mapspam.info (accessed 25.03.2022)

2-1E: Communication and education

2-1E-1

Climate change communication through narrative

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This study proposes use of narrative, an information format that has not been focused on, in environmental communication. According to dual-process theory, there are two ways in the human information processing: the deliberative and logical way and the intuitive and emotional way. In conventional environmental communication, it has been implicitly assumed that people read presented information carefully and advisedly, i.e., process through the former way. It is possible that environmental communication could be made even more efficient by focusing on the latter way. We focus on narrative as an information format that can be processed intuitively and emotionally. This study aims to reveal how narrative and logical information about climate change affect behavioral intention and policy acceptance. In an experiment conducted using the internet, participants read either the narrative (a story that focused on a person who was negatively impacted by climate change) or logical information (rational arguments that expressed

formal expression) on climate change and complete questionnaires before and after reading. The pre-survey measures participants' traits such as transportability, intuitiveness, and interest in climate change and the post-survey measures the impact of reading narrative or logical information. The results show that narrative is rated as easier to understand, evokes stronger emotions such as anxiety and fear, and leads to higher behavioral intentions and policy acceptance about climate change than logical information. They also show that this tendency is more pronounced when the participants have little interest in climate change. It may be because people with lower interest are more emotionally dependent in their decision making. Since it is difficult to encourage behavior change among people with low interest using traditional communication methods, the use of narrative can be an effective move. The findings will contribute to mitigate climate change by proposing new communication methods that transform people's behavior.

2-1E-2

Measuring sustainability education impact through handprints

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Universities have been focusing on educating students about sustainable practices and social responsibility by offering sustainability programs, courses, and grants. However, there is little research about how and how much these programs, courses, and grants positively contribute to sustainability related impacts. With the climate crisis and supply chain disruptions because of the pandemic and ongoing war in Ukraine, the proposed student action to convert the existing lawn space located in the backyard of the Centers for Women and Work building at UML into a Food Forest is very time relevant. The Food Forest at UML can serve both as a food supply and to educate students, faculty, staff, and community on sustainability. We adopted the SHINE Handprint method and developed an approach to measure the sustainability impact of students. The novelty of this approach is the methodological advancement in quantifying students' positive environmental, social, and economic impacts, i.e., handprints, which they had achieved by recommending positive changes to different organizations in a mutually beneficial partnership. A goal of our study includes 1) environmental footprint assessment of business as usual, i.e., grass lawn, 2) environmental and economic footprints of starting a Food Forest, 3) the handprint assessment of the resulting annual positive changes over the years, and 4) comparison of handprint to UML organization footprint. First, we will analyze the environmental footprint of starting a Food Forest for the UML compared to maintaining the existing grass lawn space of the same square footage with conventional fertilizer and mower. To analyze the grass lawn maintenance, we will include water, fertilizer, and lawn mower gasoline consumption as my main inputs (since the lawn already exists, we will not include in grass seed or soil). The environmental footprint assessment will be performed using life cycle assessment (LCA) SimaPro software.

2-1E-3

Teaching life cycle assessment in higher education - Insights from a global study

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The best way to ensure a better understanding of life cycle thinking of future generations and create a new generation of life cycle professionals is to teach students life cycle concepts. In line with a rise in demand for life cycle professionals around the world, an increasing number of courses are offered these days on Life Cycle Assessment and Management (LCA/LCM). While this is a positive development, these courses often differ substantially in terms of comprehensiveness, length, learning objectives and style.
There is thus a huge variation between students' LCA literacy and experience, resulting sometimes in a miss-match between employers' expectations and students' qualifications. As a result, clarity on competencies that are being taught by LCA teachers around the world is needed.
The presentation will present the results of a global survey on the state of teaching LCA carried out by the FSLCI's Working Group on LCA in Higher Education. The survey results provide a great overview of where LCA is taught, who is teaching it and how it is taught.

2-1E-4

Development of life cycle thinking-based environmental education program for childcare workers

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Environmental education (EE) is becoming more important for the realization of a sustainable society. Recently, EE programs and teaching materials focusing on the life cycle of industrial products and foods have been developed and implemented for a wide range of generations older than elementary school students. The purpose of these programs and materials is to aware the link between our living activities and global environmental problem based on the concept of life cycle thinking (LCT). In considering the goal of these

educational activities, the more sensitive early childhood is also a significant target for LCT-based EE. In the present attempt, we have developed an EE program based on LCT for nursery teachers.
There are five essential areas of childcare content in early childhood education. One of the areas is "environment" and this includes awareness of the natural environment with interests. An understanding of various things that are touched in everyday life with cherishing them is also an important issue to be cultivated in this area. Another important factor in early childhood education is the "play". The target of the "play" was examined to incorporate LCT in early childhood education and we found a wood clay made from sawdust in the production of pencils and colored pencils. We then developed a new EE program aimed at teaching an association between the feeling of cherishing things and the awareness of LCT around the play using this wood clay. The contents of the program and the responses from the students took this program will be presented.

2-1F: Acceleration of sustainability management: Concept and methodologies

2-1F-1

Quo vadis LCA? Successful standardized, scientific method or misused and mainstreamed tool? A Review of cases in a decade between freedom of science, industrial innovation, marketing and compulsory reporting.

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There are two Spheres that still do not cooperate well: Science and Industry. The topic isn't new. Walter Kloepffer wrote in 2001 clear words in „Two planets and one Journal". In 2012 LCA experts from academia, industry and consulting did refresh the topic in the article „LCA's theory and practice: Like ebony and ivory living in perfect harmony?". Today the success of quantitative LCA results due to mainstreaming Life-cycle approaches is adding more attributes between the spheres: Simplification (of complex hence holistic) quantitative LCA results is requested by decision-makers and customers/consumers alike; both need easy-to-create but clear, unmistakable figures. Acceleration (of complex hence real) LCA systems is requested by LCA experts using tools in data collection, quality-assurance, system set-up and calculation. To ensure LCA benefit for society (organizations and consumers alike), we need to understand on one hand the scientific demand for freedom to add, change and correct as knowledge increases and on the other hand the professional need for reliability and stability to plan-act-do-check in a justifiable way; acknowledging that non-LCA experts need to understand results instantly and decide properly. We present good and bad practice in cooperation among the spheres concerning standardization of the method, merit and challenges of international initiatives, and scientific - industrial cooperation. Whether the way of LCA will be "alignment/merging" or "segregation/separation" concerning key LCA aspect and its user groups, will be decided by: Database types/targets, use or misuse of attributional and consequential LCA (data), Inventory flow list translation and interoperability, mistakes in communication of LCA results, limits of simplification towards unrealistic models, avoidance of making the same mistakes again as well as to stop using LCA irresponsibly. LCA can be applied responsibly avoiding flawed results, costly decisions and legal consequences by false claims. Target group will be academia and industry alike.

2-1F-2

Distributed ledger technology for resource protection and circular economy

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Distributed ledger technology (DLT), including blockchain technology, is widely acknowledged as a software tool with a large potential to increase transparency, resource conservation and circularity within supply chains. Guaranteeing a tamper-proof, verifiable, simultaneous and confidential information exchange, DLT is already applied in sustainable supply chain management in various industries. Typical use cases include data exchange contributing to life cycle assessments; proofs that companies and products comply with environmental regulations; or verifications that material is derived from recycling sources.
However, instead of covering entire supply chains or even whole product life cycles, DLT networks focus frequently on single product systems and are often limited to a few supply chain stages. DLT is commonly used to track information about unit cargo, while it is less suitable to monitor bulk cargo, or conversions from the former into the latter. DLT systems are mostly applied by only small quantities of network participants, covering only a few different materials or products within single industries.
Combining life cycle thinking with a mass balance approach, we propose a generic concept that allows a more holistic application of DLT in sustainable supply chain management. Shifting the point of view from units of raw materials, components and products to quantities of materials, the concept allows a consistent exchange of information over entire product life cycles. The concept also allows the monitoring of both unit and bulk cargo as well as combinations and conversions as needed. Following a mass balance approach also enables a more efficient information exchange between different product systems, supply chains and industries.
Apart from the generic concept, the presentation will also include first results of a proof-of-concept. A case study conducted with

partners from the precious metal industry will provide results transferable to potential applications in other industries.

2-1F-3

Semi-automated visualization method of sustainability scenarios using natural language processing

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The University of Tokyo, Japan

A variety of sustainability scenarios have been developed by governments and organizations to support their decision making toward achieving sustainable futures. Scenarios are generally written in text format, often combined with quantitative simulations. In order to assist mutual communications with stakeholders, the authors developed the scenario structuring method to visualize the logical structure of a scenario in graph format. However, one critical problem is that the method requires in-depth reading and is therefore very time-consuming.
To address this problem, in this paper, we aim to propose a method for supporting scenario structuring using natural language processing. In the traditional scenario structuring process, scenario designers need to manually find related text pairs and label them into pre-defined relation types. We build classifiers by finetuning the state-of-the-art pre-trained language models (i.e., ALBERT and ERINE) for automating the above-mentioned classification task.
The developed classifiers take individual text pairs as input and output their corresponding label probabilities. Unlike humans, the classifiers don't have an overall comprehension of the context and are therefore not suitable to be fed with pairs between all texts at one time, especially in the case of long scenarios with many text fragments. By adjusting the operation span to pairs between 5 texts, our classifiers reached an F1 score of 81.69 in identifying the related text pairs from narrative scenarios.

2-1F-4

A case study on the automation of a scenario planning method

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For corporations, ESG management strategies and actions from a long-term perspective are becoming more important for sustainable growth. However, corporations' ESG management are made more difficult by increasing risks such as worldwide infectious disease epidemics, server attacks, and changes in international affairs.
Thus, a scenario planning method has been proposed for formulating corporate management strategies, especially when the future is difficult to forecast. However, the implementation of a scenario planning method relies mostly on experts now. With the development of the internet, huge amounts of information are updated daily. These large amounts of information are difficult to manually process on a daily basis and utilize for strategic planning. Therefore, we aim to automate the scenario planning method using text mining technology.
In this research, we examined the automation of scenario planning with the theme of decarbonization and energy strategy, which is an important theme in ESG management. In this case study, on the basis of information collected from white papers and news information for the environmental and energy field in the United States, we tried to extract the driving force in scenario planning by using a text mining tool. In addition, driving force extraction was also performed by expert analysis on the basis of the same information sources to evaluate the extraction results by text mining. As a result, though the created sentences to describe driving forces contained some unnatural expressions, the subjects that should be focused on were mostly extracted correctly. The predicates in the sentences, however, have not been able to completely expressed with the correct meaning yet. Though many challenges remain, by leveraging text mining technology, we have progressed towards analysis more efficient than fully human-powered analysis. With more improvement, we aim to realize the automation of scenario planning methods and digital transformation of corporate ESG management.

2-1F-5

Assessing municipal action CO2 impacts – Direct vs system wide approaches

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Municipalities striving for decarbonatization of their stationary energy and/or transport sectors can normally apply neither additional carbon taxation nor subsidize carbon-lean technologies, but they may in different ways facilitate certain actions and activities. It is then important to be able to assess and present the actual carbon impact of these actions and activities to be able to prove their efficiency in reaching the goal. Disregarding life cycle perspectives, the straightforward assessment would be to apply a narrow system boundary and simply calculate the direct emission user phase CO2 impacts and disregard cross-sectoral, spatial and temporal/dynamic impacts. However, will the result of such assessment be sufficiently good given the rapid development of the

energy and transport sectors, their increasing competition for the same constrained non-fossil resources and thereby resulting inter-sectoral dependencies?
Thus, the aim of the current study is to address to which extent such a simplified direct impact assessment is sufficient for regional transport system carbon lean actions or if system-wide approaches including cross-sectoral, spatial and temporal/dynamic impacts are necessary and, further, what type of system-wide expansion that is most important. The study is using a case based on six rural municipalities forming a small region consisting of a mix of small towns and rural areas. These municipalities have during the past years implemented certain activities motivated by their low carbon emission characteristics. Since tourism is an important part of the regional economy, the low carbon emission activities should also contribute to promote the region as a green destination.
System-wide expansions are done in three steps; first a cross-sectoral expansion is applied, linking transport and stationary energy sectors; then a temporal expansion by modelling the system over a time period of 30 years, then a spatial expansion by testing the importance of municipal interaction and collaboration within the small region.

2-2A: [OS] Resource issues towards carbon-neutral society

2-2A-1

A resource paradox problem of green innovations

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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 CO2 emissions (LC-CO2) or direct material input at the economy-wide, product and metallic element levels.

2-2A-2

Life-cycle resource productivity of Japanese food resources

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Ritsumeikan University

The food supply of nations is intertwined and relies on complex international supply chain. Multi – regional input – output analysis (MRIO) is an environmental system analysis tool used to conduct hot spot analysis from a consumption perspective and has been an important tool in food consumption analysis. However, the analysis has so far focused on food products in their final form rather than considering the resource perspective. The present research aims at determining the value added associated with the production of food resources (e.g. wheat, paddy rice) and their use (e.g. wheat flour, bread, rice cake, cereals). For this purpose, we first constructed a multi – regional physical input -output table of about 500 products and 200 regions using the supply utilization accounts of the Food and Agriculture Organization for the 2010 – 2019 period. We then associated the FAO reported products with the sector nomenclature of the 2015 Japanese Input – Output tables and used an allocation factor to determine the share of the value added of complex products associated with the basic food resource products. Finally, the value added of producing and using basic food resource products was calculated and normalized with the produced amount to determine the resource productivity of food resources

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2-2A-3

Global target by 2050 to reduce natural resource use in the automotive industry

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In order to reduce carbon dioxide emissions, automobile technology is expected to shift from internal combustion engine vehicles (ICEVs) such as gasoline and diesel to new-generation vehicles such as electric and fuel cell vehicles. This global trend changes the pattern of resource use. In the existing studies, the amount of resource use induced in the automotive sector by 2050 has been assessed by using resource-related indicators such as total material requirement (TMR). However, the effect of various strategies on

the reduction of natural resource use has yet to be fully evaluated. The consideration of these strategies would assist in setting the global target associated with resource use by 2050 as given in de-carbonization goal. In this study, the future inflows of ICEVs, hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), battery electric vehicles (BEVs), and fuel cell vehicles (FCVs) were firstly estimated using dynamic material flow analysis (MFA) based on the scenarios proposed by International Energy Agency. Then, the global natural resource use in the automotive sector was calculated based on the estimated future inflows of each vehicle type and the TMR per vehicle. Finally, the effect of the various strategies including lifetime extension, service provision (car sharing and ridesharing) and recycling on the reduction of the natural resource use was evaluated. As a result, under the case of business as usual (BAU), in which no efforts for reduction are adopted, global natural resources in the automotive industry increased by 116%-150% in 2050 compared to 2015. The implementation of all strategies could contribute to the reduction of TMR by 40%-53% in 2050 compared to the BAU case. In particular, of this reduction, 36%-54% comes from car sharing and ridesharing, and 37%-41% from recycling. These findings would be useful for the development of the resource guideline in the automotive industry.

2-2A-4

Can car-sharing system solve trade-offs between resource consumption and greenhouse gases emission? A simulation based on person-trip survey

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Car-sharing system is a platform of sharing mobility that potentially reduce multiple environmental impacts. Some researches pointed that alternative-fuel car does not improve all environmental impact, because EV requires more metal resources than conventional cars despite of significant reduction of life cycle greenhouse gases (LC-GHG). On the other hands, Car-sharing system is expected to solve this trade-off problem through efficient use of shared cars. However, reduction of resource requirement and LC-GHG is depend on usage of shared cars and other transportation modes.
This study developed a framework to estimate these environmental loads of car-sharing system considering resident's behavior of subscribing and use of car sharing system. The estimation is based on person-trip survey (an large interview survey of residents' travel) and stated preference survey, small scale questionnaire survey to quantify preference to use sharing cars . Number of trips by transportation mode and are estimated by a logit model using results of these survey. Then life cycle environmental load is quantified using lifecycle inventory data of production, using, maintenance of cars, and construction of stations for shared cars.
A case study targeted on Kyoto city, Japan revealed that promotion of car-sharing system can reduce both resource requirement and LC-GHG. Weighted environmental impact (using LIME2 model) can be decreased 14% in maximum. This framework can be expanded to simulate effect of car-sharing system in various condition by modeling residents' decision-making on transportation.

2-2B: [OS] Carbon neutrality and avoided emission (1)

2-2B-1

Avoided emission in Japanese industry

Ichiro Daigo

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2-2B-2

Case studies of the assessment of avoided emission of products and organizations

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2-2B-2-1

Consideration on methodology for assessing the contribution of automotive parts to avoided GHG

Akira Tanahashi

Denso Corporation, Japan

2-2B-2-2

Azbil's Organizational Contribution to the Avoided Emissions and its Issues to Consider

Ayako Nagayama

Azbil Corporation, Japan

2-2B-2-3

Avoided emission in practice: the case of TwaronR reinforced Conveyer belt by Teijin Aramid

Noor Hossain
Teijin Aramid BV, the Netherlands

2-2B-2-4

TBA

Peter Saling
BASF, Germany

2-2B-3

Comparative assessment cases of LCA applications

Masaharu Motoshita
National Institute of Advanced Industrial Science and Technology, Japan

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2-2C: [OS] Chemical industries' challenge and contribution for carbon neutral and circular society with life cycle thinking (2)

2-2C-1

Dealing with upcoming European legislation as a Japanese company

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The European Union wants to be the world's frontrunner in sustainability, ensuring worldwide sustainable value chains while leaving no one behind. The EU Green Deal aims at 55% reduction of CO2 emissions in 2030 related to 1990. Many legislative initiatives are under preparation to address the related fields, at the same time ensuring that public private investments and EU Commission investments are used for initiatives that reinforce these targets.
Japanese companies operating in Europe will be confronted with many new demands related to corporate reporting (the Corporate Sustainable Reporting Directive), connecting the sustainability of their activities to Capex, Opex and turnover in the EU Taxonomy, making sure that no adverse impacts happen in their value chain (The Corporate Sustainability Due Diligence Directive). A new carbon pricing instrument like the Carbon Border Adjustment Mechanism is under development as an attempt to ensure a level playing field for companies in the EU.
A way to address the mentioned topics together as Japanese companies with presence in the EU is to be or become member of the Japan Business Council in Europe. The JBCE's activities include sharing knowledge and approaches, giving support, workshops and regular updates in cooperation with professionals in the relevant fields, and initiate outreach activities.
This presentation will explain about the legislative initiatives under development and their proposed timings of coming into force. It will show how Japanese companies can prepare themselves, and explain the role of JBCE in these aspects. Teijin Limited supports the activities of JBCE with active contribution in the working groups and in particular being vice chair of the CSR committee.

2-2C-2

Feasibility study of carbon circularity method based on carbon footprint analysis of Japanese petrochemical products.

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In the current industrial structure based on mass production and mass disposal, petrochemical products consume a large amount of energy in their manufacturing stage and emit a large amount of CO2 by incineration in the end of their life stage.
Therefore, to realize a carbon-neutral manufacturing process and value chain cycle for them, it is essential to establish a de-mass production / de-mass disposal system based on the idea of efficient resource recycling and carbon circularity.
This time, we conducted a carbon footprint analysis of the entire supply chain of Japanese petrochemical products based on the industrial production statistics of the Ministry of Economy, Trade and Industry and others.
As a result, the analysis confirms that GHG (Greenhouse Gas) emission hotspots are obviously chemical products' manufacturing stage and final wastes' treatment stage, and efficient recycling design is an effective way to reduce GHG emissions in these stages.
The result also provides some useful suggestions on how to do this in technological or economical viewpoints.

2-2C-3

BASF approaches to reach net-zero CO2 emissions of societies

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The transition toward a climate-neutral future of societies is a fundamental challenge of the 21st century. Already by 2030, BASF wants to reduce its own (Scope 1 and 2) greenhouse gas emissions worldwide by 25% (vs 2018). Despite the growth of our business BASF is committed to have net zero CO2 emissions by 2050. Our new climate goals underscore BASF's determination and commitment to the Paris Climate Agreement.
Because PCFs of the same products from different companies can hardly be compared and to create a level playing field with harmonized guidelines for chemicals, BASF started developing a tool (SCOTT) and the underlying methodology, to calculate PCF for chemicals. The guideline is based on generic standards for life cycle assessment (ISO 14040 and ISO 14044), for Product Carbon Footprints "PCF" (ISO 14067) and on the Greenhouse Gas Protocol. TÜV Rheinland has certified that BASF's method to calculate cradle-to-gate product carbon footprints is in line with these standards.
In this context, BASF supports the preparation of an international guideline for chemicals by "Together for Sustainability" (TfS). Examples, where this guideline can be used as drop-in solution for other frameworks are the WBCSD or Catena-X
BASF is committed to economically efficient and ecologically effective global climate protection and supports the UN Sustainable Development Goal "Climate Action". This can only be successfully achieved together, in dialogue with policy and society, as well as in strong partnerships for climate protection.
BASF has launched in addition a Supplier CO2 Management Program to engage its suppliers and create transparency on the PCFs of its raw materials.
All these activities, guidelines and PCF calculations will create a high level of transparency to foster the reduction of PCF of products resulting in net-zero emissions of companies.

2-2C-4

Role of carbon neutrality and LCA efforts in the chemical industry

Akio Konishi

Japan Chemical Industry Association, Japan

In recent years, various efforts to reduce greenhouse gas emissions and other environmental loads toward carbon neutrality have expanded rapidly. The scope for reducing environmental loads is internationally required to cover not only within a factory but also the entire supply chain.
The chemical industry provides many kinds of chemical products to downstream industries. The chemical industry should act as a solution provider throughout the value chain. It is necessary to analyze and clarify the environmental load of chemical products and to consider and implement the direction of efforts for reduction. It is required to understand the structure of the environmental loads, then to work on the calculation and disclosure of LCA.
The Japanese chemical industry, led by Japan Chemical Industry Association (JCIA) and some chemical industry associations, has collected data from each industry company, and calculated LCI as chemical industry average value based on collected data about some basic materials.
Based on these studies, while considering consistency with international rules, JCIA has issued LCI calculation guidelines for chemical materials, that is also available for Carbon Footprint Calculation at each chemical plant. That shall be useful not only chemical plant users but also downstream users and bland owners to understand how to calculate LCI or CFP for chemical materials. In order to further disseminate and promote LCI as a chemical industry in the future, this LCI calculation guidelines includes the policy for utilizing the evaluated industry average results, the method for updating the results, and the governance for utilizing the results within the industry.
In this presentation, we will report the role of chemical industry toward carbon neutrality and the various efforts for LCA by chemical industry.

2-2D: Circular economy business (1)

2-2D-1

Challenges and opportunities for circular fashion in Japan: Outcomes from stakeholder workshop

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Today, more clothes are manufactured than ever before, but the clothes are worn much less frequently. As a result, the fashion industry is increasingly scrutinized for their impact on various sustainability problems such as land use, chemical pollution, labor's rights, textile waste management, and microfiber pollution. Despite the call for a change, fashion sustainability contains diverse issues that the core problem and necessary actions are largely unclear. For instance, textile recycling technologies at commercial scale are available in Japan, but there is no scheme to efficiently collect the waste textiles. To identify and propose necessary measures for circular fashion in Japan, we reviewed the role of textile waste in the current legislative framework in Japan, and organized a series of workshops involving stakeholders in fashion sector. Specifically, the workshops involved five stakeholders from textile and apparel industry, one NPO, and one academic researcher in addition to the organizing committees. As a result of the workshops, we identified numerous issues across the life cycle of clothing in Japan. Among the issues, the most critical was the lack of viable collection scheme for textile waste. In Japan, textile waste is currently collected and managed differently by diverse agents, which is partly led by the lack of recycling law for textiles. Based on the analysis of the workshop and the current legislative scheme for textile waste, we generated policy recommendations on circular fashion in Japan. We also recognize that the fashion industry should play a leading role in the development of circular fashion system, where we encourage them to actively engage in the discussions with the consumers, the government, and the researchers.

2-2D-2

Developing architecture for platform-based circular economy business: A case study of container reuse business

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Platform-based businesses using digital technologies are becoming a trend toward achieving a circular economy (CE). However, there is a key question need to be addressed: How should functions for the digital platform be derived to realize a target business? To answer this question, this paper aims to develop an architecture that represents a target CE business, a digital platform, and the relationship between them. For this purpose, we applied Industrial Internet Reference Architecture (IIRA) and proposed several representation schemes to apply IIRA to platform-based CE businesses. A case study was conducted for a container reuse business. Based on the results of an interview with a CE business provider, we described two scenarios by applying IIRA, i.e., (A) as-is scenario where the current business model is assumed and (B) proposed scenario where additional digital technologies are introduced to improve efficiency and consumers' satisfaction. Results showed that the proposed IIRA-based architecture was effective to derive functions for the digital platform to achieve the business. For example, we derived functions to improve the use process, including automatic ordering and the notification of remaining amount in a container to increase consumers' convenience. As such, using the proposed architecture will increase the transparency and verifiability of deriving the functional requirements of the digital platform.

2-2D-3

Circular design practices centered around civic participation: The case of Satsuma Future Commons in Kagoshima prefecture, Japan

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In the past decade, there has been a global paradigm shift towards designing a more circular economy on an institutional level. To promote a more systemic, bottom-up approach, this paper investigates practical methods to better involve local residents in the process of building circular societies. The paper analyzes various practices and activities led by Satsuma Future Commons, a public initiative to transform Satsumasendai City (Kagoshima Prefecture, Japan) into a circular innovation hub. We highlight the process and outcomes of two workshops that brought together designers, researchers, and Satsumasendai residents to collectively participate in circular design methods. In the Creative Repair Workshop, they dissasbled the materials of existing commercial products, explored new materials made from waste, identified other materials that can be recycled or reused, and prototyped new products made with more sustainable materials. For the Creative Fermentation Workshop, they learnt and observed the biological process of the natural environment (such as soil), gathered organisms directly from their local environment, used the organisms to ferment products, and observed and documented the fermentation process. A reflection session followed to identify potential materials and skill sets residents can utilize to practice a more "circular" lifestyle, along with an exhibition to present their products to Satsumasendai residents at large. Ultimately, we coin and propose, Participatory Circular Design, an approach for circular transitions centered around: civic participation in policy making, community education, and discourse amongst various stakeholders. This paper explores a new systemic model for implementing circular economic principles, and proposes methods, frameworks, and guidelines for other cities and regions to adopt.

2-2D-4

Environmental effect estimation of mobile phone reuse businesses

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As a result of increasing mobile phone usage, the burden to the environment is elevating with its massive pile of e-waste accumulation. Reuse/refurbishment/ remanufacturing/repairing of mobile phones is an emerging business initiative that has great potential to be expanded with the global trends and demand on sustainable society. The present study focuses on elucidating and estimating mobile phone reuse businesses' environmental load reduction effects. The study focused on the environmental load of manufacturing stage in the life cycles of mobile phones. By simply formulating, the environmental load reduction effects of selling A units of reuse mobile phones are calculated as A x B (e.g., kg-CO2 equivalent), where B (kg-CO2) is an average of environmental load of manufacturing one unit of mobile phone. However, this formulation is too simple with oversimplified assumptions. The environmental load reduction effects were formulated as follows:
A x B x b x (1-c) - A x C (kg-CO2),
where reuse increases the usage period of mobile phones by b (0 <= b <=1; e.g., if reuse increases the usage period by 50%, b=0.5), and ratio of c (0<= c <=1) of reuse mobile phones has just an effect of increasing the number of mobile phones used in society, and C (kg-CO2 equivalent) is the environmental load of reusing (or refurbishing) one unit mobile phone. We conducted a web-based survey with a structured questionnaire to estimate the value of b. We made investigations to set the values of c and C, and made a literature survey to quantify B. Based on them, we made evaluation of the environmental load reduction effects of a company's reuse mobile phone business. We discuss the implication of the results and provide the guidelines to increase the environmental load reduction effects and design the future business expansion of the reuse of mobile phones.

2-2D-5

Perspectives of evaluating product-service systems with life cycle assessment – A case study on power tool rental

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The shift towards a sustainable society includes the need for companies to implement sustainable business models. One of the proposed solutions is product-services systems (PSS) based on customers that are renting goods instead of buying. This concept is assumed to lower the environmental impacts and use of resources through reduced product manufacturing and waste. The objective of this study is to assess the potential of a rental company to achieve a sustainable business model through business model mapping and life cycle assessment (LCA). The case company provides rental of tools for private do-it-yourself applications. The tools are mainly for refurbishment, cleaning, and gardening. The idea is that the customers can rent tools they only need a couple of days per year, as well as devices they need as seldom as once or twice in a lifetime. The tools are made available through online booking and pick-up points.
Previous studies performed on similar cases found that the production of tools and transport from rental point to users are the most important contributions to the carbon footprint. Most of these studies focused on only one product, and not the whole portfolio of rental equipment offered. Accordingly, a parametrical LCA model was developed to make an assessment for the whole portfolio of products offered by the company. The results of the LCA showed that a large share of the potential environmental effects from a yearly operation perspective was limited to only a few of the products. From a single product perspective, the transport emissions are important for low weight products. For the heavy equipment where car transport is needed, the benefits of rental compared to ownership was stronger. However, the assessment of the PSS is highly dependent on assumptions of user behaviour, and user-oriented studies are therefore needed for a more accurate analysis.

2-2E: Footprints of household

2-2E-1

Household carbon footprint inequality in Vietnam: An input-output analysis

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Household consumption plays a significant role in the national carbon emission. Understanding carbon footprint (CF) distribution among household groups is vital in designing effective policies that tackle climate change. Although small developing economies, such as Vietnam, are contributing more and more to global carbon emissions, very few studies on household CF are available for such countries. To the best of our knowledge, this is the first attempt to track down the CF of household groups at different income levels, locations and types in Vietnam. We aim to answer the question of how much CF differs between household groups, and what factors

can explain these differences. Employing information from Vietnam household survey to disaggregate the Vietnam household sector in a global multi-regional input-output table, we found a very high inequality in carbon distribution by income, by region and by occupation. The richest group generates about 8 times more carbon emission per capita than the poorest group. Urban households have the CF per capita about 30% higher than rural households with the same income. Similar CF gap can be found between non-farm household and farm household. Further investigation, using multiple regression analysis, showed that the main determinants of household CF in Vietnam are household income, household size, number and type of vehicle, house size and house building material.

2-2E-2

Regional carbon footprints of EU households in 2010 and 2015

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Where carbon mitigation is no longer unavoidable, cities have become active players in decarbonization alongside countries' decisive acts. The carbon footprint (CF) has been a measure to identify the contribution of nations or cities to climate change. Recent interest has grown in the unveiling drivers of CF to find practical reduction ways while current national climate pledges are insufficient to meet Paris greenhouse gas (GHG) reduction targets. A number of studies have identified the drivers of emission changes associated with consumption in countries. However, those studies focus on the national boundary and lack detail on the regional CF accounts that reflect region-specific consumption patterns. We have calculated 547,292 households' carbon footprints (CFs) across 83 NUTS1 regions in 27 EU nations from 2010 to 2015 and discovered what had driven those regions' CF changes. This study decomposes EU household carbon footprint by population density, income level, and CF level to identify the drivers of temporal emission changes in NUTS 1 level regions. We show that disparities in carbon intensity and expenditure per capita primarily led to the regional CF differences. For example, in Finland, decreases in carbon intensity (carbon emission per unit expenditure) mainly contributed to decarbonization, while in France, reduced consumption has done that. Within Finland, change in consumption volume has not affected the CF change of the Åland (FI2) NUTS region (0.2% contribution), while it contributed 36% of carbon mitigation in the Manner-Suomi (FI1) NUTS region. Our results suggest CF mitigation policies need to reflect regionally specific situations such as affluent food consumption or demographic shift from rural to urban areas.

2-2E-3

Analyzing the differences in household carbon footprints across age generations in the US

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To achieve the demand-side climate change mitigation sufficiently, the importance of reducing the household carbon footprint has been argued in numerous studies. Besides, the drivers of household carbon footprint have been also investigated; income, region, and age. This study focuses on the US, which shows one of the largest household carbon footprints from the viewpoint of demographic trends. The US is seen with the beginning of the trend of an aging society as well as a high immigration rate nation. We aim to clarify the differences in consumption behaviors and the related carbon footprints across generations in the US and to argue the hotspots of the footprint reduction regarding the future demographic trend.
The methodology is conducted by combining the multi-regional input-output model (EXIOBASE) and the US national household budget survey. We quantified the household carbon footprints (direct and indirect CO2, CH4, and N2O emissions) for the seven age groups of the household head in 2011 and estimated the footprints between 2018 and 2038 based on the demographic statistics. The result shows the highest consumption expenditure per capita accounted for 37.3 thousand EURO, which was engendered by the 75 years and older households. On the other hand, the highest carbon footprint per capita was seen in the 55-64 years-old households by 14.0 t-CO2eq, followed by the 45-54 years-old and 75 years and older households. When looking at the differences by category, "transport, post, and telecommunications" contributed the most to the CF for all the households. The impact of the demographic change on the total household carbon footprint was estimated to be 4510.3 Mt-CO2eq in 2038, which increased by 581.8 Mt-CO2eq compared to 2018.
We will demonstrate the more detailed results and discuss the policy implications at the conference.

2-2E-4

The environmental footprints of Indonesian provinces

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The average Indonesian per capita environmental footprints are well below the world average. Within Indonesia, the per capita environmental footprints can differ in the order of magnitude between provinces because the structure of production and consumption differs substantially between the provinces. This paper calculates carbon and land-use footprint at the provincial level

from consumption and production-based point of view using a global multi-scale MRIO for Indonesia with 34 provinces and 12 countries. Our results highlight the spatial heterogeneity of consumption-based carbon- and land footprints within the country with provincial ranges varying widely from 1.98 tCO2eq/cap to 13.73 tCO2eq/cap, and from 0.08 ha/cap to 0.99 ha/cap in 2010. The carbon footprint in Java islands itself is about half of the total Indonesian carbon footprint, both from the consumption and production point of view because 57.5% of the population of Indonesia lives on Java and 54.2% of GDP is created on Java. Compared to Java, the provinces in Sumatra and Kalimantan have a 1.27-1.94 times higher land-use footprint from a production point of view caused by mining and estate crop production. On the other hand, Java has a higher land footprint from the consumption point of view which shows that Java relies on Kalimantan and Sumatra for these products. Provinces in Java play a dominant domestic role while countries in Asian Pacific play a dominant foreign role in both import and export-based footprints. Sectors such as utilities, construction, and agriculture have a steeper gradient in per capita consumption-based emission relative to per capita GDP.

2-2E-5

Analysis of lifestyle carbon footprint reduction measures towards the 1.5° C target in Brasilia, Brazil

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To achieve the goals of the Paris Agreement, the Greenhouse Gas (GHG) reduction scope has greatly expanded to several areas of research to understand better the different consumption domains associated with Lifestyles. Estimating the lifestyle carbon footprints allows identifying low carbon options and quantifying scenarios for potential mitigation. In Brasilia, the Household Lifestyle is one of the major contributors to GHG emissions since food consumption, energy demand, and mobility constitute a large part of the Carbon footprint by embodied emissions in the consumed goods, using services, and the associated food waste management. Hence, we apply the Life Cycle Assessment framework to quantify GHG emissions associated with each domain by considering the bottom-up approach, using site-specific data and Ecoinvent database 3.6 Cut-off. The results provide the intensity of the domains in terms of Food Consumption [kg CO2e/kg of food consumed], Electricity Production for Household Consumption [kg CO2e/kWh], and Mobility [kg CO2e/km-passenger]. Food consumption leads to food waste generation accounting for approximately 60 percent of municipal solid waste flow, with landfilling as the main disposal path without biogas treatment and recovery. At the same time, Electricity production relies on a national grid dependent on hydropower generation with increasing fossil fuel-based thermoelectric plants to cope with extended droughts. The assessment within the domains provides the opportunity to identify hotspots and potential reduction by implementing Low Carbon options. Based on the General Ecological Behavior scale proposed by Kaiser (1998), the results of a questionnaire survey in São Paulo are applied to infer the degree of difficulty of people in adopting low-carbon habits while providing additional information about the limitations of the potential reduction of the proposed options. The study was funded by Fundação de Apoio à Pesquisa do Distrito Federal - FAP/DF (Scientific Support Foundation of Federal District - Brazil).

2-2F: Acceleration of sustainability management: Data

2-2F-1

Design and development of data platform to accelerate regional system planning based on prospective LCA

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The installation of technologies such as renewable energy and waste valorization into the regions is important to achieve carbon neutrality and a circular economy. Such plans need to be designed prospectively, based on life cycle assessment (LCA) considering many combinations of emerging technologies. Its implementation has been time-consuming and labor-intensive to collect various data on the region, technology and society, and to analyze future changes and uncertainties.

In this study, we conceptually designed a data platform to accelerate regional system planning based on prospective LCA, and some components of this platform were developed. To define the requirements of the platform, two models were developed; an “activity model” representing the flow of work and information in the planning process, and a “data model” representing the required data items and linkages. In addition, through workshops with technology developers, consultants and municipal officials, the challenges and barriers in regional system planning were clarified. Through these works, the required functions of the tools to support the four tasks, supply-demand analysis, alternatives generation, simulation and evaluation, for the implementation of regional system planning and the structure of the database were clarified.

For the supply-demand analysis tool, a web application was developed to visualize the potential and installation records for renewable energy by municipality, which had been published from separate organizations. In addition, a tool was developed that can estimate the annual energy demand structure on a municipal basis. For alternative generation, a database of candidate technologies and a

matching function with local resources are being developed. For simulation and evaluation, individual simulators, which can generate inventory data for LCA, have been developed for several emerging technologies for renewable energy. These will be linked together in the future to enable complex system analysis.

2-2F-2

Integrating crop data, land use statistics, and a resolved multi-regional input-output table to fully regionalize ecoinvent

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A fully-regionalized life cycle assessment (LCA) can provide more accurate results for decision-makers. Well-established regionalized characterization factors (CFs) are often not applicable on the background system due to the extremely limited regionalization of life cycle inventory (LCI) databases. Therefore, this study developed a workflow to regionalize the full ecoinvent LCI database, and enhance the crop datasets using cutting-edge inventory models and the latest data (crop data, land use statistics, precipitations, etc.). In a first step, the inventories for water consumption and land use of 16 major crop production have been regionalized for all countries. A land use change imbalance issue in the land transformation part of ecoinvent 3.7.1 was discovered and solved. Then, a resolved multi-regional input-output table (RMRIO) with 163 sectors and 187 countries was integrated to regionalize the supply chains of all activities. Based on the matching between ISIC classifications in datasets and industries in RMRIO, the interregional industry flows from RMRIO were approximated as the country-specific consumption mixes.
The resulting regionalized version of ecoinvent shows better data consistency and accuracy. It is at country-level resolution for each activity, which allows wide regional impacts calculation and precise contributor analysis. We show that most of the impacts caused by crop production happen locally due to domestic irrigation, land occupation, and transformation. The database also allows regionalized LCIA, which can change the regional impacts significantly. For example, the land use impact caused by wheat production in Russia decreases remarkably after the application of regional CFs compared to global CFs, due to the relatively low biodiversity impact of land use in Russia.
The detailed analysis of crops shows the capability of the regionalized ecoinvent, which has a technosphere matrix size of 1′410′347 × 1′410′347. This matrix needs to be solved using iterative methods due to memory constraints.

2-2F-3

Data foundation for carbon accounting and decarbonization

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While the determination of Scope 1 and 2 emissions are nowadays considered a very basic and standard procedure, the quantification of emissions throughout the value chain (Scope 3) is still a considerable challenge for most companies, despite the existence of excellent guidance such as the GHG Protocol Scope 3 Standard.
Procurement systems often capture purchase volumes in financial terms and without physical attributes (weight, size, number of pieces etc.). And even if there are physical attributes available for at least some of the purchased goods and services, organizations often have no access to reliable emission factors to calculate climate impact of these purchases (representing the entire upstream value chain of an organization) and often even several different production routes and technologies for the same product exist.
The easy fix to this is to simply use the purchasing volumes in monetary terms and combine these with so-called environmentally extended input-output (EEIO) tables and models. Particularly for Category 1 ‘Purchased Goods and Services’ (defined as ‘Emissions from all purchased goods and services not otherwise included in the other categories of upstream Scope 3 emissions’ by the GHG Protocol), many are using this approach.
There are several ‘uncertainties’ associated with this approach, such as time (date of data), price variability, precision (specific types of material rather than ‘industry sector’) and unknown supply technology all contributing to uncertainty ranges in the order of magnitudes. This type of approach may be suitable for a first, very rough, screening, and for a rough estimation of Scope 3 categories that are not relevant for a particular organization, but not a foundation to reduce carbon emissions and track these reductions.
The need for and sources of data and methods to develop carbon reduction strategies comprising value chain emissions via a suitable approach are presented and discussed.

2-2F-4

Development of a common system to map the elementary flows (EF) lists from major LCA databases

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1

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The Global LCA Data Access (GLAD) network is an open platform that aims at providing datasets for life cycle assessment (LCA) from data providers worldwide. The aim of the GLAD Working Group on Nomenclature (WG1) was to develop a common system to map the elementary flows (EF) lists belonging to major nomenclature systems connected to GLAD:
the U.S. Federal LCA Commons, the International Reference Life Cycle Data System (ILCD) of the European Commission, the Inventory Database for Environmental Analysis (IDEA) of Japan, and the ecoinvent database.
Three aspects were prioritized: collecting the information necessary for establishing and running a semi-automatic procedure (using a mapping script), setting up the criteria for the review of its output, and documenting those criteria. The inputs of the script were classified as follows based on the EFs: “flowables” related to the name of the EF (e.g., carbon dioxide) and “context”, the environmental sub-/compartment related to the EF (e.g., emission to air). These inputs for the mapping script were compared for the source-target list combinations in both directions (=12 mapping files).
The matching rates between the different lists were found to be around 20% for some combinations while above 95% for some others, with seven combinations showing a matching rate above 50%. It was determined that the number of unique “flowables” of the target list generally drives the ability to cover the source flowlist.
Overall, it can be observed that in the current state, the mappings between the different lists are not always perfect. In this regard, more efforts might be focused on the harmonization of nomenclature systems. This project paved the way in this direction, providing the base to identify the most suitable EFs for a centralized nomenclature system. Another output of this project is an LCI dataset format converter available open access on GitHub.

2-2F-5

Directing practices for technology developments with the aid of deductive LCA

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Lifecycle thinking and analysis are recognized and encouraged in the current greenhouse gas (GHG) emissions reduction-oriented society. Recently, estimating emission reduction potential is often required even in the early stage of technology development projects. Therefore, LCA is not an activity attempted at the final stage of a project anymore. Rather than that, LCA researchers are sometimes expected to take a role as a conductor of the project. Due to the data intensity and high uncertainty in LCA, completing all assessments at the early stage of development tends to be hard, particularly for evaluating new technologies and processes. The most significant barrier for LCA for such progressive developments is the lack of process inventories for uncommon substances and materials. Missing inventories can somehow be filled by an artificial neural network-based model (e.g., FineChem) and proxy methods. However, such methods may introduce uncertainty to the evaluation. In addition, process parameters such as yield and energy consumption would change in the course of the development. Furthermore, the energy-related GHG emission inventory also changes with social conditions. There is no time to wait to determine such fluctuating parameters for a project conductor. Contrary, by comparing the emissions from predetermined factors and a target emission, the difference is obtained as an emission margin for undetermined factors in the deductive LCA approach. Acceptable ranges of undecided parameters and inventories are deductively figured out by break-even analysis based on the margin. The obtained ranges provide concrete directions to technology developers that enhance the developments. This study introduces the practical examples of the deductive LCA and the break-even analysis for encouraging LCA researchers to be conductors of technology developments.

2-3A: Supply risk

2-3A-1

GeoPolRisk: Current developments and future mainstreaming opportunities of a life cycle impact assessment method for the supply risk of abiotic resources

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Life Cycle Assessment (LCA) focuses on systematically quantifying impact indicators of a product system that relates to the three main Areas of Protection (AoP): human health, ecosystem health, and natural resources. As a complement to environmental LCA, the concept of criticality has been introduced to assess accessibility to raw materials in relation to the AoP Natural Resources. The genesis of the GeoPolRisk method is based on the integration of criticality considerations in LCA, making it recognized as a suggested midpoint indicator method by the Task Force on mineral resources of the Life Cycle Initiative hosted by UN Environment (UNEP) for quantifying “the relative potential accessibility issues to certain raw materials for a product system related to short-term

geopolitical and socioeconomic aspects". Over the past few years, multiple opportunities for improvement in the methodological development and application of the GeoPolRisk method have been identified and addressed. Among these, the most recent ones relate to the extension of the indicator from a midpoint to an endpoint assessment method and the definition of an improved integrated characterization model for the use of geopolitical supply risk to calculate impacts in the AoP Natural Resources for abiotic resources. Most recently, a webbased tool has been developped to generate a wide matrix of GeoPolRisk characterisaiton factors tailored to different countries, years and abitoic resources, including now also fossil fuels. This contribution aims to explore and summarize the developments based of the GeoPolRisk method and to discuss future application opportunities.

2-3A-2

Investigation of fire accident caused by lithium-ion batteries in the disposal process and evaluation of countermeasures

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In recent years, fires and other accidents involving lithium-ion batteries (LIBs), which are believed to be the cause of ignition, have been increasing at municipal waste disposal facilities and recycling facilities for small home appliances. In Japan, small secondary batteries including LIBs are subject to voluntary collection based on the Law for Promotion of Effective Utilization of Resources. However, the voluntary collection is not fully functional due to an increase in consumption and disposal of small home appliances, mobile batteries, and electronic cigarettes containing LIBs, as well as many products that are difficult to remove, and the difficulty in understanding disposal methods. With the development of the information and communication environment and the spread of electrical and electronic products, it is certain that the consumption and disposal of LIBs will continue to increase, and there is an urgent need for measures to prevent fires and other accidents related to LIBs in the circulation and disposal process.
The purpose of this study is to provide basic information on the current status of fires, etc. at municipal non-combustible waste treatment facilities (including similar bulky waste treatment facilities) and preventive measures. For this purpose, an interview survey of municipalities and thermo-camera monitoring at non-combustible waste disposal facilities were conducted. In addition, in one municipality, the status of LIB contamination in noncombustible waste and small home appliances was investigated. Finally, as measures to prevent accidents such as fires caused by LIBs in the disposal of noncombustible waste, we took up sorting measures and pre-sorting to prevent LIB contamination, and attempted to evaluate the effectiveness of these measures.

2-3A-3

AIST-MeRAM: A free tool embedded with toxicity test data and risk estimation methodologies for ecological risk assessment of chemical substances

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Ecological risk assessment (ERA) of chemicals is complicated because it requires enormous time/labor in collection and assessment of the hazard data and a high level of expertise in interpreting the risk. AIST-MeRAM is a free user-friendly software for ecological risk assessment and management of chemical substances. By installing AIST-MeRAM Ver 2.0 (Standalone Version) on your computer or click to the Web version of AIST-MeRAM Ver 3.0 (scheduled to be released at summer 2022), you can perform assessment with only a few mouse clicks – ranging from Hazard Quotient risk assessment to high level risk assessment using species sensitivity distribution and population-level effect models. AIST-MeRAM contains not only these assessment models, but also toxicity test data on approximately 3900 substances and the emission factors of chemicals under CSCL (Chemical Substances Control Law of Japan). You can thus use the tool even if you don't have data at hand or expertise in ecological risk assessment and statistical analysis. In addition, AIST-MeRAM can automatically determine uncertainty factors (UF) according to multiple regulatory rules and can conduct the risk assessment under the scheme of CSCL (Chemical Substances Control Law in Japan), serves as a model for demonstrating Japanese-style regulatory chemical management.

2-3A-4

Considering synthesis of chemicals in chemical alternative assessment

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Chemical alternatives assessment (CAA) identifies toxic and concerned chemical substances and suggests safer alternatives. However, hazard assessment of chemicals usually addresses the human exposure risk in the use stage of products. In order to include the synthesis of chemicals in hazardous chemical management, this study aims to provide a framework for CAA with a life cycle assessment (LCA) approach.

Formaldehyde, in the formalin solution and used as a specimen preservative, was the target chemical in the case study. Information on the potential alternatives, including Formalternate, Wardsafe and Streck Tissue Fixative, were collected from the report released by the Toxics Use Reduction Institute (TURI), US. Preliminary results showed that the synthesis of potential alternatives could have higher environmental impacts than the target chemicals. Detailed analysis is being conducted to consider the functional unit and the substitution factors of formaldehyde and its alternatives.
It is suggested that the potential alternatives should be selected based on the hazard assessment of chemicals in the use stage. Then LCA can be applied to recognize the environmental impacts of chemical synthesis and contribute to improving green chemistry and green production. Therefore, we expect that introducing LCA into CAA will optimize hazardous chemical management by providing holistic information of chemical impacts and avoiding unexpected environmental risks.

2-3A-5

Metals industry's involvement with the SDGs in their SDG reporting

Hiroki Hatayama
National Institute of Advanced Industrial Science and Technology, Japan

Growing public interest in environmental, social, and governance issues requires all organizations to address the United Nations Sustainable Development Goals (SDGs). Because the metals industry has been less likely to report engagement with the SDGs than other sectors, exploring its relationship with the SDGs is essential in accelerating its engagement with these goals. This study examines the relationship between the metals industry and the SDGs by analyzing reports of 61 metal companies. The analysis adopts the number of activities associated with SDGs as a proxy indicator in measuring the intensity of association between the company and 17 SDGs. The results show that the metals industry places most focus on SDGs 8, 3, and 12, but its activities are less associated with SDGs 14, 2, and 1 on the whole. Furthermore, this relationship with the SDGs shows different trends among metal producers: the steel industry places great weight on SDG 12 and less on SDGs 1 and 2, whereas the copper industry recognizes the relevance to SDGs 1 and 2. This is attributed to the different positions of the production companies in the supply chain because current SDG reporting seems to be strongly affected by the circumstances and stakeholders they face directly. For further commitment to the SDGs, these findings recommend that metal producers consider the values and benefits that the metals provide throughout the value chain.

2-3B: [OS] Carbon neutrality and avoided emission (2)

2-3B-1

Carbon Neutrality using ISO 14068

Ian Byrne
Ian Byrne Energy & Carbon Consultancy Services, the United Kingdom

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2-3B-2

Avoided emission of IEC/WD 63372

Takako Hiruta
Schneider Electric Japan Holdings Ltd., Japan

2-3B-3

Discussion for ISO14064-1 and ISO/TS14069

Romain Poivet
ADEME, France

2-3B-4

Beyond Value Chain Mitigation and Its Role in Achieving the Science-based Emission Reduction Targets

Dedy Mahardika
CDP, Indonesia

2-3B-5

The new Net Zero Guidelines in ISO IWA42

Ian Byrne

2-3C: [OS] Development of corporate value and organization well-being

2-3C-1

[Keynote talk] Roadmapping for strategic alignment

Robert Phaal
University of Cambridge, United Kingdom

Roadmaps are structured visual diagrams that support strategic understanding, communication and planning. The flexible and integrative nature of roadmaps can help to address the significant strategic challenges facing humanity in the 21st century, such as environmental and social sustainability. However, although roadmapping has been established industrial practice in technology-intensive sectors for more than 50 years, the method is not generally included in standard business and management education and research, limiting its potential impact for addressing these challenges.
The roadmapping method emerged in the 1960s in US high-tech sectors such as aerospace and semiconductors, to support strategic alignment of technology within the context of complex engineered systems. Since then, the approach has been adopted (and adapted) by many organisations around the world, in many sectors and at all levels, ranging from components of complex systems to new ventures, corporations, sectors, nations and international collaborations.
The first sector-level application of roadmapping was in the semiconductor industry, with the first International Technology Roadmap for Semiconductors (ITRS) published in the early 1990s. This industrial collaboration created an industry standard for planning and investment, contributing directly to the rapid development of digital electronics, devices and systems. While most company level roadmaps tend to be very confidential, and not shared widely, the reverse is true for sector level roadmaps, which are used to coordinate activity on a much broader basis. Thus, roadmapping has contributed to the foresight toolbox, used by governments, corporations and other organisations to support long-term strategic planning.
This presentation will provide an overview of roadmapping, including its evolution and application in business, government and other organisations. It's role in the foresight toolbox will be elaborated, including relationship to other methods, such as scenario planning. The key features that enable to the method to contribute to environmental and social sustainability will be emphasised.

2-3C-2

[Invited talk] How foresight activity contribute LCA and better future development

Kuniko Urashima
NISTEP, Japan

When the government makes policy decisions, it is desirable to collect opinions and ideas from as many people as possible and guide the optimal strategy. However, scientifically creating the future is a difficult task. Foresight to create the future is a method adopted by many government agencies because it is an evidence-based instrument that includes qualitative and quantitative elements such as expert panels, hearings, scenario creation, and Delphi research. National Institute of Science and Technology Policy (NISTEP) has been carried out "Foresight survey"that has been conducting every five years since 1971 in Japan and the purpose of this survey is for contributing National S&T strategy as S&T basic plan development. However, due to changes in national economic conditions and social conditions, survey methods have become diversified. The 11th Foresight survey purpose of this study is to provide basic information that contributes to the consideration in science and technology innovation policies and strategies, including the 6th Science and Technology Basic Plan. The prospective period is about 30 years until 2050, and the target year is 2040. First, the trends and signs of change in science and technology and society were obtained, and then the future image of society (the desired future image) and the future image of science and technology (the medium- and long-term perspective of science and technology development) were separately examined. Finally, these trends and images were integrated in order to examine the future images of society through the development of science and technology. In examining the future image of society, 50 future images were extracted. For examination of the future image of science and technology, 702 science and technology topics were selected, and the expert questionnaire surveys were conducted regarding importance, international competitiveness, and prospects for implementation of the topics.

2-3C-3

[Invited talk] Organizational futures literacy in a well-being economy era

Kunio Shirahada
Japan Advanced Institute of Science and Technology, Japan

Companies are shifting their objectives and purposes from an emphasis on economic value to a contribution to the formation of multidimensional well-being that includes positive impacts on society, the environment, and individual lives. In this so-called "well-being

economy" (Fioramonti et al., 2022), it is important for actors in both profit- and non-profit-oriented organizations to form an attitude to think about their own products and services while considering well-being from a collective perspective with a future time axis, and to take actions in a collaborative manner to realize their ideal value propositions. This indicates the need to renew the concept of "futures literacy" proposed by UNESCO in 2012 indicating the basic ability to imagine the future and review one's own behavior by using that imagined future, from the perspective of organization and well-being. In this talk, I will propose the concept of organizational futures literacy and discuss its potential for creating corporate value in the age of well-being economy based on the perspectives of well-being-oriented service research (Transformative Service Research), knowledge management study in a social context, and roadmapping study focusing on well-being that I have been engaged in.

Fioramonti, L., Coscieme, L., Costanza, R., Kubiszewski, I., Trebeck, K., Wallis, S., Roberts, D., et al. (2022), "Wellbeing economy: An effective paradigm to mainstream post-growth policies?", Ecological Economics, Vol. 192, p. 107261.

2-3C-4

Collaborative research of the University of Tokyo and NTT -A case analysis to identify the subjects on the supporting technologies for strategy planning

Minako Hara[1], Machiko Shinozuka[1], Masahiro Sotoma[1], Xiaoxi Zhang[1], Midori Kawada[1], Yusuke Kishita[2]

[1]Nippon Telegraph and Telephone Corporation, Japan; [2]The University of Tokyo

The University of Tokyo and NTT have been collaboratively researching scenario planning methodology aiming to unbiasedly support corporate strategy planning related to environmental and social sustainability. For the first step, we held in-person and digital workshops intended to find current problems in the practical scenario planning procedure. After personal life planning was selected as a case study, a roadmap with three layers including targets, life events, and social circumstances was used for the workshops. Although the planned scenarios covered targets and life events, social circumstances were not sufficiently covered due to the theme being about personal issues. To apply this procedure to corporate strategy planning, additional layers with diverse expressions would be needed to consider complexed relations from several perspectives such as time series or uncertainties. The planned scenarios also had limited branch numbers due to the time limit as well as the limits of the participants' imagination. The results indicated the use of computing could be one option to overcome these limitations as well as avoiding biases in the scenario planning procedure.

2-3D: Circular economy business (2)

2-3D-1

CO_2 reduction potential of car sharing services considering used car market

Daisuke Yoshizawa[1], Yuya Nakamoto[2], Shigemi Kagawa[1]

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In September 2020, the Japanese government has declared the goal of achieving a carbon-neutral, decarbonized society by 2050. Looking at CO_2 emissions by sector in Japan in 2020, the transportation sector accounts for 18.6% of the total emissions. More specifically, passenger cars account for 45.9% of the total emissions from the transportation sector. Therefore, it is crucial to reduce CO_2 emissions from passenger cars in order to achieve the carbon neutrality by 2050. Among the expected evolution of passenger cars in the future, car sharing service is a method that will most significantly change the way we use cars. It is important to understand the effect of expanding car sharing services on the overall CO_2 emissions of passenger cars. This study develops a new framework for analyzing the life-cycle CO_2 emissions of passenger cars associated with expanding car sharing services in a country. Based on the analysis framework, we quantify CO_2 reduction potential of expanding car sharing services in the society through a comparison between the baseline scenario where no car sharing service exists in the society and the counterfactual scenario where the number of car-sharing users increases at a certain rate during the study period between 2009 and 2018. We assume that the percentage of owners choosing car-sharing services would gradually increase during the study period, reaching ρ% in the final year (i.e., 2018). A comparison between the baseline and counterfactual scenarios shows that the ρ=10% increase in car-sharing services would have led to a decrease of 6 million t-CO_2-eq. during the study period, accounting for 3% of the CO_2 emissions from Japan's transportation sector. This study finally presents an effective CO_2 mitigation policy through improving car sharing services.

2-3D-2

The impact of consensus building on sustainability in eco-friendly supply chains

Jundai Koketsu, Aya Ishigaki

Tokyo University of Science, Japan

In recent years, stricter regulations and growing environmental awareness have required an eco-friendly supply chain. Closed-loop supply chains, recycle/reuse technologies, and various other eco-friendly factors have attracted attention as important research

areas, and a large number of studies have been conducted. On the other hand, to achieve an eco-friendly supply chain implementation, it is necessary to share the benefits and burdens among the players in the supply chain. However, today's supply chains require various elements such as globalization, social responsibility, and reverse logistics. Under such complex and uncertain conditions, it is difficult for all players to agree. Unfair supply chains may be constructed according to the power relations among players. This unfair situation creates problems for the sustainability of the supply chain. For example, it is a situation in which a business that generates a high environmental impact is imposed on other players. The burden of reducing environmental impact is concentrated, but the benefits are not. As a result, there is no progress in the development of technologies to reduce environmental impact, and sustainable supply chains are not realized. We believe that building a supply chain that is fair and satisfactory to all players is necessary to improve sustainability.
This study investigates the sustainability impact of consensus building among players in an eco-friendly supply chain and shows that a negotiated fair consensus can enhance the sustainability of the supply chain.

2-3D-3

Survival of the fittest or the most efficient?

Marlene Preiss, Christian Haubach, Mario Schmidt
Pforzheim University, Germany

Fifty years ago, the Club of Rome commissioned a study known as “The Limits of Growth” which analyzed the impact of the growing population and economy on the environment. The study concluded that a persistently growing consumption of energy and materials will exceed the plantar boundaries and irreparably harm the environment. As a consequence, the decoupling of economic growth and resource consumption became a declared common objective.
A strategy to achieve this objective is the more efficient utilization of energy and raw materials. For manufacturing companies, an improved resource efficiency is economically advantageous. In addition, it also has a positive impact on the environment and the progressing climate change, provided that rebound effects are not considered. So, for many years’ companies have been working steadily to make their production processes more resource efficient e.g., through technical improvements, reduced inventory or recycling of production wastes. The European Green Deal also pursues the transition to a modern, resource efficient and competitive economy.
In evolution, however, survival and persistence are attributed to the fittest. Lately the COVID-19 pandemic revealed that the pursuit of efficiency and, e.g., the associated reduction of inventory, make companies vulnerable as soon as supply chains start to falter. That circumstance has put the concept of resilience on the map. Rising the question if being efficient really is the right way for companies to sustain, or whether they will increasingly have to combine it with being flexible and resilient in the future. Manufacturing companies from the German state of Baden-Württemberg are innovative, export-driven and an important pillar of the economy while also being part of a highly branched worldwide supply chain depending on the import of materials and components. Insights based on case examples and interviews from some of these companies are used to shed light on the risen questions.

2-3D-4

Evaluation of energy reduction by the adoption of distributed recycling system using microwave: Obsolete alkaline batteries in Japan as a case study

Keita Kozaki, Shoki Kosai, Shunsuke Kashiwakura, Eiji Yamasue
Ritsumeikan University, Japan

Today, rapid population and economic growth have led to the mass production and consumption of a wide variety of products. This type of production and consumption produces a large amount of waste. Hence, it is important to develop an efficient recycling system for a recycling-oriented society.
A centralized recycling system is a present recycling approach. Many studies have stated that the high energy consumption in the collection and transportation process is a major problem of the centralized recycling. Although the distributed recycling system has been proposed as a solution to address this problem, its effectiveness in terms of energy reduction has yet to be fully analyzed. Thus, considering a distributed recycling system in which multiple small-scale treatment facilities are distributed and employed to complete the final treatment of waste generated in each region, we applied this concept to the recycling of alkaline batteries in Japan as a case study using microwave furnace. Microwave furnace is considered to be an appropriate technology for the distributed recycling system from the perspective of miniaturization and adaptability. The energy reduction obtained through the transition of recycling system from centralization and distribution in the transport and heating process is evaluated under some scenarios.
It was found that the larger energy reduction obtained by the implementation of distributed recycling system can be achieved in the municipalities with greater distance from final treatment facilities and larger populations. 86,000 GJ of energy reduction at maximum could be expected in Japan as a national scale when adopting distributed recycling system in all 1,700 municipalities.
Although the effectiveness of distributed recycling system in each municipality varies depending on transportation means in each scenario, it was confirmed at least under the national scale.

2-3E: Consequences of consumption

2-3E-1

Agent-based modeling of consumer behavior and product circulation for ex-ante assessment of emerging circular economy strategies

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Introducing circular economy strategies into consumer durables, such as refurbish, repair, leasing, and sharing, are expected to contribute to sustainability. However, its environmental and resource consequences may require a more rigorous ex-ante assessment due to expected changes in consumer behaviors and potential rebound effects. To date, various assessment methodologies have been developed including life cycle assessment, material flow analysis, and discrete event simulation; however, none of them can reflect dynamic changes in consumer behavior and its heterogeneity, which are critical parameters in the circular economy transition. In this study, a novel agent-based simulation model of consumer behavior and product circulation in the circular economy transition has been developed. The simulation tool can reflect various elements of consumer behavior and product circulation, including product-service choice, parts-level failure, obsolescence, repair choice, dead-storage, product discharge choice, preparation for reuse, refurbish, upgrade, leasing, and renting. As each consumer and product are both modeled as an agent, their interactions such as through learning of product-service availability, social utility, and cascaded use of products and their heterogeneity and segmentation can be modeled. The model was designed to be calibrated with empirical data such as questionnaire surveys, choice-based conjoint analysis, and public statistical data. By incorporating the life cycle inventory data and impact assessment methods, it can be used to quantify life cycle environmental impacts, resource consumption, and circularity indicators. In this presentation, the proposed structure of the model and case studies with home appliances will be introduced. A preliminary result of the simulation demonstrated its ability to assess the comparison and integration of multiple circular economy strategies, such as leasing refurbished products or repairing reused products. The proposed methodology is useful for circularity assessment of various product circulation strategies and contributes to the development of policies and business models for the circular economy transition.

2-3E-2

Consumption value of second hand products: Using transaction data from the online flea market platform

Dami Moon[1], Kiyo Kuris[1], Kiyotaka Tahara[2]

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

This study examines the consumption value of secondhand products using transactional information on the online flea market platforms (online marketplaces) and discusses the possibility of extending the utilization of the secondhand product toward achieving sustainable consumer behavior. Recently, as the online marketplaces through the consumer-to-consumer transaction system have spread, various types of secondhand products are being traded by consumers. Among them, it was found that there are quite a few cases where consumers trade the products with poor functionality and appearances. Here, this study analyzes the consumption value of secondhand products by focusing on the status of the product condition traded on the online marketplaces. As a method, first, target products were selected from various products used in daily life, and classified according to the characteristics of the product acquisition mode, such as purchasing new or secondhand products and using sharing. And, the grade of the product condition was divided into six stages according to the Marketplace guidelines. Moreover, transaction volume, price, and the demand situation to check the transaction status by grade of the product condition were analyzed and compared by product classifications. As a result, this study was demonstrated that the product condition perceived by consumers as an available product might differ depending on the product classification. Besides, it was identified that the product condition could be considered not only from the physical aspect of the product but also from the social aspect related to the reality of the function, which can be an essential factor in understanding the consumption value. Additional analysis to secure consumer acceptance to expand the utilization of secondhand products will be needed as a future task. This presentation is the result of Value Exchange Engineering research conducted in collaboration between Mercari and RIISE.

2-3E-3

Method for assessing the environmental impact of daily food consumption habits: Study on the consumption of land-based protein sources in Japan

Helen Stewart, Takashi Furutani, Masaki Hisada

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The systems currently supporting global food consumption are responsible for the degradation of terrestrial and aquatic ecosystems, depletion of fresh water resources and contribute an estimated 34% to global greenhouse gas emissions. Despite this, the impact of food on the environment across its life cycle is frequently ignored in climate change mitigation strategies. In particular, animal products, including meat, dairy and eggs, use 83% of the world's farmland despite providing only 37% of protein requirements. Protein sources are hence an important point of focus when formulating climate change mitigation strategies. This study proposes a novel method of estimating daily food consumption quantities and subsequent environmental impacts. This method uses product names, revenue, and sales numbers derived from supermarket point-of-sale (POS) data to estimate daily food consumption masses. Life cycle assessment meta-analysis coefficients for significant food categories are used to estimate environmental impacts under five indicators: greenhouse gas emissions, fresh water withdrawals, land use, eutrophication and acidification. Trends in daily consumption patterns of land-based protein sources are compared from 2012 to 2022, using a national-level POS data set covering supermarkets across Japan. Consumption trends for beef, lamb, pork, chicken, tofu and soy meat products, their associated environmental impacts, and consequences for future climate change mitigation strategies are discussed.

2-3E-4

Holistic sustainability evaluation framework cognizant of demographics and behaviour

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This research seeks to establish a sustainability evaluation framework which incorporates the three aspects of the environment, economy and society, cognizant of human behavior and demographics which impact our preferences toward economic, environmental and social issues and policies. Building on previous efforts to quantitatively evaluate social equity and thus to provide the third pillar of sustainability evaluations, this research incorporates stakeholder preferences to determine an appropriate evaluation framework cognizant of societal needs and behavior. Behavior here is represented by people's (household) consumption and resultant environmental loads, determined via input-output analysis, leveraging national survey data. Further, by utilizing machine learning approaches to evaluate and cluster stakeholder preferences and behavior based on demographic factors and time-series survey data, estimations of future environmental loads and policy needs can be extracted and proactively applied. The advantage of this holistic sustainability evaluation framework is its ability to compare future scenarios quantitatively, and to identify hotspots in consumption and expressed preferences toward environmentally proactive behavior to identify policy levers to achieve a fair transition toward carbon neutrality.

2-3E-5

A scenario analysis for exploring the potential for achieving carbon neutrality in Japan's household sector

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In 2020, the government of Japan pledged to achieve complete carbon neutrality by 2050. Meanwhile, in order to achieve this goal, in addition to carbon sequestration, it is regarded as essential that the current effort to reduce carbon emissions should be maintained or enhanced. With the overall emissions resulting from household consumption being estimated to account for over 70% of societal emissions, carbon mitigation by the household sector is expected to play an important role in the pathways toward carbon neutrality. To explore the potential for carbon mitigation within the household sector, the trend in household carbon footprint, lifestyle changes in accordance with carbon neutrality goals, the adoption of technological innovations, and the evolvement of socioeconomic conditions, etc. need to be considered, whereas no existing study has covered all these aspects.
To address the abovementioned research gaps, in this study, based on the time-series forecasts of household carbon footprint, a scenario analysis is conducted from the perspective of household consumption to explore the potential for achieving carbon neutrality in Japan toward 2050, while accounting for probable changes in household socioeconomic and demographic attributes, improvements in energy efficiency enabled by innovative technologies, and consumption behavior changes. Various scenarios – ranging from business-as-usual (BAU) to three different levels of behavioral change – are built. For each scenario, the carbon mitigation effects corresponding to the assumed alterations in individual lifestyles and in the social context are estimated quantitatively from a life cycle perspective. The results are expected to fill the gaps in existing studies regarding the quantitative assessment of future carbon footprint pathways based on historical data, and help identify probable factors related to the household sector contributing to carbon neutrality in the future.

2-3F: Acceleration of sustainability management: Tools

2-3F-1

Net Zero in 2050: Implementation of a scalable digital tool for calculating high numbers of product carbon footprints in the chemical industry

Peter Saling[1], Alessandro Pistillo[1], Jan Schöneboom[1], Kent Yano[2]

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Many sectors in the world and therein the Chemical Industry has a huge challenge: to become climate-neutral by 2050. This ambitious target creates several opportunities for the chemical industry to contribute for a better future. Steering decarbonization requires full transparency of the carbon footprints along the value chains to identify the opportunities and for that a standardized methodology for Product Carbon Footprint (PCF) calculation at scale must be established. The upstream part of many products, the purchased products have a significant contribution to PCF of chemical products. That needs to be handled via helpful guidelines and via support of the suppliers, e.g. with the Together for Sustainability (TfS) guideline for PCF that is currently under development.
These challenges were the starting point for BASF to develop a tool and an approach to calculate a high number of PCF in a relative short time frame. Build on our 25 years of experience in methodologies to quantify sustainability performance, we defined the methodological principles and product specific guidance for the calculation of a cradle-to-gate PCF following ISO standard 14067:2018 for carbon footprint of products, which is based on ISO14040:2006 and 14044:2006 for life cycle assessment. Additionally, the approach was aligned with the GHG Protocol Product Standard (WRI & WBCSD, 2011). Data were consolidated along the specific cradle-to-gate process-network of each product, including the decision tree logic for multi-output processes where allocation is needed.
The PCF determination tool (Strategic CO2 Transparency Tool = SCOTT) enables carbon accounting at scale and provides unparalleled transparency of carbon emissions at product level in every step of the manufacturing process, leveraging company primary data. SCOTT has been deployed and validated across the global production and swiftly calculates cradle-to-gate PCFs of the 45,000 products, allowing in depth analysis of carbon emission drivers for our sales products.

2-3F-2

Assessing the sustainability performance of entire product portfolio using PSA: Example from a specialty chemicals company

Martijn Gipmans[1], Angel Vergara[1], Anja Laqua[2], Didier Houssier[3], Yoshihisa Inui[4], Tsuyoshi Date[4], Hiroyuki Ogi[4], Akiko Ide[4], Masahiro Osumi[5]

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Kuraray Co., Ltd. and Sphera have jointly developed a Portfolio Sustainability Assessment (PSA) methodology to assess risk and opportunities from sustainability across the entire product portfolio. The Kuraray PSA method is based on guidance from the World Business Council for Sustainable Development (WBCSD)1. The PSA considers the specific context of a product, the value chain and a region by making the assessment at the level of the Product-Application-Region-Combination (PARC). The methodology uses a life-cycle approach to assess the sustainability performance of the PARCs over a diverse set of criteria in three different assessment categories – basic compliance, stakeholder requirements and benchmarking.
Kuraray group had a strong desire to set a future target of sustainability contributing products during the Medium-Term Management Plan period 2022-2026. To identify the goal of sustainability contributing products, chemical companies in Japan has implemented their own assessment systems. Kuraray group want to introduce a common assessment system and has decided PSA which is widely adopted especially with many chemical companies in Europe. Also, Kuraray group decided to install a PSA system by getting support from Sphera. The system is compliant with WBCSD guidance and provides a transparent and objective assessment of product sustainability performance.
The methodology is applicable for existing products and services as well as R&D projects and as such enables companies to apply a common framework with regards to sustainability and ESG performance of its products. The results of the PSA is the starting point for Kuraray group to manage its product portfolio towards more sustainable products and higher value creation.
1: https://www.wbcsd.org/Programs/Circular-Economy/Resources/Chemical-Industry-Methodology-for-Portfolio-Sustainability-Assessments

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2-3F-3

Scaling up LCA and LCC with ECOFACT

Emilia Ingemarsdotter, Georgios Pallas, Eric Mieras

PRé Sustainability, the Netherlands

The demand for life cycle information is increasing at an accelerating rate. Organizations want to use their life cycle assessment (LCA) and Life Cycle Costing (LCC) results to improve the eco-profile of their products and the sustainability performance of their

operations (Nygren & Antikainen, 2010). To resolve the growing demand for data, it is essential to scale up LCA. Moreover, it is crucial to be flexible and coherent as data gets outdated quickly. In this context, using a dynamic approach for LCA and LCC can help identify the varying bottlenecks and impact patterns that otherwise would not be possible. If data and results can be updated automatically, significant efficiency gains can be achieved compared to mainstream LCA/LCC practice, which often relies on stand-alone studies and static documentation.
This presentation introduces an innovative approach by the EU-funded 'ECO-innovative Energy FACTory Management' (ECOFACT) project (EcoFact, 2021) that brings together multiple partners to scale up LCA and its application. ECOFACT aims to make life cycle information widely available through automated and digitalized data collection and modelling at large scales, enabling four factories to monitor their environmental and costs impacts over time. Eventually, the insights from the ECOFACT platform can assist in targeted actions for optimizing production systems in terms of energy, cost, resources and life cycle impact.
The ECOFACT approach does not only provide the environmental snapshot that traditional LCA delivers, but also enable new temporal insights on an hourly, daily, monthly and yearly basis. In essence, it will enable the factories to observe patterns such as seasonal variations in environmental performance and variations due to changes in operational parameters. This way, the goal is to provide in-depth monitoring of the current state and help reveal effective improvement opportunities for the factories to minimize their impacts.

2-3F-4

Social analysis as module of sustainability assessments with SEEbalance®

Peter Saling[1], Thomas Grünenwald[1], Takeshi Irie[2], Kent Yano[2]
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Sustainability assessments should address all dimensions of sustainability. Easy to understand results are important for decision-making processes, mainly in industry. The results need to cover all important aspects if it comes to the identification of the more sustainable product to avoid wrong decisions. The assessments of economy, ecology and social impacts need to apply with different approaches to generate meaningful information. The goal and scope definition but as well the calculation approaches should be outlined and performed in a way, that the different type of information gathered can be used in a meaningful way. Furthermore, it is important, that the single results can be summarized in a manner that allows different stakeholders an easy understanding of the outcome of an assessment.
The SEEbalance® can be executed on different levels of information and with different views on a supply chain to identify the relevant disparities between the evaluated alternatives. The approach consists of four modules that together address economic, environmental and social impacts.
The use of sustainability assessments and their results will help industries along supply chains to improve the sustainability of the products, to identify improvement potentials, to trigger R&D activities, to interact with their customers and to report on progress against benchmarks. Sustainability management is a key area, where decision-making processes focus on due to the increasing importance of this topic. Together with suppliers and customers, the optimization of products and their application can generate benefits for the whole society and make them transparent.

3-1B: Diagnosis of current system (1)

3-1B-1

Resource intensity of the transportation system considering the infrastructure development: Japan as a case study

Naotaka Haraguchi, Shoki Kosai, Shunsuke Kashiwakura, Eiji Yamasue
Ritsumeikan, Japan

Economic growth across the globe has resulted in the larger resource use as an input associated with the transportation system. To use resource effectively in the transportation sector, it is important to estimate the amount of natural resource currently used in the first place. Although the infrastructure in the transportation sector is essential for the operation of transportation means, most of existing studies have separately analyzed the resource use of transportation means and infrastructure. Thus, the integration of transportation means with the associated infrastructure is important to estimate the natural resource use in the entire transportation system.
This study employed total material requirement (TMR) which is one of the indicators to evaluate resource use. To compare various transportation means and associated infrastructure, this study indicates the resource use in the form of resource intensity as a functional unit. The resource intensity of transportation means and infrastructures was calculated based on the inventory data for each transportation modes. The four transportation modes including roadways, railways, aviation, and waterways under the stages of manufacturing, operation and maintenance, and infrastructure development are considered in this study. The framework for the

infrastructure associated with each transportation mode was developed, covering a location for stop of transportation means (referred to node), a structure linking between nodes (referred to link), a secondary structure as a support for link, a facility for the fuel supply, and a fuel storage as constituents of infrastructure.
As a result, the resource intensity of transportation system increases in the order of high-speed railway, bus, aircraft, automobiles, and ship. In particular, the infrastructure development accounts for a significant share in resource intensity of high-speed railway and automobiles.

3-1B-2

Structural decomposition analysis of changes in South Korea's industrial hazardous waste generation

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Industrial hazardous waste (IHW) has been a disastrous impact on the environment and humans. Moreover, it caused social issues, such as waste transactions between countries in unequal status. The Basel Convention has been signed to regulate the transboundary movements and trade of IHW. Under this convention, the world had to be equipped with the domestic level of efficient IHW management capability.
Based on waste extended input-output (WEIO) model and structural decomposition analysis (SDA), this study identified the factors that contribute to the IHW generation in South Korea during 2008-2018. The results showed that the IHW generation increased 57.68% from 2008 to 2018. Among the three factors ,that is the factors of final demand expansion, imports substitution and technology change, the factors of final demand expansion and imports substitution are most important ones for the increase to +53.04%p and +13.79%p, respectively, while the factor of technology change acted to reduction to -9.16%p. The secondary industry's contribution to IHW generation increase was +53.26%p, accounting for more than 90% of the total IHW generation increase, which was led by exports demand expansion (+34.24%p) and waste generation coefficient change (+30.04%p). In tertiary industry, the contribution of IHW generation increase was +4.41%p, accounting for only 10% of the total generation increase, which was led by consumption expansion (+11.14%p).
The critical finding from this research is that IHW generation in South Korea is more affected by exports and imports than domestic production and consumption. That is because there are more numerous hidden waste flows in international trade than in domestic manufacture. This result suggests that when we establish a waste policy, international trade considering the imports and exports characteristics by industry should be considered as important as domestic production activities.

3-1B-3

Regional freshwater overconsumption induced by the agricultural crop production in a highly dense population setting

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Global crop production is responsible for creating huge pressure on the limited freshwater available for humankind. The planetary boundary for global freshwater use is it set to be ~4,000 km3/year; on a regional scale, we are already overconsuming it in major watersheds. We as a global community is facing the dilemma of finding ways to feed the growing billions and ensuring that the food is produced in a sustainable manner. Bangladesh, a densely populated country having one of the lowest per capita agricultural lands in the world, is trying to become self-sufficient in food production. There are few issues regarding the limited freshwater resources of the country: seasonal freshwater overconsumption during the dry period, and water pollution due to agricultural intensification. In this study, we aim to assess the sustainability of the crop water use for supporting Bangladesh's diet and gain the implications for future sustainable national diet focusing on the aspect of water resources. The updated WaterGAP 2.2.d model is used to calculate the freshwater overconsumption of Bangladesh's watershed, and the overconsumption associated with the crop production in the country is estimated corresponding to the total agricultural production for 1960–2019 period using updated crop evapotranspiration value. According to the results, the average overconsumption of freshwater from agricultural crop production during 2000–2016 period in Bangladesh was ~4,053 million cubic meter which was mainly due to own consumption of several crops. Furthermore, we also seek to identify the relationship between the nutrient density of the food crops and induced freshwater overconsumption, which gives the implications towards the achievement of the sustainable national diet. The outcome from this study will provide strategies for sustainable crop production in the country with the identification of the key crops and the watersheds that need improvement in the context of sustainability of water use.

3-1B-4

Life cycle assessment of coal: from mining to combustion

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The IPCC 2018 special report on Global Warming recommended the phasing-out of coal-fired power generation by 2037 for non-OECD countries, including Indonesia as one of the largest coal-producing countries. Accordingly, this study is conducted to identify the life stage of crushed coal that contributes to the most potential environmental impact through Life Cycle Assessment (LCA). This study covered cradle-to-grave boundary as an initial step to mitigate the impact and phasing-out preparation.
LCA methodology was implemented from the extraction of coal, coal processing, transportation until the usage of coal for electricity generation at coal-fired power plants and distribution of electricity in the grid network. The system boundary includes land clearing, land use and transformation, land reclamation, and revegetation. The functional unit is 1 kWh electricity distributed from the coal-fired power plant. The assessment was based on the data provided primarily from one of the biggest coal producers in Indonesia. Twelve potential impact categories were assessed.
The LCA results show that the potential environmental impact was mainly contributed by the combustion of coal in the subcritical coal-fired power plants. For 1 kWh of electricity distributed, the combustion of coal has the largest contribution to nine out of twelve environmental impact categories. The GWP produced by 1 kWh of electricity was 1.58 kg CO2 eq., contributing 91.17% from the coal-fired power plant. Details of the environmental impact are elaborated in this paper.
In addition to phasing out, upgrading the power plant technology to super or ultra-supercritical can significantly reduce the emissions from the coal-fired power plant. Meanwhile, the current carbon sequestration through land reclamation and revegetation in the mining process is not sufficient to replace the carbon loss. The effort for replacing the carbon storage loss from the land clearing and the land transformation through intensive land reclamation and revegetation should be improved.

3-1C: Agriculture and aquaculture

3-1C-1

Environmental life cycle assessment of precision agriculture technologies – A case study of crop production in Austria

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Precision agriculture technologies (PATs) aim to maximize resources and minimize environmental impacts by varying crop input rates based on crop requirements. Some of these technologies are proximal and remote sensors, automatic section control (ASC) and automatic steering for tractors. Several studies have shown the environmental benefits of the above-mentioned PATs however, a life cycle analysis (LCA) comprehensive comparison study is inexistent. Moreover, few of the LCA studies focus mostly on variable rate input technologies. This research aimed to perform an LCA of employing PATs for crop production in an Austrian context. A crop rotation with five different crops was modelled. Preliminary results revealed that rapeseed was the most input intense crop showing higher outcomes in all of the evaluated environmental impacts. On the other hand, remote sensing using satellites images to produce nutritional maps for fertilizer application was the most effective PAT showing the lowest results. For example, a 21% reduction in global warming potential (GWP) was achieved by implementing nutritional maps in comparison to conventional fertilizer application on rapeseed. PATs optimize crop inputs and bring positive environmental impacts, they help to tackle global warming and food scarcity.

3-1C-2

Estimating regional distribution of greenhouse gas emissions from paddy rice production using farm household surveys: The case study in the Philippines

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There has been increasing policy needs to expand research focus of farm sustainability studies from small to large scales. For example, a comparative study between controlled irrigation vs. rain-fed cropping (uncontrolled irrigation) necessitates regional perspectives. However, the regional approach to mitigating greenhouse gas (GHG) emissions remains a significant challenge because of the vast variations of farm practices across different site-specific conditions, and no studies have incorporated these issues so far in the study of GHG emissions from paddy rice production in the Philippines. Here, we present an approach to estimate GHG emissions for the 15 provinces in the Philippines using PhilRice's farm household surveys of the four different cropping periods. We scrutinized earlier life cycle inventories for agricultural inputs and emission factors for direct field emissions. The results indicate that the irrigated rice during the dry season cropping system is about 26% higher than the non-irrigated rice. The irrigated rice cropping is about 32% higher than the non-irrigated cropping system during the wet season. This relatively more significant GHG emissions

from the irrigated system was also associated with the relatively higher NPK fertilizer application in the irrigated system than the non-irrigated. Moreover, among the 15 regions, the Ilocos region had the highest GHG emissions per hectare and GHG emissions per yield for irrigated and non-irrigated, likely attributed to its high fertilizer application. These results imply the importance of more efficient use of agricultural inputs in achieving sustainable rice production in the Philippines, while coping with increasing food insecurity.

3-1C-3

Towards environmentally sustainable aquaculture: Investigation on the environmental impact of the pearl oyster farming using life cycle assessment

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Pearls are known as the queen of jewelry and have been used as symbols of material wealth throughout human history. Pearls are formed by the secretion of nacre from epidermal cells within mollusk mantle tissue. Pearl oyster aquaculture represents a significant portion of the world's total aquaculture production. This industry is a growing multibillion-dollar sector of mollusk aquaculture. Their secondary product is also valuable and is utilized for fertilizer, which creates a symbiosis between aquaculture and agriculture. Pearl production is entirely based on health. Any decline in water quality, resulting in poorer pearl quality and increased oyster mortality. In particular, mollusk culture has a low potential for environmental impact. However, there have been substantial adverse impacts in the pearl farming regions of Japan and China over some decades, and the potential remains for adverse environmental impacts from pearl farming industries. In some countries, sustainable pearl aquaculture production is being emphasized to contribute to achieving the United Nation's Sustainable Development Goals. This research analyzes the potential environmental impact of pearl aquaculture to provide data for more sustainable practice and lower the environmental impact using life cycle assessment. The study design consists of three steps: First, survey primary input data of pearl oyster aquaculture to the pearl oyster farmers and pearl practitioners; Second, define the boundaries and the limitation of the study; and Third, perform an impact assessment by the miLCA application. The preliminary findings report the emissions generated by 1 kg of pearl production are as follows: 1.1 x 10−1 Carbon dioxide (CO_2), 5.1 x 10−2 Methane (CH_4), 1.3 x 10−2 Nitrous oxides (N_2O). The Global Warming Potential (GWP) is 5.37 kg CO_2 equivalent, higher than the GWP for live classic oysters. Further research will analyze the environmental impact per subsystem and the transportation trades for sustainable pearl oyster farming practices.

3-1C-4

Beyond recycling – Using LCA to support emerging technology development and benchmarking

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The agroecological system deserves special attention as it possesses both anthropogenic and natural traits. To secure food production and soil fertility, fertilizer and soil conditioner are being applied worldwide, and demand keeps growing. Nevertheless, fertilization is a double-sided sword. The production is often associated with high energy consumption and resource depletion. The pressure on transforming the fertilizer industry into a more sustainable business model is increasing.
Germany has been seeking alternatives for phosphorus (P) fertilizer production to lower the supply-chain risk and promote sustainability. A joint research project was launched to recycle P from a wastewater system to produce fertilizer. The high concentration of P in the wastewater system makes it ideal for P extraction, while pollutants such as heavy metals bring new problems to the receiving environment - the soil.
My proposed presentation is based on an ongoing research project in Germany on developing P recycling technology from sewage sludge ash with heavy metal removal procedures to produce high-quality fertilizer. It shall showcase how life cycle assessment contributes to emerging technology development and promotes regional industrial symbiosis. Through this demonstration, the inadequacy in LCA and difficulties in the real-life case will also be brought forth.

3-1D: Circularity

3-1D-1

LC3SA framework: Addressing circularity and criticality of materials in LCSA

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The Covid-19 pandemic has triggered a global economic slowdown with a shortage of supply of goods and services. It emphasized a growing concern about resource resilience and efficiency. In this sense, industry, policymakers and researchers have been dedicating their efforts to produce materials' circularity and criticality indicators to promote both resource efficiency and sustainability.

However, a more circular or less risky system does not necessarily mean a more sustainable one. Integrating these two concepts in a sustainability assessment framework such as LCSA is therefore key. Nonetheless, this integration is not a straightforward task. The differences in scope of circularity and criticality methods (2Cs) as well as among LCSA approaches (i.e. LCA, LCC and sLCA) represent a gap in the interpretation of how these methods can be integrated into LCSA. To tackle this challenge, this research analyzes the scope of the methods of LCSA and the 2Cs in detail. The analysis addresses the exchanges and effects of a product system on the natural and human-made environments. Furthermore, this research analyses how the effects are communicated through different indicators in the impact pathway within the respective environmental, social, economic, circularity or criticality assessments. Potential double-counting and overlapping issues that occur when integrating the approaches and the complementary benefits are highlighted. Finally, an LC3SA framework is proposed, along with a discussion on open research questions and challenges for the application of the framework.

3-1D-2

Circularity metrics in context of circular economy transition: A review and critical assessment of material circularity indicator

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In recent years, Circular Economy (CE) has become a popular topic on policy agendas as a promising, innovative avenue to enhance resource efficiency and economic prosperity. Whether CE is a precondition to achieving sustainability goals or a source of potential trade-offs is still open to debate. Indicators are thus needed to measure and trace the progress of circular strategies towards sustainable development. Among the many indicators, the Material Circularity Indicator (MCI), mainly developed and championed by the Ellen MacArthur Foundation (EMF), has gained momentum among practitioners. MCI is supposed to measure how well a product performs in a CE context; nevertheless, several criticisms have been raised towards this tool, as, according to scholars, MCI just partially captures the relevant dimensions which need to be taken into account for realising the transition towards a CE. As such, MCI has been used alongside other approaches. Being more focused on the flow of materials, MCI has often been considered complementary to a Life Cycle Assessment (LCA), and both have been coupled at different integration levels. However, these integrations have themselves been criticised for not being able to overcome MCI's fundamental limitations and for their industry-specific nature. This work aims at reviewing the methodological premises of MCI as an indicator, along with its applicability. A short review of its adoption at industry level since its conception is performed to evaluate its real-world applicability. Analytically assessing its criticisms, an attempt is made to offer potential solutions to overcoming them by proposing a revised product-level circularity metric based on MCI.

3-1D-3

Sustainability and Circularity

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In a context where the transition to a circular economy is increasingly required, it is necessary to clarify the relationship between sustainability and circularity.
Life Cycle Assessment (LCA) is a methodology developed for assessing and quantifying the potential environmental impacts associated with entire product life cycles. Indicators allow to raise understanding of complex phenomena and help to set target and to measure performances based on them. Recently, circularity indicators have been introduced.
In this presentation we will discuss about what are circularity indicators and what is LCA, and what circularity indicators and LCA do and do not do in terms of improving circular decision making. Based on an analysis of recent studies, we can state that either considering the results separately or integrating the circularity and environmental sustainability assessments, no authors have concluded that circularity indicators can be used alone to choose the best option in circular economy projects. This is because the circularity indicators only provide a partial view on the multiple environmental performance of a system. At the same time, the circularity indicators are easier to communicate, and a high degree of circularity could help to build good relationships with customers and increase reputation among stakeholders, as well as to have an easier access to funding.
At the end, we will present a framework to take into account in the assessment of circular economy strategies both their sustainability and their degree of circularity.

3-1D-4

Production-consumption-waste management material flow analysis as a tool for circularity measurement: Macadamia products plant

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Circular Economy (CE) concept has been developed and gained attention globally due to scarcity of raw materials and environmental issues. However, measurement of circularity performance is still a challenge because of diverse activities and complexity of the assessment. Therefore, this study aims to develop a comprehensive yet robust and simple circularity measurement tool using production-consumption-waste management material flow analysis (PCW-MFA) to help companies assessing their circularity performance and setting CE target. To achieve this, production-consumption-waste management (PCW) model was used as a universal model to simulate materials imports and exports in production, consumption, and waste management stages, following with material flow calculation of both universal model and their subsequence subprocesses which can be different from one business to another. The MFA was calculated using STAN freeware published by TU Wien, Institute for Water Quality, Resource and Waste Management and the circularity index was then evaluated based on the modification of material circularity index (MCI) which was proposed by the Ellen MacArthur Foundation. For validation, macadamia production plant was assessed as an industrial case study. The results indicated that it is possibly used as a tool in the assessment of circularity performance. Moreover, it has high potential for companies to identify and track their circularity performance throughout life cycle stages not only on material layers but also cost and environmental benefits. Policy makers can also utilize it as a result-oriented monitoring and evaluation tool of CE policies.

3-1E: Consumer behavior

3-1E-1

Estimation of telework efficacy rate during COVID-19 Pandemic considering time-series changes in human behavior rule

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Large social events such as disasters and pandemics have changed our lifestyles and impacted the global environment. For example, in reaction to the COVID-19 Pandemic, work and consumption have been severely restricted, so greenhouse gas (GHG) emissions have decreased. This shows people's behavior is an important factor in creating sustainable societies.
Several studies simulated behavior changes due to large social events such as evacuation after an earthquake and migration due to regional economic decline. These studies assumed that rules of behavior were constant over time, but they can actually change in the long run due to emotional changes such as fatigue or become less responsive to the impact of the events.
Therefore, in this paper, a model for predicting the telework efficacy rate in Japan during the COVID-19 Pandemic was constructed as a case study for predicting long-term changes in people's behavior due to social events.
The behavior rules were described with motivation factors for telework including government actions such as a state-of-emergency declaration by using an agent-based model. The changes in the agents' behavior rules were expressed by changing the contribution of each motivation factor at different times. The telework efficacy rate in Japan was calculated by totaling the number of teleworker agents every month.
The estimation results with the model roughly reproduced the actual fluctuation in the telework efficacy rate. Furthermore, ways to increase telework penetration will be discussed in terms of characteristics of job type by comparing the estimation results and the real-world telework efficacy rate by using detailed attributes such as region or industry.

3-1E-2

Understanding public acceptance of energy harvesting technology from already existing radioactive waste

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Due to the limited supply of fossil energy sources and carbon neutrality challenges, practitioners have tried to find the best solutions for the current energy system by addressing various renewable energy sources such as solar, hydrogen fuel, biofuel, wind, etc. This study focuses on radioactive waste as a renewable innovative energy source. The idea of energy harvesting from already existing radioactive waste is not new, and at least, it has been mentioned inside the nuclear research community. However, the public's negative perception and low acceptance of radioactivity and related technology are barriers to realizing this idea. Thus this study aims to understand and break down public acceptance, attitudes, and perceptions of energy harvesting technology from existing radioactive waste. By performing an online survey and analyzing a representative sample of 1,000 Japanese residents, we examine if and how public perception of knowledge, risk, benefit, and trust level can explain the public acceptance of this new energy technology. Based on our findings, this article also provides implications and recommendations for gaining greater acceptance of energy harvesting technology from radioactive waste.

3-1E-3

Perceived air quality, socio-economic characteristics, and willingness to pay for improved air quality by installing new energy buses

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Electric vehicles are increasingly playing an important role in solving not only global warming but also air pollution problems. The Chinese government announced subsidies would be cut by 10% in 2021 and by 20% in 2022 for new energy vehicles to be used for public transport. Then citizens' support becomes important to further expand the use of new energy buses. In this paper, a contingent valuation method was used to analyze people's environmental awareness and willingness to pay for new energy buses in Rizhao City, Shandong Province, and this study took place March 2 to March 24, 2020. Answers were obtained from respondents and approximately 73.5% of the respondents would like to pay an extra fare to support the adoption of new energy buses. Most of the zero willingness to pay answers were due to protest reasons to the assumed conditions in the payment question. To better understand the relationship between people's socioeconomic characteristics and their willingness to pay for the new energy busses, a k-means clustering technique was applied, and three clusters were identified. We found that those who are satisfied with current air quality and those who believe that air pollution is improving will pay for better air quality. In contrast, those who believe that air quality is becoming poor refuse to pay for improved air quality. Based on the principle of altruistic behavior we also found that the willingness to pay is high among those who actively participate in environmental volunteerism. The results of the correlation analysis and the discussion of willingness to pay for new energy buses provide insightful results for cities introducing new energy buses.

3-1E-4

Feasibility study of Kawasaki city contributing to citizens' change of environmentally conscious behavior

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Fujitsu is implementing a number of initiatives to realize a sustainable society by utilizing technologies such as AI and HPC. As one of the initiatives, demonstration tests have been conducted since FY 2021 in Kawasaki City, which has been designated as a future city of SDGs, with the aim of making environmentally conscious actions widely known to citizens. The company examines measures that combine environmental points and uses an action modification app. The main elements of the application are, from a technical perspective, sensing of environmental behavior, providing a process for dynamic behavior change for each person, providing environmental points and recommendations, and from a business perspective, linking with businesses that provide environmental services. As a result, we conducted user interviews with a wide range of citizens and interviews with companies, and grasped the needs of behavior modification applications and environmental points. Specifically, we analyzed a questionnaire survey conducted at soccer stadiums, and found that many people were more interested in environmentally conscious behavior than expected, and that depending on the trigger, they would take environmentally conscious actions. We also examined approaches to encourage environmentally conscious behavior through sustainable events at retail stores. Specifically, it revealed a group of citizens who could change their behavior without financial motivation. Based on the knowledge obtained here, we will implement actions tailored to the citizens through the behavior modification application. In this presentation, we will report on the results of behavior change in Kawasaki citizens and the issues we have found in developing apps that promote behavior change. In the future, the government will aim to establish a regional model that can support both an increase in eco-friendly activities and economic sustainability. I hope that we can have many discussions with life-cycle-oriented experts in order to be even more useful to citizens.

3-2A: Impact assessment

3-2A-1

Spatially explicit characterization factors for impacts of nitrogen emissions on biodiversity

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The anthropogenic emissions and deposition of nitrogen affect terrestrial ecosystems through eutrophication and acidification, with potentially severe consequences for plant community diversity worldwide. In life cycle impact assessment (LCIA), characterization factors for nitrogen emissions are currently based on relative plant species richness loss as a biodiversity indicator. This indicator does not incorporate the impacts on populations, like alterations in species abundance. Mean species abundance (MSA) is a regularly

used metric in ecological assessments, which expresses the mean abundance of species in disturbed situations relative to their abundance in the pristine state. The MSA takes changes in inter- and intraspecies abundance into account, making it a suitable indicator for LCIA because it expands from just richness to richness and abundance.
Here, we establish novel characterization factors for nitrogen emissions by combining spatially explicit data on nitrogen emissions and deposition with a comprehensive database of nitrogen impacts on terrestrial plant communities. We use the impact database to establish stressor-response relationships for nitrogen, based on local biodiversity intactness expressed by the MSA metric, as a novel biodiversity indicator in LCIA. For comparison, we also quantify local relative species richness loss. We use the TM5-FASST model to quantify the atmospheric deposition of NOx and NH3 at a 1°x1° spatial resolution for each source region. Subsequently, we use the stressor-response curves to determine biodiversity loss due to nitrogen inputs in the soil. This enables us to determine spatially-specific characterization factors for air emissions. With this, we evaluate local biodiversity losses on a global scale. These insights will improve the impact assessment of nitrogen emissions on terrestrial biodiversity loss for use in life cycle assessment.

3-2A-2

Development of ecosystem service impact pathways and endpoints in LCA

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The Life Cycle Initiative, hosted by the UN Environment Programme (UNEP), has been working to build consensus on a broad range of impact category models and consolidate these models into a consistent impact model which includes both midpoint and endpoint results.
In the area of ecosystem services, 'The Global Guidance for Life Cycle Impact Assessment Indicators 2' (UNEP 2019) contains a chapter on soil quality impacts from land use (Grant et al. 2019) which recommends that changes in soil organic carbon and soil loss due to erosion be used as indicators of soil impact from land use. Both of these indicators have a strong link with ecosystem services, however they did not create a quantified link to an endpoint and are by no means the only measure of the available ecosystem services.
In the third iteration of the Global Life Cycle Impact Assessment Methods (GLAM) project, a task force was established to propose impact methods and endpoints for natural resources and ecosystem service impacts. This paper outlines the process for selecting these impact methods, the resulting recommendations for additional ecosystem service impact pathways, as well as an approach to consolidate these in a single endpoint or area of concern.
The five ecosystem services that were included are change in mechanical and physio-chemical filtration of soil, change in soil perviousness, and change in groundwater recharge, all of which lead to an increase in water quality and supply of potable water, as well as soil loss from water erosion and change in soil organic carbon (SOC).
The endpoint for the ecosystem services is based on the economic cost of the change in ecosystem service to society either through the value of the services lost and or the cost to recreate these services with alternative technologies.

3-2A-3

Dietary impacts on human health for food LCAs

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Dietary impacts on health are dominant risk factors impacts on human health as determined by the Global Burden of Disease (GBD) but have been paradoxically often disregarded in food LCAs, neglecting main use phase impacts. Building on the Health Nutrient Index (HENI) developed by Stylianou et Al. (2021) based on the 2016 GBD. the present work aims to update the HENI characterization factors for the latest 2019 GBD risk ratios and evaluate dishes and diets in US, Brazil and Europe.
For most risk factors, the dietary risk factors are a factor 1.25 to 1.9 higher in US than in Switzerland due to higher background mortality rates in the US, Brazil being in between the other two countries. Compared to the 2016 GBD, latest 2019 risk ratio have substantially increased the red meat impacts by a factor 5 and reduced the fish benefits. A combined intervention replacing half of the red and processed meat and if the sugar sweeten by fruit, vegetables and whole grain rice enables to reduce the Brazilian dietary carbon footprint by 50% and gain 20 minutes of healthy life per person per day. Combining food content in 15 dietary risk component with these dietary risk factors calculated for all 200 countries and region of the world is a powerful tool towards healthy and sustainable foods.

3-2A-4

Marine invasions in life cycle assessment: Towards a global impact assessment

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Invasive species pose great threats to biodiversity, yet their impacts in the marine environment are poorly understood and lack characterisation within life cycle impact assessment. Tools to holistically assess potential impacts from invasive species are needed to reach sustainable development goals (SDGs) 12 (responsible consumption and production) and 14 (life below water) especially. Invasions have usually been assessed more qualitatively than quantitatively, i.e. based on expert knowledge and arguments rather than data [2,3] . However, a quantitative effort to assess effects of marine invasions confirmed negative impacts from invasions [3]. We construct an effect factor indicating biodiversity impacts caused by introduction of non-native species. Our work continues with Molnar's data combined with data from the IUCN red list, OBIS, and others, comprised in a database called MarINvaders [4]. The proposed method is as follows: (i) We convert the IUCN threat level to a numeric probability of extinction for each threatened species. (ii) We create a probabilistic heat map indicating how much of the threat stems from invasions. (iii) The sum of species potentially lost due to invasions is divided by number species in each marine ecoregion which gives the potentially disappeared fraction (PDF) of species, (iv) which is then found per non-native introduced in every marine ecoregion. This novel effect factor can be used in LCA, is quantitative based on probabilistic modelling, and certainty develops along with database development.
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3-2A-5

Development of Thai weighting factors in LCIA using conjoint analysis

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Life Cycle Impact Assessment (LCIA) is one step of the Life Cycle Assessment (LCA) framework that aim to quantify various environmental impacts from inventory analysis result. Even though weighting is not the mandatory component of LCIA but this element of the country data has important. Measurement of the importance level is practicable by weighting the considered environmental damage. Therefore, this study aimed to develop Thai weighting factors (WFs) by taking the environmental damage into consideration for the context of Thailand. Four areas of environmental protection based on the Life-cycle Impact assessment Method based on Endpoint modeling (LIME) consisting of human health, social assets, biodiversity, and primary production were selected in the study. The WFs of these categories were quantified by using a conjoint analysis method. In the survey, random sampling was obtained from 400 samples (households) in each region of the country consist northern, central, southern, and northeastern. Statistical analysis based on this model can be examined to regard the variation among each environmental issue, with a significant statistically at the 1% level. The p-value for coefficients for each safeguard subject was less than 0.0001. The study can be obtained the dimensionless weighting factors. A relative comparison of importance among the four categories indicates that the WF of human health is the highest, followed by biodiversity and primary production, whereas the WF of social assets values is lower than other subjects. Precise WFs representing the environmental point of view of the national public is needed to conduct general LCA for Thai products. This value can be used to develop integration factors and can be analyzed uncertain factors in future LCA case studies.

3-2B: Diagnosis of current system (2)

3-2B-1

Towards sustainable nitrogen use: The launch of inter- and trans-disciplinary research

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Nitrogen is an indispensable resource of humanity that provides great benefits as fertilizer for food production and materials for industrial production. And recently, a new use of nitrogen as an energy source, fuel ammonia, is attracting attentions with respect to decarbonization because ammonia does not create carbon dioxide when combusted. However, the production and consumption of food, goods, and energy create a huge loss of reactive nitrogen (nitrogen compounds other than inert and harmless dinitrogen) to the environment that induces a variety of nitrogen pollution such as global warming, stratospheric ozone depletion, air pollution, water pollution, acidification, and eutrophication. The nitrogen pollution threatens human and ecosystem health. We need to address this severe tradeoff, the nitrogen issue, to achieve sustainable nitrogen use.
The present knowledge of the nitrogen issue leaves much to be elucidated, e.g., ecosystem responses to human-induced nitrogen input and removal, nitrogen flows within human society and to the environment for each reactive nitrogen species, and physical and

economic effects of policy, technology, and behavior on the nitrogen issue. To enable sustainable nitrogen use in the future, we have launched a new 6-year project in 2022 "Towards Sustainable Nitrogen Use Connecting Human Society and Nature" (Sustai-N-able) funded by the Research Institute for Humanity and Nature, Japan. The Sustai-N-able Project will tackle the nitrogen issue covering all human nitrogen uses as fertilizers, materials, and fuels considering their links between natural and human systems. We aim to produce a tool to assess the benefits and dangers of nitrogen use to support policy decision making that addresses the nitrogen issue. We share interdisciplinary and transdisciplinary knowledge of nitrogen with domestic and international stakeholders and also introduce practices of Future Design to guide them towards sustainable nitrogen use for humanity and nature.

3-2B-2

Post-consumer polyethylene terephthalate (PET) waste management in Thailand

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Single-use plastic is increasing rapidly used due to the new life style and the food packaging. The packaging is the highest industrial sector that generate the highest plastic waste. Thailand has a roadmap on plastic waste management and target 100% recycled plastic waste by applying the circular economy principle by 2030. This study aim to study and analyze post-consumer polyethylene terephthalate (PET) which is the highest recycling rate of post-consumer single use plastic in Thailand. The Material Flow Analysis (MFA) of PET in Thailand were developed using statistic data of plastic waste generation, collection and management in Thailand to analyze the plastic waste flow, hotspot, and recommendation for improvement. The main portion of plastic waste in Thailand were disposed by landfill, recycle, incineration, and energy recovery methods. There are some plastic waste lost from collection and mismanagement which can be contribute to the ocean plastic waste problem. The PET waste have the high mechanical recycling rate which mainly to the textile industry. The need of improvement should be on the separation and collection of plastic waste which can increase the recycling rate toward circular economy.

3-2B-3

Life-cycle environmental performance of sludge anaerobic digestion and land application under different management practices

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Even though anaerobic digestion followed by land application has been widely endorsed as a low-impact approach to sludge management, the influence that the operational conditions of digestion and the management practices of land application can have over the environmental performance of this strategy has been scarcely studied. In this scenario, the objective of this work was to assess the influence that 4 management practices can have over the environmental impacts of this approach: solids retention time during digestion, inclusion of a pre-treatment process, sludge application rate to soil, and the type of crop growth in the receiving soil. In order to do so, an attributional Life Cycle Assessment (LCA) was performed over a total of 16 scenarios, including 10 impact categories: climate change, fossil resource depletion, terrestrial acidification, ozone depletion, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, and human toxicity non-cancer effects. The inventories were built based on an integration of data from a full-scale facility located in the south-central region of Chile, laboratory assays, and the use of models for the estimation of emissions in agricultural activites (IPCC, SALCA, and others). Results showed that the environmental impacts are greatly influenced by the studied practices. Solids retention time and the inclusion of pre-treatment mainly influenced climate change, fossil resource depletion and terrestrial ecotoxicity potential, while sludge application rate influenced the eutrophication and toxicity categories. The type of crop in the receiving soil was a significant driver behind the differences observed in the human toxicity category, which showed the highest variation and relevance in the final weighted result. Based on the results, several recommendations are formulated to optimize the environmental performance of sludge valorization, and the relevance of using context specific data and quantify the fate of nutrients, metals and pollutants during LCA of sludge management is highlighted.

3-2B-4

Estimation of greenhouse gas emissions from wastewater treatment plants: A case study of Ulaanbaatar, Mongolia

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Ulaanbaatar city is the most populated administrative area in Mongolia. In the last decade, the city's population fact that such as the contamination of traffic jams, air pollution, solid waste, water pollution, in the capital are caused by the population overconcentration and an overload of community and government facilities. It adversely impacts the comfort of the living environment and has become a confining factor in human development and health, conditions of the livelihood. In addition to these reasons the greatest issue surrounding the wastewater treatment is greenhouse gas emissions during the treatment process. In Ulaanbaatar households generally, dispose of wastewater in two ways. Including transmission from a central sewage system to a WWTP or straight removal into the pit latrines. It causes severe living environmental, soil, and groundwater pollution problems. This study was estimated by using the IPCC's GHG inventory methodology the total emissions of GHGs from the WWTP, and Ger districts in Ulaanbaatar city. Households of Ger districts discharge their wastewater directly into pit latrines. Therefore, GHG emissions from the wastewater treatment process were predicted based on the master plan and development approaches for 2030 in Ulaanbaatar city. The results showed that 56.55 Gg CO2e GHG were emitted from the WWTP, a 22.7% increase compared to 2012 (12.84 Gg CO2e). Ger districts accounted for 13% of the total GHG emissions, while residential areas accounted for 87%. If the CWWTP would not be upgraded the total GHG emission will be emitted 25% more in 2030 than it currently does. If all households in Ulaanbaatar move into residential areas, GHG emissions are expected to increase by 55%. However, GHG emissions are projected to decline by 59% in 2030 even though residents in the Ger district moved into the residential area, while the CWWTP upgraded as well as the industrial wastewater was pretreated.

3-2B-5

Analysis of nitrogen flows in wastes in the urban environment of Tokyo

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Halving nitrogen waste by 2030 is the goal of the Colombo Declaration adopted by the United Nations Environment Programme (UNEP) in 2019. Since the 21st century, accelerated urbanization has made urban areas more severe nitrogen hotspots than rural areas. Tokyo, as a typical urbanized city with the highest population density in the world, has become a focus of research on nitrogen flows in solid wastes and wastewaters as well as nitrogen emissions into the environment. This study calculated nitrogen flows from 24 types of waste in the Tokyo metropolitan area from 2000 to 2018, and presented the nitrogen flows and the trend of waste nitrogen emissions in the Tokyo metropolitan area over the last 19 years. Our result was able to visualize the image of waste-related nitrogen flows and their patterns according to their magnitude in Tokyo. This study can provide a scientific basis for sustainable nitrogen management of urban wastes. Furthermore, the Asia-Pacific region has the highest urbanization growth rate in the world, waste-related nitrogen management in the Tokyo metropolitan area will be meaningful guidance for the developed countries and rapidly developing emerging economies in this area.

3-2C: Plastics

3-2C-1

Integrate the impact of marine plastic debris on carbon sequestration into life cycle impact assessment

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Oceans play a crucial role for achieving a sustainable future, and marine ecosystems provide important resources and services. However, marine ecosystems are increasingly confronted with stressors, such as plastic debris and invasive species, which affect many ecosystem services including food provision, recreational opportunities, and carbon sequestration. For a sustainable future we need to understand the relative importance of different human impacts affecting the marine ecosystems services (MES). For example, plastic debris can lead to growth inhibition of microalgae, which in turn could undermine the function of the oceans as one of the largest carbon sinks on Earth, and thus challenging our effort fighting against climate change.

Currently, one frequently used tool for addressing environmental impacts is life cycle assessment (LCA). Within the framework of life cycle impact assessment (LCIA), there has been a strong focus on terrestrial and aquatic ecosystems, though the impact category for ecosystem services is still under development. As a result, an operational impact assessment for MES is missing. We strive to narrow this gap by developing a characterization factor (CF) for marine ecosystem's carbon sequestration in response to microplastic, which is quantified in monetary value of USD.

To calculate the CFs, growth inhibition rate of microalgae exposed to different microplastic concentration are collected, which is used in combination with climate zone division and occurrence records of algae to construct 5 spatial-differentiated species sensitivity

distributions (SSDs). SSDs are coupled with algae primary production of at different depth to calculate carbon sequestration loss, which is then converted to monetary values by mutiplying the cost of carbon capture and storage (CCS). Our results present the first global and spatially-differentiated CFs for quantifying anthropogenic impacts on one ecosystem service. This provides a valuable starting point for stakeholders and LCA practitioners to account for marine ecosystem service impacts in the future.

3-2C-2

Achievable circularity of plastic material flows and related environmental benefits

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With the ongoing efforts to reduce CO2 emissions, the share of the carbon budget constituted by plastics is estimated to possibly be as high as 15% in 2050. The plastics' contribution to climate change is mainly attributable to their production and end-of-life incineration, both of which can be avoided if plastics are increasingly recycled.
Therefore, we investigate how to increase plastic recycling using material flow analysis and life cycle assessment (LCA), considering all life cycle stages of 11 plastic types in 69 product groups in Switzerland. One system change modelled is increased collection. This might, however, without other measures taken lead to secondary plastics that can only to 58–90% be utilized in product manufacturing [1]. Therefore, we assess additional system changes compared to today applying life cycle thinking. For example, we model the implementation of marker-based waste sorting, which requires collaboration of stakeholders across the value chain. This change leads to secondary plastics with properties so to be utilizable in additional products compared to today. Another technology that may lead to additional amounts of secondary plastics utilizable in product manufacturing is chemical recycling. We compare such processes to other possible treatments for those plastics that pose challenges for mechanical recycling.
We assess, on one hand, the material circularity by using the true recycling rate (TRR), an indicator that we have developed and that is based on the secondary plastics actually applied in product manufacturing [1]. On the other hand, we assess the contribution towards carbon neutrality of different system designs. Based on the results, the highest increase of the TRR can be achieved with system designs involving improved sorting. The highest TRR achievable by only mechanical recycling, implementing increased collection, improved sorting and aligned product design with lower multimaterial shares, lies only at 30%.
[1] 10.1016/j.wasman.2022.01.002

3-2C-3

Recycled plastic packaging from the Dutch food sector pollutes Asian oceans

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Plastic food packaging is key to minimize food waste due to its beneficial properties and cost-effectiveness. Despite this, plastic food packaging rapidly generates plastic waste and if mismanaged can be leaked to the environment causing negative consequences for ecosystems and humans. The extent to which food item packaging contributes to global plastic leakage, however, remains unknown. In this study, we quantified the plastic waste potentially leaked to the marine environment due to food consumption in the Netherlands by developing a novel model that tracks the fate of the plastic packaging used in the food sector. By combining food consumption patterns, food waste estimates, and plastic packaging life cycle inventory data, we developed an estimate for the plastic packaging intensity of the Dutch diet. We then mapped the fate of the plastic food packaging waste generated in the Netherlands according to the Dutch plastic waste management patterns, including litter and global plastic waste trade. We estimate that 6.4 kt out of a total of 294 kt plastic food packaging used in the Netherlands every year is leaked to the marine environment. Of this leakage, 75% results from the export of plastic waste to Asian countries, 3% to all other countries, and 22% is due to domestic littering. We conclude that despite being a high-income nation with an efficient domestic post-consumer plastic packaging waste network reporting a 78% recycle rate, Dutch post-consumer plastic food packaging waste is leaked to the marine environment at a globally average rate, raising questions about plastic recycle rate metrics and Dutch/EU plastic waste export policies.

3-2C-4

Designing the future resource circulation system of plastics in line with changes in the structure of the arterial industries towards decarbonization

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In 2021, the Law for Promotion of Resource Circulation of Plastics was enacted, and it explicitly promotes efforts related to the entire life cycle of plastic products. This law aims at achieving recycling/recovery goals which were laid out in the Resource Circulation Strategy of Plastic in 2019. It specifies the intention for a circular economy to achieve carbon neutrality in 2050. The policy of

decarbonization is introduced in most industries, but not all are necessarily compatible.
In this study, we aimed to design the future resource circulation system of plastics consider the structural changes in the arterial industries that have potentials to accept waste plastics as raw material and energy sources, including the steel industry, inorganic chemical industry, etc. First, we projected the future capacity of recycling/recovery of waste plastics in those industries, particularly focusing on the introduction of technologies and process transitions that can affect the capacity of waste plastic utilization. Second, changes in the demand for plastics and the generation of waste plastics were also projected. These projections were analyzed under the common scenarios, including [D] decarbonization, [P] aggressive waste plastic use, and [U] business-as-usual scenarios. Under each of the scenarios, the material flow of waste plastics between waste source sectors and recycling/recovery processes that would maximize the amount of GHG emission reduction or the recycling rate of plastics was specified using linear programming. Differences and relationships between the results and the factors that affect the results are clarified depending on the subjects evaluated, and recommendations are made for designing more effective resource circulating system. Energy recovery in the cement industry played a major role for maximizing the GHG emission reduction under the scenarios [D] and [P], whereas waste plastics need to be allocated to various recycling processes including material recycling, gasification, and blast furnace/coke oven feedstock recycling.

3-2C-5

Integrated assessment of environmental, economic, and social impacts of waste plastic recycling in Japan

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Since China's ban on waste plastic imports in 2017, there has been a growing need for promotion of domestic treatment and recycling worldwide, particularly in Japan. Export of waste plastic or plastic scrap from Japan was halved during the period 2015-2020, from 1.61 Tg to 0.821 Tg. Considering this background, in this study, we apply input-output analysis for integrated assessment of Japanese waste plastic recycling scenarios, wherein 1.61 Tg of waste plastic is not exported but treated or recycled in Japan. The base-case scenario describes incineration without energy recovery and landfill. The other scenarios include recycling in the 'Pig iron' sector via coke oven chemical feedstock conversion, 'Petroleum products' sector via liquefaction, 'Chemical fiber' sector via mechanical recycling, 'Plastic products' sector via mechanical recycling, and 'In-house power generation' sector with energy recovery via RPF (refuse paper and plastic fuel) conversion. When the recycling sector cannot accept a portion of waste plastic due to capacity limitations, that portion is incinerated without energy recovery or landfilled. For each scenario, we quantified the environmental, economic, and social indicators (carbon dioxide emissions, income, employment, and total import). These indicators are used for integrated assessments of the scenarios. The assessment results show that neither the 'Petroleum products' nor 'Chemical fiber' sectors can accept all the waste plastic due to capacity limitations. The 'Plastic products' sector performs well considering economic (increasing income) and social perspectives (increasing employment and decreasing the dependence on foreign resources), while the 'Pig iron' sector achieves the least carbon dioxide emissions among the recycling sectors fulfilling certain economic and social conditions. The results of this study exemplify the usefulness of input-output analysis for integrated assessment of recycling scenarios without calculating single aggregated indicators.

3-2D: Circularity assessment

3-2D-1

Resource efficiency account with considering the quality of circulated material

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Developing the evaluation index of circularity and resource efficiency is vital to enhance stakeholders' efforts to promote the circular economy. Creation, retention, and regeneration of value of resources are critical to increase the resource efficiency of the economy, and thus, the index should take the circulation mass and circulation quality into account. The authors propose a new index REA (Resource Efficiency Account). The index consists of two sub-indices, MUE (Material Utilization Efficiency), and "a-circularity." The MUE represents the material use efficiency and reflects the longevity and occupation in an evaluator-defined term that includes several life cycles. It is calculated by the occupied functioning ratio for a subjected service per the sum of the value of consistent material of physical equipment for service. A-circularity is the distance from the entire circular life cycle (multi cycles in a term), evaluated by the requisition of the resource value from nature and the dissipation of the value by human action. The communization stage is introduced as the interface among various life cycles. For instance, raw material for recycling is put on the market with material values and picked up by another life cycle in the communization stage. Some values are dissipated in communization because of impurity. On the other hand, some dissipated values are recovered in the industrial regeneration process, such as sorting into another life cycle that accepts it. A-circularity is calculated by the sum of the requested value and dissipated value divided by the

value of consistent material. Though TMR (Total Material Requirement) is a robust evaluation measure, various possibilities should be considered beforehand. The division of MUE obtains REA by a-circularity while REA evaluates efforts of enabling circular systems, such as eco-design, recycling, lean production, servicing, quality management.

3-2D-2

Analysis of model selection for electrical and electronic equipment based on lifespan and breakeven point

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In recent years, the demand for Electrical and Electronic Equipment (EEE) has been globally growing. A significant increase in energy demand due to the use of EEE is a major concern. To mitigate the energy consumption, attentions have been paid to improving the energy efficiency of EEE. However, it should be noted that the improvement of energy efficiency requires new resource uses, worsening the environmental impacts at the production stage. Therefore, it is necessary to determine whether energy-efficient models can compensate for the increased resource and environmental impact at the production stage before the EEE reaches the end of its life.
Thus, the research question of this study is “how do increasing energy efficiency in appliances affect the breakeven point (BEP) for different EEE models of energy efficiency?” Taking air conditioners (ACs) in Japan as a case study of EEEs, the resource use and greenhouse gas emissions of low-efficiency and high-efficiency models were firstly analyzed considering the different energy mix, and then the advantages of model selection from the perspective of product lifespan and BEP were evaluated.
It was found that the 2019 energy mix showed an advantage for high-efficiency models, while the 2050 energy mix showed an advantage for consumer models. This is because the BEP increases as the share of renewable energy, which has a low intensity of greenhouse gas emissions and resource use, increases.
Based on the findings, depending on the changes in the energy mix, high-efficiency appliances may not always be superior to low-efficiency appliances from the perspective of breakeven point and lifespan. This indicates that, in the future, it will be required to provide advice on the selection of appliances according to the user's attributes based on the BEP.

3-2D-3

Ecodesign of EEE : optimizing circularity by integrating recycled plastics from WEEE

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Nowadays, electrical and electronic equipment (EEE) become more and more complex. Indeed, their components often incorporate critical materials, and are assembled in a very intricate way, making materials in EEEs difficult to separate and recover.
This is notably the case for plastics: unseparated waste of electric and electronic equipment (WEEE) enter the recycling chain, plastics remain usually blended with metals, rare earths elements, alloys, glass, or minerals after shredding. As a result in Europe, only 2% of recycled plastics are dedicated to new EEEs. This is a consequence of two main issues.
- Firstly, the end-of-life treatment chains are not adapted to the products, materials or substances they encounter: plastics are often put aside while other more economically viable materials are recycled. Moreover, there is a lack of design for end-of-life in the field of EEE: plastic parts in these products are not sufficiently designed to be easily dismantled and recycled, which leads to material loss during the end-of-life treatment.
- The second issue is the lack of communication between the recycling companies and the plastics users. Indeed, studies show that the main concerns of the EEE producers are the lack of knowledge about the available recycled resins, missing data about the quality of recycled plastics, and stock supply issues.
All these concerns lead to the construction of a technical sheet for recycled plastics that acts as a communication tool between plastics recyclers and plastics users. This tool aims to list of all information needed to assess the quality of any given recycled plastic batch, but it can also be used as a database when filled in by multiple recyclers for different references. Made available to plastic users, this database would allow to search for a specific property in a batch of recycled plastics, thus facilitating the choice of the optimal one.

3-2D-4

Evaluation framework of environmental policies considering its effects on product lifetime

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In a transition to a circular economy, product lifetime extension is one of the main strategies. Along with this, environmental impacts of product lifetime change have been paid attention and previous studies have analyzed the impacts based on product flow analysis with engineering product lifetime models such as Weibull distribution. On the other hand, we cannot directly change product lifetime and it is usually aimed by implementing policies. Therefore, it is more important to analyze environmental impacts of policies related with product lifetime considering effects of policy implementations on product lifetime. Although some previous studies have proposed such frameworks, they focused on the effects only on a part of product lifetime and could not consider the effects on an entire product lifetime.
Motivated to the above research background, this study tries to develop a framework for analyzing environmental impacts of policies to include effects of policy implementations on an entire product lifetime. We use a dynamic discrete choice model (DDCM) which is an econometric model to quantitatively analyze a relationship between consumer's product replacement decisions and factors affecting the decisions. We applied a DDCM as a product lifetime model in conventional product flow analysis to include effects of policy implementations on product lifetime in environmental analyses.
We focused on GHG emissions derived from production and consumption of air conditioners. As case studies, we analyzed effects of energy efficiency improvement policies and product lifetime extension policies in a circular economy on the GHG emissions. The results showed that both policies can reduce the GHG emissions even if environmental impacts of product lifetime change by their policy implementations are considered. The proposed framework can help us to discuss environmental policies related with product lifetime and we believe that this study will be beneficial for better policy discussions of mitigating environmental impacts.

3-2E: Sustainability assessment

3-2E-1

Even LCA-based absolute environmental sustainability assessment is relative

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Over the past years, an increasing number of scholarly papers have used the planetary boundaries (PBs) within life cycle assessment (LCA) to determine if the life cycle impacts of a product system fit within those PBs and thereby establish the absolute sustainability of the product system. This type of LCA has been coined as LCA-based Absolute Environmental Sustainability Assessment (AESA). 'Absolute' thereby refers to methods enabling the comparison of environmental impacts of products, companies, nations, etc, with an assigned share of environmental carrying capacity for various impact categories. A recent review of LCA-based AESA methods, and their applications characterized 47 studies "according to their intended application, impact categories, basis of carrying capacity estimates, spatial differentiation of environmental model and principles for assigning carrying capacity". However, the review and the majority of studies reviewed did not, or only to a limited extent, discuss potential temporal issues of assigning carrying capacity to product systems. Several of the carrying capacity estimates have a time dimension while LCA results lack a time dimension. In this presentation we show that assigning planetary boundaries (PBs) to product systems is only technically possible when adopting several fundamental though unrealistic assumptions and conclude that even product LCA-based AESA is relative. This should not withhold scholars from developing approaches applying the PBs in LCA, but it should prevent them from claiming and using the term 'absolute'.

3-2E-2

Introducing a multi-level approach for operationalising life cycle sustainability assessment

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A coherent sustainability assessment of products across their life cycle is increasingly demanded in the EU market, with effects going beyond the EU borders. UNEP/SETAC proposed a framework for a comprehensive life cycle sustainability assessment (LCSA), combining environmental life cycle assessment, social life cycle assessment and life cycle costing. However, conducting an LCSA requires interdisciplinary knowledge and access to distinct methods, tools and information. Thus, entry-level barriers exist that can hamper the operationalisation of LCSA.
The EU H2020 project ORIENTING found that developing a flexible approach to facilitate the consistent implementation of product LCSA for users with different levels of expertise or resources (e.g., SMEs vs. multinationals) is a critical need to operationalise LCSA. An approach to LCSA is presented that starts with simplified considerations, before progressing towards more in-depth studies, addressing different types of purposes and audiences.
The initial step of the approach consists of identifying the intended LCSA application, which can be internal (e.g., product design

improvement, life cycle management) and/or external (e.g., communication to customers). This is followed by an evaluation of related needs, available resources and level of experience. An entry level allows users to familiarise themselves with LCSA, relevant impact categories, potential impact improvement strategies (through qualitative approaches) and interpretation of results. This experience facilitates progressing towards more comprehensive, quantitative LCSA studies. Intermediate and advanced levels involve increased demands in terms of data (quality and type), modelling of life cycle impacts, interpretation and reporting requirements.
The approach is expected to ease the spread of LCSA, avoiding that only front-runners with sufficient resources can engage in LCSA studies. However, independently from application and level of complexity, it is fundamental to ensure critical interpretation and transparency of LCSA information, and fulfil requirements associated with intended purposes (e.g., standardised rules are needed for comparative sustainability claims).

3-2E-3

Global commons stewardship index: Safeguarding the shared resources of the planet

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Sustainable management of the Global Commons in line with the Planetary Boundaries framework requires data and metrics to guide better poli☒es. The 2021 Global Commons Stewardship (GCS) Index aims to inform policymaking to reduce negative impacts on the Global Commons and to accelerate implementation of the Sustainable Development Goals. It provides scores for 99 countries and the European Union. Five major principles guide the design of the GCS Index.
First, the Index integrates six impact categories: Aerosols, Greenhouse Gas Emissions, Terrestrial Biodiversity Loss, Marine Biodiversity Loss, Nutrient Cycle disruptions, and Water Cycle disruptions. This year's edition includes 33 indicators using data from official sources and scientific research.
Second, the Index tracks impacts within territorial borders and transboundary impacts, or spillovers embodied in traded goods and services.
Third, the Index estimates the distance to pre-defined sustainability thresholds to quantify and compare priorities within and across countries.
Fourth, the Index focuses on outcome-based measures of environmental impacts at the country level, leaving out policies, input measures, or measures of access to resources.
Fifth, the Index relies on data that are fresh, high-quality, and can be updated regularly.
This year's GCS Index generates five key findings:
1) Major transformations are urgently needed in all countries to address negative impacts on the Global Commons generated by unsustainable production and consumption.
2) Rich countries generate the largest share of the international spillovers that need to be addressed.
3) Ambitious actions to protect and restore the Global Commons domestically and internationally must go hand-in-hand with efforts to improve living standards everywhere.
4) G20 countries bear a special responsibility in reforming the governance of the Global Commons.
5) Persistent data gaps and limitations should be addressed for more real-time and forward-looking monitoring of countries' impacts on the Global Commons.

3-2E-4

Novel SLCA method to overview more-good and less-bad social impacts

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Social life cycle assessment (SLCA) is a tool to assess the social impacts of a product systemically. A standard framework for SLCA is still under discussion. While most SLCA methods highlight negative impacts and reductions (less-bad impacts), less attention has been paid to positive social impacts and their increments (more-good impacts). Positive social impacts highlight chances for improving human well-being and present a complete picture of a product's total social impact. Though few studies attempted to highlight the positive aspects of products using different methods, the current condition of those products could only be highlighted therein. Hence, fluctuations of positive social impacts after the insertion of a decision could not be overviewed with those methods. In addition, none of the previous studies reports a straightforward methodology to distinguish between the positive and negative impacts of a product. Referring to both is required for appropriate decision-making using SLCA. Therefore, a novel SLCA methodology is proposed to address the above lacunas. We demonstrated the performance of the new SLCA method by performing a case study on lightweight materials produced in Japan for vehicles. The positive aspects of vehicle light-weighting could be

identified as Aluminum- and CFRP-substituted ICEVs, resulting in more-good social impacts. However, only less-bad impacts could be observed in the overseas supply chain due to the lack of social data. This inability could be a notable drawback in the proposed method and need to be addressed by future research.

3-2E-5

Linking the UN sustainable development goals to product-level impact information

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While the UN Sustainable Development Goals (SDGs) prove to be a relevant compass for governments, they are less relevant for businesses. This was the starting point for the two approaches that link LCA and the Sustainable Development Goals (SDGs), developed with support from the UNEP Life Cycle Initiative and a number of companies. After three years, the main structure of the approaches, and all 17 of the LCA-to-SDG linking documents are now finalized, and have been tested in case studies with industry partners. The final methodology and most important learnings about the links between LCA and the SDGs will form the focus of the presentation.
The methodology builds upon the well-established basis of the LCA approach: goal and scope, inventory analysis, impact assessment and interpretation. Links between environmental and social LCA impact categories to the SDGs are established on a target level. Having linked all 17 SDGs with LCA provided some interesting conclusions. The project pointed out a number of specific social and environmental LCA categories that seem crucial for the overall achievement of the SDGs, since many links were identified. Next to that, a number of SDGs have only a few links with LCA.
The method was applied to the specific products of our industry partners in three case studies In the goal and scope phase, companies selected the SDGs they want to analyze. This allowed them to understand how they contribute to that goal, to monitor and increase their positive contribution over time, and to communicate about their contribution. On the one hand, the case studies helped to address shortfalls and learn from feedback to make further improvements. On the other hand, this exercise provided the companies with relevant insights about their SDG contribution on product level.

3-2F: Policy and supporting science

3-2F-1

What countries induce the world asbestos flow? : A multi-regional input-output approach

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Asbestos is a fine fibrous mineral that has been used extensively in different industries because it has excellent properties as an industrial raw material. However, long-term exposure to high concentrations of asbestos has been shown to have serious health risks. Occupational asbestos exposure caused approximately 5.68 million deaths from 1990 to 2019, and approximately 239,333 people die annually due to asbestos exposure. Although the use and mining of asbestos has been banned in most advanced countries, many developing and semi-developed countries continue to mine and use asbestos in products and building materials, and mineral asbestos and asbestos-containing products are also exported to other countries. In these countries, asbestos use has caused serious health risks and social issues. In this study, we extended the OECD Inter-Country Input-Output Tables for 2014 with data for mineral asbestos production in the main asbestos mining countries of Russia, China, Kazakhstan, and Brazil. Using the compiled multi-regional input-output table, we clarified that the asbestos mining countries China, Russia, and Brazil induced 515,923, 510,579, and 94,417 tonnes of mineral asbestos per annum, respectively. Countries with well-developed industrial sectors, such as India, USA, Japan, Germany, UK, Indonesia, and Vietnam also induced asbestos mining, and accounted for 118,974, 106,153, 94,417, 51,393, 39,322, 22,309, 14,120, and 8,373 tonnes per annum, respectively. Numerous countries induce less than 2% each of the annual total mineral asbestos production. The findings showed that countries that have already banned the use, production, export and mining of asbestos and asbestos-containing products domestically, also induce asbestos mining. To be effective, measures for restricting asbestos utilisation around the world require not only efforts by the asbestos producing and using countries that are exposed to asbestos-related health risks, but efforts need to be adopted by all countries around the world.

3-2F-2

Quantification of the material flow from the modal shift of motorcycle electrification under climate change adaption policy in Taiwan

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Motorcycle is a major means of transportation in many Asian economies, including Taiwan. Modal shift into electric motorcycle is a

potential solution to pollution problems, but corresponding resource requirement in motorcycle production and End-of-Life (EoL) motorcycle generation cannot be neglected. This work presents a dynamic material flow analysis of modal- related resources from motorcycles under the Climate Change Adaption Policy in Taiwan in 2021-2050. Our result showed that electric motorcycle ownership ratio will rise to 44% in 2050 under the policy, resulting in a 48% reduction of CO2 emission comparing to 2021. However, due to the different material composition in conventional and electric motorcycles, the material stock of copper and aluminium will increase while iron and plastic decreases. A more significant change in material input and output is observed due to the sharp rise in the electric motorcycle numbers. This work presents essential primary information for the estimation of the material flow related to motorcycle and it can be utilized to analyse the resource consumption and recycling potential in Asian countries. The system developed in this work can be applied to predict future waste flows in detail, which is important for planning purposes and policy shaping in the recycling sector.

3-2F-3

The role of the distance-to-target weighting method in life cycle assessment: A case study of membrane capacitive deionization (MCDI)

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This study aims to develop a set of weighting factors (WFs) by the distance-to-target (DTT) method to improve the LCA results of an emerging water treatment technology of MCDI. The DTT method considered the world normalization references (NR) between 1990, 1995 and 2000 in the CML-IA method, with WFs set as WF90-00, WF90-95 and WF95-00. Quantification of the impacts were conducted using the functional unit of production of desalinated water of 1 m3. Relatively lower overall impacts were observed after applying different WFs sets, mainly due to their decreased values for most of the impact categories. In the WF90-00 and WF95-00 sets, the impact of terrestrial ecotoxicity (TEP) had the highest relative importance, contributing significant changes in the overall impact results up to 10 times greater (from 0.05% to 0.68%). The impacts of human toxicity (HTP), abiotic depletion (ADP, fossil fuels) and global warming (GWP), on the other hand, showed little change in the results. In the WF90-95 set, the impact of ADP had the highest importance, while the impact of ozone layer depletion (ODP) had the lowest. Our results also revealed that the overall impact results under different renewable energy sources were less affected by the WFs sets.

3-2F-4

LCA implementation in policy: National adoption of life cycle assessment in Indonesia

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Since the announcement that LCA will be included as one of the indicators in the national environmental performance rating, known as PROPER, in 2018, LCA implementation and adoption in Indonesia have increased significantly. Companies started to conduct LCA and slowly implement it to make strategic decisions. Early in 2021, the Ministry of Environment and Forestry (MOEF) announced the regulation on environmental performance rating that integrates LCA into the rating system. This regulation is a breakthrough from Indonesia as the first country in the world that uses Life cycle assessment to quantify environmental impacts. This regulation shows a strong commitment from the Government of Indonesia to combat climate change through collaborative efforts from the government and private sectors.
With this new regulation, LCA is encouraged to be integrated into the company policy, governance, technical capacity requirements, strategic planning, inventory database preparation, environmental labeling, and quantitative impact-based environmental performance, especially for the green and gold rated companies. This national adoption has opened up new opportunities for companies to pursue sustainable activities, utilize LCA results as a quantitative metric for sustainability, set targets, and stay competitive in the global market.
This paper will address the consequential impact of the adoption of LCA in the national policy to the broader scope. In the first year of its implementation, more than 280 companies across over 40 sectors have initiated to conduct LCA.

3-3B: Urban system

3-3B-1

Floating urban development for sustainable coastal communities

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Floating urban development can alleviate the pressure on coastal areas by creating much-needed space with a relatively small environmental impact. This interdisciplinary study explores the alternative of urban expansion to the adjacent marine environment of coastal cities, focusing on floating residential dwellings. The research combines ocean engineering, urbanism, and industrial ecology to examine the hypothesis that floating manmade structures could potentially provide additional useable space at sea. The main technological challenge refers to the ability of the floating structures to withstand the incoming waves, while maintaining the allowable comfort margins for residential buildings in operational conditions; and to maintain the structural integrity during extreme events. In addition, little is currently known about the spatial layout and urban design requirements for a floating development offshore, and what are the actual ecological consequences, compared to the available alternatives on land. To date, there are no comprehensive Material Flow Analyses (MFA) or Life Cycle Assessments (LCA) for floating urban developments, mainly due to the lack of an integrated knowledge that encompass all the required stake holders. The technological aspects of this research are based on physical and numerical studies currently conducted in the Ship Hydromechanics Laboratory at Delft University of Technology. Then, a spatial planning approach is created for this unique domain using urban planning and urbanism strategies, to examine the interaction of the offshore development with the existing coastal community. Finally, scenario-based macro-scale MFA and LCA are used to assess material flows and environmental impacts of large-scale future implementation. Together, these approaches inform and navigate amongst the various sustainable design possibilities, tradeoffs, and maximum potentials of floating urban development. The purpose is to cultivate and to provide tools to activate the alternative of sea and ocean space utilization in sustainable and responsible ways.

3-3B-2

Estimation of life cycle CO2 emission and analysis of factors associated with medium-capacity passenger transport systems

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CO2 emissions from the transport sector in Japan account for approximately 20% of total emissions. Shift to public transport is one of the methods for reducing CO2 emission. Furthermore, medium-capacity passenger transport systems, such as LRT and BRT, have been introduced. However, CO2 emissions from each transport mode vary due to the differences in the region, energy resources, and vehicle properties.
The life cycle of transport systems is divided into four phases: 1) manufacturing of vehicles, 2) manufacturing of infrastructures, 3) operation of vehicles, and 4) operation of infrastructures. We estimated the medium-capacity passenger transport systems' life cycle (LC)-CO2 emissions based on these four stages. Moreover, we analyzed the influence of different factors, such as CO2 coefficient of electricity, average temperature, route gradient, power regeneration function, and so forth, on LC-CO2 emissions of medium-capacity passenger transport systems.
As a result, the study shows that CO2 emissions increase during operating phases of vehicles and infrastructures is proportional to the demand volume increase. The difference in regional traits is expected to reduce CO2 emissions from medium-capacity passenger transport systems. Also, the extent of impact from such elements differs among various transport systems. Some factors, such as power regeneration function and CO2 coefficient of electricity were found to have a non-negligible effect of up to 20~30% on the CO2 emissions of the medium-capacity passenger transport systems. Additionally, the findings show that constant-speed operation is more effective in reducing CO2 on steep gradient sections. These results suggest the importance of impact analysis of regional and vehicle characteristics in the various phases of the transport system life cycle. We also examined the construction of a simplified CO2 emissions estimation methodology as a tool designed for operators and municipalities.

3-3B-3

Quantifying greenhouse gases emission from buildings and vehicles in redeveloped areas under the transit-oriented development strategy: A case study in Taipei city, Taiwan

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In urban, excessive private vehicles cause traffic congestion, air quality deterioration, and greenhouse gases (GHGs) emission that makes transport become a waste of economy and energy. Transit-oriented development (TOD) is one of the adaptions which is the creation of compact, walkable, pedestrian-oriented, mixed-use communities centered around public transit systems. Otherwise, TOD is the advised strategy included in the Comparative study on Urban Transport and the Environment matrix by the World Conference on Transport Research Society.
The Taipei City Government has delineated the areas applicable for development permits around the 33 selected mass rapid transit (MRT) stations in 2018, to improve urban development toward TOD.

Many past studies have shown that the environmental benefit of TOD is a reduction of GHGs emissions of person-kilometers of travel. However, few studies have investigated the environmental impacts of land-use intensity changes and integrated travel behavior and land-use intensity.
This study focused on the extent of GHGs resulting in redeveloped areas from changes in land-use intensity and the shifting of private vehicles to public transportation. We utilized the building life cycle assessment and traffic-related GHGs emissions calculation method by IPCC. Six of 33 selected MRT stations along the transport corridor from the MRT Beitou Station to the MRT Taipei Station were study cases. Each station scoped a 500 m service area as a studied area. This study aims to compare the trend of energy consumption and GHGs emission from vehicles and the GHGs emission of building life cycle of TOD under 3 land-use intensity scenarios.
In Scenario 3 (rebuilding over 30 years old of buildings), all areas show emission reduction, with the highest in the MRT Shipai Station. As the total floor area of buildings increases, life-cycle CO2 emissions will be dominated by emissions from redeveloped buildings during the use phase, accounting for about 60%.

3-3B-4

Toward Sustainability: Comparative life cycle assessment framework of green road pavement using industrial by-product as alternative materials

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Roadway Infrastructures are impressive targets for effective Sustainable Development Goals (SDG) and construction initiative. Frequently, they involve notable amounts of financial resources also use up remarkable extent of materials and energy which leads to waste and adverse effects on the environment and cause social disturbance. This is necessary to accommodate growing transport demands, while ensuring that traffic density and condition of road infrastructures remain at desirable levels, and that the road network is adaptable, automated, and resilient. Failure to meet road infrastructure investment needs, disregard for sustainability concepts, could be costly in terms of wasted time, consumption of non-renewable resources, and growing environmental problems, with all the consequences it has for living standards, also it can even cause a constant and irreclaimable sectional loss for this notable asset. Therefore, road construction industry needs to be evaluated and Life Cycle Assessment (LCA) as comprehensive recognized framework, can be used for adequately evaluate the resource use and environmental effects.
Method
Life Cycle Assessment (LCA) (ISO 1404-44) is carried out for road pavement with various use scenarios of Crumb Rubber (CR) deriving from the End-of-Life Tires (ELTs) and Electric Arc Furnace (EAF) slag from steelmaking as waste/ by-products materials in road pavement construction layers in comparison to conventional road component. Firstly, both of scenarios were implemented separately and then simultaneous use of EAF and CR was applied in road pavement during all stages of the LCA, from the raw material extraction and processing(cradle) through the acquisition manufacturing, construction and use stage until the end-of-life stage(grave).
Result
Preliminary results obtained from the LCA analysis indicated that placing CR and EAF slag as secondary by-product material consumption in road pavement can lead to significant benefits in environmental impacts. The results show remarkable contribution to the reduction of Cumulative Energy Demand (CED) and Global Warming Potential (GWP).

3-3C: Material and waste flow

3-3C-1

Identifying flow of aluminum alloy to aluminum alloy recycling through end-use products using matrix optimization

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Aluminum is the second largest produced metal, and its consumption has increased in recent years due to its useful properties. Environmental impact and primary resource usage associated with the aluminum production process can be reduced by recycling; however, the current recycling system is regarded as cascade recycling due to using various types of alloy in the same product and insufficient separation of them. For promoting closed-loop recycling of aluminum alloys, it is required to identify the recycling flow of aluminum with consideration for alloy type and its alloying elements. Previous studies have revealed the amount of scrap generation and alloying elements associated with it; however, they have not distinguished the recycling flows of scrap to secondary alloy production processes. This study estimated the flow of aluminum alloy to aluminum alloy recycling through end-use products. To identify the supply-demand matrices from aluminum alloys to end-use products and from scrap types to secondary alloy production processes, we used RAS method-based technique with consideration for confirmed flow information. A dynamic material flow analysis

was conducted to calculate the amount of scrap generation from each end-use product. From these results, the flow from primary aluminum alloys to secondary alloy through end-use product were identified. Beverage cans, sashes, other interior and exterior of buildings, and printing plates were recycled to wrought alloys. A difference between products recycled for wrought alloys and those for diecast and casting alloys is the variety of alloys used in each end-use product. Because automobiles and other end-use products consume various types of wrought, diecast, and casting alloys, scrap from these products exceeds the tolerance of alloying elements for wrought alloy production. For the closed-loop recycling of wrought alloys, separation of alloy types and avoiding contaminants are required.

3-3C-2

Systematic synthesis of mixed waste plastic sorting scenarios

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Towards carbon neutrality, end-of-life (EoL) plastics must be thoroughly exploited as a valuable carbon source. Material recycling (MR), in which mixed waste plastic is recycled as resin, and chemical recycling (CR), in which mixed waste plastic is converted into chemical raw materials, can retain the carbon within the society, while energy recovery (ER), dissipates the carbon into the atmosphere through combustion. Currently, purity of MR feed must be high and the properties of recycled products by CR vary depending on the composition, though CR can accept a wide range of compositions. These constraints hinder the application of MR and CR for container and packaging plastics discharged from general households in Japan. If the recent development of sorting technology enhances the ratio of EoL plastics sent for MR and CR, at most ca. half of carbon in petrochemical products can potentially circulate. In this study, we evaluated the effect of changing the recovery rate and technical requirements on recycling for a case study, from the perspective of greenhouse gas (GHG) emission. For treatment of 11,368 tons of mixed plastic containers and packaging consisting five-type resins (PE, PP, PS, PET, and PVC), assuming near-infrared radiation sorting targeting any one of the five resins together with gravity sorting as available sorting technologies, systematically synthesized 522,150 sorting scenarios in total were evaluated. The scenario with the lowest GHG emissions reduced emission significantly compared to the case where only ER is implemented. Furthermore, the GHG emissions were evaluated for the scenarios in which recovery rate of the target resin was increased by 10 % and 20 % for the sorting technology, and the CR requirement (total composition ratio of PE, PP, and PS) was lowered from 0.95 to 0.85 and 0.75. These affected the structure of sorting scenarios, and the resulting GHG emission reductions were quantified.

3-3C-3

Evaluation method of recycled content and classification of scraps for materials

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An evaluation method and calculation formula of recycled content for materials were developed. The method was developed for an uniform material, because recycled content of composite material and a product can be calculated as the weighted average of each composing uniform material. Proposed recycled content expresses the ratio of recovered material consumed as an input during material production in the specific system. The system boundary was set in two levels based on industrial needs: a factory level and a material level. For both levels, the denominator of the calculation formula includes all the input to the material production system, both primary and recovered material. The numerator is the total mass of the recovered material included in the input. As for a factory level, recycled content is calculated using input materials for a whole factory. Although in-house scrap is basically omitted from the calculation, some in-house scrap that requires additional treatment for recovery is counted and regarded as in the same status as old scrap. As for a material level, classification of scrap was developed to identify in-house scrap used for different materials from in-house scrap used for the original material: i)scrap internal – material closed, ii)scrap external – material closed, iii)scrap external – material open – used without additional treatment and iv)scrap external – material open – used after additional treatment. By introducing the new classification, all types of scrap can be considered in the calculation. In the calculation, the recycled content of the original material contained in in-house scrap and process scrap is considered to avoid the overestimation of recycled content. The proposed formula is independent of the system boundary of the calculation. Therefore, the formula can provide the constant recycled content though the value calculated by the conventional formula varies depending on the system boundary of the calculation.

3-3C-4

Time series analysis of capital-embodied material footprint in Japan towards a material flow management in a carbon-neutral society

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A huge amount of material is required for our society. Even in Japan, a mature economy, more than 1.5 billion tons of material flow—material use for products, services, and fixed-capital formation—annually supports the society. Considering that material use triggers substantial carbon emissions, understanding the relationship between the materials use and carbon emissions is a prerequisite for achieving climate change targets. Without through management of material use, a carbon-neutral society is hopelessly unattainable. This study aims to find a pathway for carbon-neutral society in parallel with maintaining the mature society, and material management targets for that society. We developed a fixed-capital endogenizing input-output model to calculate capital-embodied material footprints (MF) and their induced carbon emissions. To analyze how changes in consumption structure affect material flows, we created a time-series input-output table with endogenized fixed-capital for the period 2000, 2005, 2011, 2015 and material flow database of each year. Decomposing the industrial supply chain and final demand, We analyzed what factors influence changes in material flow. As the result, we identified that the service sector is highly responsible for the material consumption if we include fixed-capital formation effect. As of 2015, the fixed-capital supply chain for the service sectors caused 168 million tons MF and indicated the high level of carbon intensity. This trend indicates that the service sectors are key to material management on both the supply and demand side. Our findings highlight that breaking the stimulus to the fixed-capital formation by service industries is imperative for curbing material use and carbon emissions. Strengthening circular economy policies and companies' and cities' Scope 3 carbon management, focusing on fixed-capital, will be instrumental in driving this change.

3-3D: Lifecycle thinking for eco-design

3-3D-1

Supporting technology developers to upscale rare-earth-magnet recycling systems for sustainability

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Due to the increasing adoption of wind turbines and electric motors for battery-electric mobility, the energy transition requires an increasingly secure supply of permanent rare earth magnets. While the current supply chain of rare earths heavily relies on mining them in China, neodymium recycling outside of China is expected to play a prominent role in the future. One of the alternative recycling processes currently under development in the Horizon 2020 project "SUSMAGPRO" involves using hydrogen to retrieve Nd-Fe-B from end-of-life magnets. Within SUSMAGPRO, technology developers are testing pilot plants and defining processing routes, starting from various sources of magnetic scrap, with several types of magnets as potential products. To support the technology developers through this wide solution space, we planned a sustainability assessment in three stages. In the first stage, we quantified neodymium waste in European countries using material flow analysis. We also performed a prospective life cycle assessment on the primary production of Nd-Fe-B magnets. In the second stage, we performed an LCA of the recycling systems at their current scales (lab or pilot). We then identified hotspots and defined a set of upscaling and optimisation parameters. The third stage consists of integrating the knowledge of the two previous stages and evaluating the most promising routes in upscaled scenarios projected into the future. The iterative process involved scenario workshops and expert consultations. The sustainability assessment, also including the assessment of prospective economic and social factors, will be concluded by the end of the project, in 2023.

3-3D-2

Multifaceted approach to achieve increased polyester textile monomer recycling with reduced GHG emissions

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The apparel life cycle releases approximately 3.3 billion metric tons of Greenhouse Gases (GHG) annually (6.7% of all sectors) making it a compelling area to reduce GHG emissions. Polyester textiles accounts for 60% of all textiles production. Therefore, polyester textile recycling is significant for transitioning to carbon neutrality. PET bottles are widely used as feedstock for mechanical recycling because of their ease of recycling. However, waste polyester textile material cannot be used as mechanical recycling feedstock due to containing dyes. As PET bottle-to-bottle recycling development matures and is established in future, it is predicted that waste PET bottles will not be available feedstock for recycled textiles. However, monomer recycling can be applied for waste polyester textiles as feedstock because it enables regenerated polyester textile with virgin-equivalent quality from waste textile regardless of containing dye. Therefore, it is required to quantitatively evaluate the advantage of monomer recycling in the polyester textile life cycle.
JGC performed LCA to evaluate potential GHG reduction by waste polyester monomer recycling process compared with production from hydrocarbon sources. In this process, recycled polyester is produced by polymerization of monomer made from waste polyester textile. This recycling process is conducted on a commercial-scale plant, and design data is available for evaluation. The waste of

unrecoverable chemical residue is assumed to be incinerated. Through this study, it was found that monomer recycling has an advantage of 50% GHG reduction because carbon of waste textile can be captured as recycled product instead of incineration. Design improvement in waste textile recovery systems contributes to a stable feedstock supply for monomer recycling and meshes with the proposed approach. The topic of waste textile recovery systems will be discussed in detail in another oral session.
In conclusion, we showed the advantage of life cycle GHG emissions for waste polyester textile monomer recycling.

3-3D-3

Closing the silicon loop: A lifecycle environmental implication of upcycling Japan's solar panel wastes into next-generation thin-film silicon solar PV cells

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Crystalline silicon solar photovoltaic (PV) technologies have remarkably reduced the lifecycle GHG emissions of electricity by two orders of magnitude compared to fossil fuels. However, the end-of-life solar panels will soon pile up; and the zero-carbon trend will demand a cleaner production. These prompted us to reinvestigate the hotspots of solar PVs, including the purification of metal-grade silicon, and material loss during the wafer slicing. A potential solution is to "recycle" the silicon from PV wastes, then "upcycle" them to produce next-generation thin-film silicon solar cells – that can perform as effectively with one-tenth of the silicon requirement. This early-stage technology can chemically vapor deposit silicon film with a minimum loss and may use recycled silicon as feedstock. Therefore, this study examines the environmental implication of closing the silicon loop while "upcycling" the solar cells using a series of what-if scenarios in the context of Japan. The government's GHG reduction targets are 46% of the 2013-level by 2030 and net-zero by 2050; the PVs installation targets are 108 GW in 2030 and 370 GW in 2050. We first model the PV wastes. The wastes contribute negatively when undergoing recycling treatments but positively when avoiding virgin materials; the silicon is recycled into metal-grade or solar-grade. We then model the impacts of PV production in three scenarios: business-as-usual, recycling (Si wafer), and upcycling (Si film). Our tentative results show that the 2050 net-zero carbon target can be met in the upcycling scenario, considering the reduced PV production impacts and credits of recycled materials. But the 2030 carbon reduction target cannot be completed because of the disproportionate amount of silicon needed for PV production and domestically available recycled silicon. The upcycling to a flexible thin-film PV will also have ripple effects on the ease of transportation and installation.

3-3D-4

Environmental trade-offs of decarbonisation pathways for domestic water heating

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Reducing the carbon footprint of water heating plays a significant role in the decarbonisation of heat, given that it can account for 20% or more of domestic heating fuel consumption. However, policies to date have prioritised decarbonisation of the electric grid. The transition of domestic water heating towards renewable energy requires the installation of new equipment to use (renewable) electricity and renewable heat sources, replacing boilers for gas and other fossil fuels; such technologies each come with their own environmental footprint. Whilst previous studies have explored the environmental trade-offs of an increase of renewable electricity generation, such research has gained little attention for water heating.
This study aims to quantify the environmental footprint of equipment necessary for the transition to renewable domestic water heating in the United Kingdom (UK) through a Life Cycle Assessment, focussing on greenhouse gas emissions, resource depletion and water consumption of the life cycle of electric boilers, heat pumps, solar thermal collectors, biomass boilers and others. In order to establish scenarios on the role-out of the alternative water heating technologies under different policy choices and market developments, we use information from Energy Performance Certificates (EPC). These are collected for sold and rented properties in the UK and contain data on the fuel type and yearly costs for water heating, which we use as our basis for a marginal CO2 abatement cost curve to establish the most cost-effective technology mix on a county level resolution.
The resulting regionalised data on the application of renewable water heating technologies under several scenarios and their related environmental footprint will be highly relevant to inform policies supporting a low-cost and low-trade-off transition to green water heating in households. It will also enable us to quantify regional recycling efforts necessary to replace the old water heating infrastructure.

3-3E: Organizational and regional sustainability

3-3E-1

New assessment method for companies' ESG activities toward well-being society

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A new assessment method is developed on the basis of Gross Social Feel-Good (GSF) Index to evaluate the contribution of companies to the realization of a well-being society, which people want their society to become, especially from environmental, social, and governance (ESG) aspects. The GSF index was originally developed for evaluating the contribution of ICT services to the realization of a sustainable society and used to evaluate the positive and negative effects of ICT services in terms of their environmental, social, and economic impacts. By enhancing the target and the concept, the new assessment method enables us to estimate both the positive and the negative effects of a company's activities in terms of their ESG impact. We assessed a part of ESG related activities including reducing greenhouse gas emissions, preventing work-related injuries, increasing employment, improving employee health, and protecting privacy of an ICT company using disclosed annual ESG information and statistical datasets. This case study clarified the possibilities that the new method could estimate the improvement and importance of a company's activities from an ESG viewpoint quantitatively by comparing the estimation results from current and past ESG information.

3-3E-2

From waste towards carbon neutrality: An innovative paradigm shift to material flow cost accounting 2.0

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Carbon neutrality is a worthwhile intermediate goal for businesses on their journey towards sustainability. If GHG emissions equal zero, global warming can be reduced and hopefully come to a standstill. Despite the lively ongoing debate about what carbon neutrality means, we should not neglect the question of how it can be achieved.
Material Flow Cost Accounting (MFCA) is a powerful method to detect and reduce waste in production processes, thereby decreasing GHG emissions and costs simultaneously. Stemming from environmental management, MFCA has the major strength to unite economic and ecological goals. It was developed in Germany and Japan and standardized as ISO 14051 in 2011. Nevertheless, it has not yet gained a foothold in the manufacturing industry, for which it has large potential. Two main reasons for this are the difficulty to find suitable improvement measures and to correctly quantify the overall saving potential of these measures. So far, there is no guidance how to systematically derive suitable measures within an MFCA project. Moreover, the saving potential is only calculated based on the one point in the production system where it occurs.
The research project MaFImA Project (Material Flow Based Improvement Assessments) closes this gap with a software tool based on innovative algorithms that enable scenario comparisons, hot-spot analyses and holistic assessments of potential improvement measures. The software tool calculates the correct saving potentials associated with the individual measures and also combinations thereof. Moreover, a linked database enables the search for suitable measures.
This methodological paradigm shift results in MFCA 2.0, a more pragmatic MFCA method that enables the reduction of environmental emissions and sustainable business management through innovative software support. MFCA 2.0 has a high practical relevance and thus paves the way for carbon neutrality and sustainable development for the production industry.

3-3E-3

Recursive calculation of scope-3 emissions in the supply chain with input-output analysis

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The use of materials, goods and services is associated with greenhouse gas emissions. In climate footprints of companies these upstream scope-3-emissions represent a large share of overall emissions. Calculating them is difficult because they occur in the supply chain, which can usually only be traced back to the first supplier. Economic input-output analysis (IOA) is one method to estimate these emissions in supply chains. It provides indications of the origin of emissions by country and industry sector. IOA was used as backbone in developing a simple web-based tool for the calculation of corporate carbon footprints which is provided free of charge to the manufacturing industry in Germany (https://scope3analyzer.pulse.cloud/) and international companies.
Besides allowing companies to calculate their scope 1&2 emissions, companies can use the tool for estimating their upstream scope 3 emissions by analyzing the purchasing data. This is done by simply entering the monetary volumes of used products and services, categorizing them into different groups of goods and countries of origin. The envisioned dissemination of the tool in supply chains would even allow the determination of actual upstream emissions as each supplier would share his direct emissions. Only his purchased goods and raw materials would still be estimated with IOA. The broader the supply chain is covered by applicants of the tool, the more accurate the data would become. This creates a recursive method that is initially based on international trade data but will represent a company´s individual supply chain more accurately with each iteration.
For such a procedure to work and be adopted by companies, however, numerous obstacles must be overcome. Companies such as ZEISS and BOSCH, as well as several suppliers, have been involved in the research project as pilot users. Their reports can be used to

enhance the tool´s practicability and sharpen its value proposition.

3-3E-4

Proposal and verification of global comparison framework of eco-industrial parks

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Industrial symbiosis has attracted worldwide attention as one solution to sustainable development. Some countries have adopted industrial symbiosis by establishing Eco-industrial parks (EIPs). This study aims to extract the key factors influencing the development of EIPs by collating the relevant literature on industrial symbiosis, with a particular focus on their interrelationships with EIP. An analytical framework enabling international comparison was explored. The analysis framework comprised operation (including waste, energy and water treatment, resource recycling and cascade utilization, strategic measures of management departments, information, education, infrastructure and living facilities) and support (technical and financial). Analyses were within and outside the selected EIPs. Each region comprised enterprises, citizens, educational institutions, and research institutions. We examined three EIPs to verify the applicability of the analytical framework: Kitakyushu Eco-Town in Japan and Tianjin Economic-Technological Development Area and Tianjin Ziya Economic Technological Development Area in China. In the management strategy part of the framework, three eco-industrial parks are accurately characterized and classified according to development strategies, policy measures, and the actual situation of EIPs. We focus on a variety of strategies, measures, and material exchanges, as well as key elements of the analytical framework for visualizing EIPs, such as the support of national and autonomous regional, etc. The results highlight that strategic interventions and support from the state, autonomies (local governments), management at the EIP level (management committee), and measures taken by autonomous organizations within an EIP are effective in industrial symbiosis.

◆◆◆Presentation list: Poster session

P-1

System development of resource logistics toward minimizing supply chain risks of mineral resources

Kazuyo Matsubae[1], Kenichi Nakajima[2], Kazuyo Hirose[3], Yoko Yamakata[4], Zhengyang Zhang[1], Eiji Yamasue[5], Ichiro Daigo[4], Shinsuke Murakami[4]
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The large-scale development and diffusion of climate change mitigation technologies is urgently required in our society. The additional resource requirement of these technologies will involve greater costs to the environment and to society. As such, there will be a number of negative impacts associated with the transition to climate change mitigation technologies.
With the globalization of the supply chain, various social and environmental issues related to mineral resources need to be considered in order to improve the resilience of our economic activities.
Various organizations that support the stable procurement of mineral resources have been reporting risk factors affecting the flow of resources in the form of newsletters and reports. However, the extraction of risk information heavily relies on the skills of experts with many years of experience. Furthermore, the analysis of resource risk impacts through the supply chain is highly dependent on a small number of experienced professionals. For a more comprehensive overall perspective, it is necessary to develop a new integrated platform to share the risk information related to the mineral flows through the supply chain.
The aim of this project is to develop a platform for resource intelligence support using AI technology to minimize the impact of supply chain risks related to mineral resources on economic activities in Japan. The platform is expected to be suitable for application to describe any global supply chain risk scenario.
In this study, we showcase the following three outcomes:
(1) Organizing information on risk factors that occur around mines through satellite image analysis;
(2) Establishment of AI-assisted method for extracting risk events in mineral resource utilization; and
3) Development of an analytical framework to visualize the flow of mineral resources through the supply chain.

P-2

A framework for modelling transport modal shifts in relation to planetary boundaries and the impacts of battery mineral supply

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Transportation accounts for almost one-third of all global CO2 emissions, making this sector one of the main contributors to climate change. In the last five decades, the growth in greenhouse gas emissions from the transportation sector has outpaced any other energy-consuming sector – and still, motorization and road use are increasing steadily, especially in developing nations. To address this, several global and local policies are being implemented to decarbonise the transport sector through a shift towards renewable energy generation and electrification of vehicles.
Current strategies for decarbonization of transport may create high dependence on the supply chains for lithium-ion batteries and the raw materials required for their manufacture. While there is an effort to guarantee a steady supply of responsibly sourced critical minerals, over-reliance on single sources of minerals has been problematic over the years. As a result, many open questions are emerging regarding the long-term stability and adaptability of these supply chains. In addition, it is unknown if the environmental trade-offs necessary to produce LIBs and decarbonize transportation are bearable by our planetary boundaries.
Global and local policies would benefit from more sophisticated modelling and analysis that examines the complex sustainability trade-offs associated with transport systems and battery supply chains. As part of this, there is a need for better modelling of how transport modal shifts (i.e., changes to the share of public transport, motor vehicle, and non-motorized solutions) translate into altered battery material supply chains and sustainable development outcomes. This study proposes a framework to assess alternative transportation sector decarbonization pathways in relation to planetary boundaries and the need to control the potentially negative consequences of battery minerals extraction. Application of this will facilitate more holistic policy development and forewarning of potentially unsustainable transport decarbonization pathways.

P-3

Evaluation of atmospheric carbon dioxide balance associated with forest growth and utilization

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Carbon dioxide associated with the burning of wood is considered carbon-neutral because it is absorbed from the atmosphere during the growth process of trees, and this concept has become one of the grounds for promoting the use of energy in forest biomass as a measure against climate change. But in recent years, there have been criticisms that this concept is too simple. When counting carbon from wood, biomass power generation and biomass boilers have higher carbon dioxide emission basic unit than commercial power and fossil fuel boilers, thus temporarily increasing the concentration of carbon dioxide in the atmosphere. In addition, forests take time to grow and regenerate, and it takes several decades to reabsorb carbon dioxide. Considering these points, there is a question that the use of fossil fuels may suppress global warming.
In order to quantitatively evaluate the carbon dioxide balance, it is necessary to consider the time axis and set the forest growth and operation, forest biomass utilization, decay conditions, etc. in detail. In this study, we created some scenarios for using forest biomass as energy and wood-based materials, and evaluated the carbon dioxide balance per one hectare forest. We also evaluated the carbon dioxide balance of the scenario of using fossil fuels and non-wood-based materials which substitute forest biomass without using forests, i.e. without cutting trees, and compared the carbon dioxide balance with the scenario of using forests.

P-4

Global supply-chain network analysis for environmentally-important shipping routes and ports

Tomomi Shoda, Keitaro Maeno, Shigemi Kagawa, Taiga Shimotsuura

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CO2 emissions from transportation sector account for 27% of global CO2 emissions in 2019. In particular, maritime transportation sector accounts for 2% of the global CO2 emissions in that year. Thus, it is crucial to reduce CO2 emissions in this sector for achieving future climate goals. With a rapid increase in demand for maritime transport services through the development of global supply-chain networks, the International Maritime Organization (IMO) has noted that CO2 emissions will continue to grow due to expanding supply-chain networks. Based on the Sea-web Movements Database provided by the IHS Markit Ltd, this study focuses on 8881 container ships owned by shipping companies in 2020 that play an important role in international trade. We estimated energy consumptions of a specific container ship that moves between ports and calculated the energy-related CO2 emissions for a specific shipping route by totalizing CO2 emissions from the movement of container ships. We visualize the CO2 emissions network for more than 44 million shipping routes and identify environmentally-important routes and ports by using network centrality analysis and cluster analysis. The results show that Pasir Panjang (Singapore) and Tokyo (Japan) were identified as key ports in the global supply chains network. Thus, we suggest that effective CO2 mitigation polices with a focus on the key ports and relevant shipping routes are necessary.

P-5

Biomass-based plastics strategies based on material characteristics, product application, and recycling methods

Hiroaki Kuroda, Eri Amasawa, Jun Nakatani, Masahiko Hirao
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There is a growing interest in biomass-based plastics to mitigate climate change, but whether or not their introduction would actually result in the reduction of environmental impacts as a whole remains uncertain. Previous studies presented LCA of biomass-based plastics with specific raw materials, applications, or the end of life. In reality, biomass-based plastics can be made from a combination of different raw materials and manufactured into distinct applications. Thus, there is a need to assess the environmental impact while considering diverse options in the life cycle of plastics.
To explore biomass-based plastics strategies for Japan, this study developed a plastics utilization system model for nine types of fossil-based plastics and twelve types of biomass-based plastics including biodegradable plastics based on linear programming. The model consisted of minimization of life cycle GHG emission as an objective function, and the matching/applicability of material properties, product applications, and recycling methods as problem constraints.
The results show that life cycle GHG emission from all the plastics used in Japan could be reduced by 47.2 million t-CO2eq/year from the current situation, which means net-negative of GHG emissions can be achieved. This is because Japan still uses coal as a main energy source, so the reduction of GHG emissions from substituting coal with plastics becomes significant. In addition, the use of 7.5 million tons of biomass plastics significantly reduce the GHG by carbon sequestration. However, when the recycling capacity was limited, the reduction will be only 34.5 million t-CO2eq/year, an increase of 12.7 million t-CO2eq/year from the previous result.
To realize a plastic utilization system with low GHG emissions, our analysis showed the importance of the matching of plastic characteristics and recycling capacity. These scenarios omitted other constraints such as the amount of biomass-based plastics, so various scenarios need to be analyzed as a future task.

P-6

Exploring low-cost pathways to achieve the 2050 decarbonisation goals of airlines

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Although aviation is a sector expected to enjoy a rebound in demand in the post-COVID19 pandemic, the sector will have to meet the own 2050 international CO2 reduction goals. As the aviation sector faces difficulties in the rapid uptake of innovative decarbonisation technologies other than gradual improvements in fuel efficiency, a recovered demand will just lead to a rise in CO2 emissions. Here, we find out the combinations of three feasible abatement measures which airlines can undertake (improving fuel efficiency, changing the lifetime of their aircraft, and restricting the flying distance) to achieve the 2050 target and the cost of the measures. Through the Japanese case, the result shows that even if fuel consumption improves by 2% annually, it is hard to achieve the 2050 goal of halving emissions to 2005 levels without at least 17.6 % suppression of the flying distance projected between 2020 and 2050. If airlines choose the least costly pathway towards the goal, the cumulative emissions by 2050 become 120% higher than the minimum case of the emissions, undermining the effectiveness of climate change action and resulting in unfair contributions amongst companies. If the cumulative emissions are set as a new goal in 2050, the least costly ways to achieve the goal are to extend the aircraft's lifetime and to start suppressing flight distances without waiting for a temporary demand recovery from the pandemic. If passengers are responsible for the achieving cost of the new goal, an 75% revenue increase per 1km will be required. Fostering consumers' understanding of carbon-intensive nature of airplanes and co-operation are critical to the decarbonization of the airline industry.

P-7

The role of urban structures on the CO2 emissions

Chisato Hososhima, Daisuke Yoshizawa, Shigemi Kagawa
Kyushu University

With the adoption of the Paris Agreement in December 2015, Japan has declared its goal of achieving carbon neutrality by 2050. In order to achieve this goal, a municipality is required to reduce CO2 emissions through specific policies. However, since there are significant differences in urban structures in each municipality, the policies that should be implemented for decarbonization differ across municipalities. This study estimates the impacts of different spatial structures on life-cycle CO_2 emissions from private vehicles and examines effective urban structures in reducing CO_2 emissions, in order to determine how to achieve sustainable cities. To analyze how CO_2 emissions from private cars change due to the development level of public transportation, an econometric analysis at prefecture level in 2020 was performed by using annual CO_2 emissions per driver (t-CO_2) as an objective variable, percentage of electric vehicles among passenger cars, number of train station per land area, number of bus stops per land area, percentage of drivers over 75-year-old who have returned their licenses, number of stores per land area, dependence on private cars, and average number of walking steps taken per day as explanatory variables. Subsequently, the spatial econometric analysis

framework was combined with a multi-regions input-output analysis framework of the Japanese prefectures. This study demonstrated that an increase in the number of train stations and bus stops considerably contributed to reducing life-cycle CO_2 emissions from private vehicles. This is because the development of public transportation makes it possible for each individual to lead a lifestyle without driving a car. For CO2 mitigation, we also found that increasing the number of stations and bus stops is more effective in cities than in rural areas. The sustainability analysis framework at prefecture level proposed in this study can help each municipality determine the most suitable urban policy toward the decarbonization.

P-8

Natural resource use in west Asia: Status and trends of environmental impacts using enhanced MRIO

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The world economy has been facing increasing problems of land degradation, water shortages, natural resource depletion, and biodiversity loss due to impacts of climate change and rapid production expansion. Global material demand grew substantially from 27.1 billion tonnes in 1970 to around 92 billion tonnes in 2017. Most of the increase in global material extraction over this period was driven by development in Asia and the Pacific, and West Asia, with annual rates of increase at 4.5 per cent and 3.4 per cent, respectively.
We assessed GHG emissions, biodiversity loss and water stress in the West Asia region, from a production perspective and a consumption perspective from 1995 to 2019. The results demonstrate very tight connection between economic growth and environmental impacts. The production perspective (PBA) features weak absolute decoupling for biodiversity loss, weak relative decoupling for water stress and no decoupling for GHG emissions. The consumption perspective (CBA) shows for water stress a very weak absolute decoupling, and for GHG emissions there is no decoupling.
Per-capita GHG emissions in 2019 amounted to 12.1 tCO2eq (PBA) and 10.6 tCO2eq (CBA). In both cases, GHG emissions are considerably above the global average (6.4 tCO2eq) and similar to GHG emissions observed in China and the European Union. Nearly 90% of land use related biodiversity loss impacts are embodied in imported product, which requires supply chain management actions. West Asia has some of the largest per-capita water-stress impacts in the world, which can potentially be reduced through adjustments of trade, especially reduction of exports and adjusting imports.
Increasing population and affluence were the key forces for increased impacts. Surprisingly technological change had an increasing effect on GHG. This indicates heavy dependence on fossil fuel-based energy systems in West Asia region and the heavy reliance on energy intensive sectors.

P-9

Consumption patterns of primary and secondary steel resources based on market share of steel in different economic conditions

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The secondary steel production contributes to both retarding iron ore mining and GHG abatement, and acts as one of direct closed loops of materials. The consumption of steel scrap varies among countries due to the differences in the portions of new scrap generated from fabrication processes and old scrap recovered from end-of-life products and demolition. The demand of steel scraps is determined by the share of end uses for higher or lower grade application. However, few studies concerned about the recycling pattern of steel scrap. In this study, we focus on consumption pattern of primary and secondary resources of steel to explore the disparities of steel scraps recycling pattern in twenty-five major economies. First, we built a material flow model, based on physical input-output table of iron and steel and analyzed the component of primary resources (pig iron and direct reduction iron) and secondary resources (steel scraps) in the intermediate productions of flat steel (higher quality steel products) and long steel (lower quality of steel products), respectively. Consequently, we explored the correlation between the components of iron resources in flat or long steel products and economic levels. Results show the larger long products were consumed in lower economic level. The production of long product consumes more old scraps in higher economic level, which seems to be derived from mature industrialization and more old scrap generation. The production of flat product relies on primary resources accounting for about 73% of total input of iron resources. This study provides a general analytical framework of primary- and secondary-resource consumption, applying to a case of iron and steel under the present resource consumption patterns, and found the correlation between consumption patterns of secondary resources and the economic development levels. It would have a contribution to understanding the global efforts toward circular economy.

P-10

Quantifying the linkage between fatalities from tailings dam failures and automobile industry

activities

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Tailings dams are facilities that deposit slag from the mining, beneficiation and smelting stages of mining. Tailing dam failure cause immediate damage in the form of environmental pollution, loss of economy and loss of human life. Increased demand for lithium-ion batteries used in electric vehicles could result in around 80 tailings dams by 2050, equivalent to the size of the Brumadinho dam that collapsed in Brazil in 2019.
Given the environmental and social impacts of tailings dam failures, a comprehensive dataset is needed.
Knowledge of the impact of tailings dam failure on the industrial structure of each country through the supply chain will allow us to take measures to minimize the impact of supply chain risks We aim to develop a new model capable of analyzing mineral resource supply chain risks that affect the flow of resources in each country and industry through the international supply chain.
In this study, using a Multi-Regional Input-Output analysis and new indicators to quantify the linkages between the fatalities of tailings dam failures and the automobile industries in Japan, the USA and China, respectively. The result shows that the share of responsibility for the number of fatalities allocated to the Chinese automobile industry was the largest. As the increasing demand from the Japanese and US automobile industries will also account for a large share of the responsibility allocation of fatalities occurring in China, it is important to build a responsible supply chain with China.

P-11

Nationwide waste footprint using the Japanese input-output table and impact assessment method

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Tokyo City University, Japan

In Japan, the shift from a linear economy to circular economy is paid attention.To achieve the above goal, the Basic Law for Establishing a Recycling in Society has put into operation since 2000, many of measures for the reduction of disposal and landfill have been examined. Because the space for landfill of waste is limited, Japanese government prioritized recycling and combustion for volume reduction. But the method which enables us to evaluate the environmental impacts of landfill of waste is limited so far. To solve this problem, it is necessary to develop a model to assess the efficiencies of reuse and recycle and to promote the realization of circular economy in Japan The aim of this study is to develop a methodology of waste footprint to quantitatively assess the environmental impact of waste. Waste footprint evaluates environmental impacts on social assets due to the loss of space for landfill. We used waste input-output method developed by Kondo et al. as inventory data and applied them to damage factors listed in LIME3 for the implementation of impact assessment.

P-12

Carbon footprint for outdoor sports events

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The organization of a large-scale sporting event emits all kinds of environmental footprints related to its operation. Environmental impact assessments of sporting events such as the Tokyo International Marathon have been known to be very effective in raising environmental awareness among organizers and participants because of the existence of previous studies.
This study focuses on an outdoor sporting event: the "Kitakyushu-Hiraodai Trail Running Race 2022" to be held on Sunday, April 17, 2022, and the environmental footprint emitted throughout its operation will be evaluated using the carbon footprint as an indicator.
After Covid-19, interest in the outdoors is growing worldwide. Trail running races are found all over the world, ranging from short-distance races to grueling races lasting dozens of hours.
Outdoor sporting events are held in natural settings and minimizing the environmental impact of operations is essential for the sustainability of the event.
The "Kitakyushu-Hiraodai Trail Running Race," the subject of this study, is held at Hiraodai, a Kyushu National Park, and is produced by professional trail runner Hiroki Ishikawa. Since the first event, the event has been run under the concept of "having fun while protecting nature," and has sought to manage the event in an environmentally friendly manner. For example, to protect the trails, experts have studied the impact of the event on the trails, limited the number of participants, used private bottles for water supply, repaired trails, and even planted trees to restore and protect nature as part of the program.
The results of this study will be used as a benchmark for reviewing operational details and establishing an offset plan for emissions. Additionally, I will discuss sustainable outdoor sporting events.

P-13

Development of a business model for bioplastics recycling acorn by-products

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Recently, as the use of disposable products has increased, consumption related to plastic packaging is also increasing. Plastic packaging materials take at least 100 to 500 years to decompose, and a large amount of carbon is emitted during the production process, so interest in bioplastic packaging materials that will replace plastic packaging materials is increasing. Meanwhile 50% of acorns are generated as a by-product in the production process of acorns, so recycling is necessary.
Therefore, in this study, the possibility of recycling acorn by-products into bioplastics is confirmed and a business model of bioplastics is developed. Material composition and particle size analysis were conducted to analyze the recyclability of acorn by-products. When checking the composition under a scanning microscope, the acorn by-product is composed of more than 90% carbon and oxygen, which is similar to wheat flour. In addition, as a result of particle size analysis using X-ray diffraction analysis (XRD) after the secondary grinding experiment of the acorn by-product, the initial median particle size was reduced from 145.922 μm to 3.285 μm. The result of mixing the crushed by-product with water and glycerol It was confirmed that the film can be manufactured. As a result of commercialization analysis of the crushed by-product film, it was found that the raw material price when manufacturing straws with acorn by-product film was 0.3 won per acorn powder, which is significantly lower than that of the existing paper straws 19.6 won. It was found that they were more likely to use acorn straws than straws. As a result, when expanding the business and developing additional business models such as cosmetics and toilet paper, it is competitive with existing businesses and high added value is also expected to be created.

P-14

Mercury legacy: Use, trade, and anthropogenic emission

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Mercury is a highly toxic element that is found both naturally and as an introduced contaminant in the environment, and mercury accumulation occurs in the oceans and soil with an effect of anthropogenic mercury emissions. Appropriate implementation of the Minamata Convention on Mercury, effective since 2017, may reduce global supply and demand for mercury and anthropogenic mercury emissions and releases to the environment. However, there are concerns regarding the significant increase of mercury emissions from major sectors (e.g., coal combustion, artisanal small-scale gold mining, and cement production) depending on future socio-economic conditions and implementation scenarios.
This paper shows future projection of anthropogenic mercury emissions in global scale and evaluate the effects of cobenefit- and tradeoff effects in reducing mercury emissions due to decarbonization measures for achieving the carbon-neutral target. In addition, we also discuss inconsistencies in the global mercury use and trade to achieve sound mercury management for sustainable development.

P-15

Comparison of the environmental performance of small to medium scale sewage treatment plants in south-central Chile

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Wastewater treatment represents a cornerstone of the urban water cycle, necessary for the preservation of both human health and the integrity of aquatic ecosystems. Even though the environmental assessment of wastewater treatment is an area with more than 20 years of development, comprehensive evaluations of the effect that context specific data such as plant capacity and management practices can present over the environmental performance of the systems are not common. Moreover, in developing countries such as Chile, there is a lack of systematized inventory data for wastewater treatment, limiting the possibility of performing robust environmental assessments. In this study, 16 small to medium scale (~240 - 51,000 m3/day) sewage treatment plants located in south-central Chile were assessed and compared by means of attributional LCA. Data from the full-scale facilities was obtained for the 2017 - 2020 period, including energy and chemicals consumption, sludge and solids waste generation, affluent and effluent characterizations, and other relevant parameters. Eight impact categories were selected and assessed through the ReCiPe midpoint methodology. The results show that even though most of the plants use very similar technological configurations for treatment,

important differences between the environmental performance of the facilities are observed. In particular, most of the categories were greatly influenced by energy consumption, showing maximum values ranging between 8 to 37 times higher than the minimum results, depending on the category. Treatment efficiencies also led to noteworthy effects over the eutrophication categories, while the contribution of sludge management to the differences was not very relevant, mainly due to similar sludge generation rates between the plants. Overall, the results show the relevance of using context specific data for the assessment of wastewater treatment plants, highlighting the necessity of constructing inventory databases that reflects their operational variability in terms of resource use and emissions.

P-16

Vanadium redox flow battery to support the use of renewable energy in stationary applications

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The transition towards low carbon emissions is highly dependent on renewable energy, especially renewable-based electricity. However, renewables are cyclic and subject to local environmental conditions, meaning that for a continuous operation, storage systems that match the supply and demand are needed. Lithium-ion batteries (LIBs) are one of the most widely used technologies, but in view of the increasing demand for this technology, it is also important to consider alternatives. Vanadium redox flow batteries (VRBs) have demonstrated positive performance for stationary applications, being considered also environmentally friendly, which makes them an interesting alternative for LIBs. Although rechargeable batteries are often reported to be environmentally friendly technologies, their production and use also result in environmental burdens, which were investigated in this study. A comparative life cycle assessment was performed for a LIB and a VRB, including their subsystem components. Both storage systems were tested for stationary applications using solar and wind sourced electricity. The impacts through the entire life cycle of the storage systems were assessed using experimental data from test set-ups located at Engie (Belgium). The provided data correspond to the supply phase, use phase, and end-of-life of both storage systems. The batteries compositions were investigated in detail as a factor for the final impacts, by comparing two types of cathodes for the LIB and the use of recycled electrolyte for the VRB. Results indicate that in comparison to the lithium-based storage system, the vanadium-based storage system results in overall lower impacts when manufactured with 100% fresh raw materials, but the impacts are significantly lowered if 50% recycled electrolyte is used, with up to 45.2% lower terrestrial acidification and 11.1% lower global warming potential. The new LIB cathode chemistry with higher nickel content results in overall higher impacts, with 41.7% more particulate matter formation and 52.2% more terrestrial acidification.

P-17

Digital WEEE manifest as a potential tool for WEEE management: Case study of Thailand

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Waste from electrical and electronic equipment (WEEE) or E-waste management is one of global problematic issue, typically in developing countries. In Thailand, WEEE is mostly managed by informal sector and untraceable, especially non-valuable parts which are possibly toxic and harmful to human health and environment. Valuable parts are generally sellable, but non-valuable parts are prone to mismanagement such as open burning and discarding to municipal landfill or empty land. Thus, (draft) WEEE Act based on extended producer responsibility (EPR) concept has been proposed to cope with this issue and also to encourage circular economy (CE) practice. However, it is vital to establish a tool which make the mechanism traceable and transparent. To achieve this, Digital WEEE manifest (DWM) was proposed in this study. Firstly, key stakeholders in WEEE management were identified, from producers, consumers, waste collectors, waste transporters to dismantlers either formal or informal, following with determination of WEEE management system based on EPR concept. DWM is a digital platform and database coupled with material flow analysis (MFA) to track and trace WEEE, materials, value, and cost throughout supply chain of WEEE management, resulting in traceability and transparency. Also, post-consumer recycled materials could be certified via this system, resulting in increasing competitiveness of secondary raw materials. Therefore, DWM can be considered as a potential tool for gaining collaboration along the value chain in order to achieve sustainable WEEE management in Thailand, typically in this transition period. Moreover, DWM can further enable safer in WEEE dismantling practices.

P-18

Comparative analysis of environmental impacts for Fenton-based wastewater treatment processes

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Wastewater treatment and management is the core to ensure a safe and clean water environment. However, chemical-based wastewater treatment processes often involve significant resource consumption, either in chemical or material uses, to achieve desired water quality, which may potentially lead to remarkable environmental impacts. The objective of this study is to investigate the environmental impacts associated with two Fenton-based wastewater treatment processes, including fluidized-bed reactor (FBR) and conventional Fenton methods. The study follows the standardized method of ISO 14040 for life cycle assessment, using the IPCC 2013 and ReCiPe Midpoint (H) V1.13 methods for environmental impact assessment. The functional unit is defined as the removal of 1 kg COD equivalent from the treatment process. The results showed that the FBR process has a relatively lower environmental impact than that of the conventional process, in both the IPCC and ReCiPe impact results, mainly due to the differences in chemical use of sodium hydroxide and sulfuric acid. The IPCC assessment results showed that the conventional Fenton method had a relatively higher global warming impact than that for the FBR process, with impacts of approximately 13.95 kg CO2 eq/kg COD and 12.52 kg CO2 eq/kg COD, respectively. The environmental hotspot for the Fenton processes was identified as sodium hydroxide, mainly due to its high electricity and fossil fuel consumption during the manufacturing process. It was worth noting that although the amount of sodium hydroxide used in the FBR Fenton method was significantly reduced, the increased use of sulfuric acid in the method compensated the reduction in impact results, thus, resulting in little change in the overall impacts. Future advancement in the Fenton-based wastewater treatment process is suggested to explore the replacement or optimization of chemical uses of sodium hydroxide and sulfuric acid, to reduce the associated impacts that achieve environmental sustainability.

P-19

A life cycle assessment of electric and conventional motorcycles in Taiwan

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Combustion driven motorcycles are an important mode of transportation, especially in Asia, where they contribute up to 60% of the total road traffic share. Given their small size and versatility, they help to ease congestion in dense urban centers while having a relatively low energy consumption in comparison to light passenger vehicles. Nonetheless, a share of the tailpipe emissions from combustion engine motorcycles has a toxic nature and present a considerable threat to human health. In recent years, electric motorcycles have been promoted extensively as a suitable solution to address the air quality issue without compromising well-being. However, despite the anticipated emission reduction in urban centers, a deeper understanding of the environmental impacts from conventional and electric motorcycles over their life cycle is still missing. To address this gap in knowledge, this study applied a Life Cycle Assessment (LCA) to both motorcycle types from a cradle-to-grave perspective. Life cycle inventory data was obtained from the disassembly of a Gogoro S2 and a Sym Duke. The results show that the environmental burdens associated with electric motorcycles are highly related to the use of precious metals during the manufacturing process and electricity generation of the use phase, while the potential impacts of conventional motorcycles mainly respond to the fuel consumption during the use stage. The influence of sensitive parameters, electricity mixes and the indicator specific breakeven points between the two motorcycles will be discussed in detail at the conference.

P-20

A shifting paradigm with life cycle thinking for material flows analysis to atmospheric aerosol loading

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As the most recent updated analysis of the planetary boundaries framework implies, we risk catastrophic overshoot of proposed limits for climate change, and land-use change, while the aerosols loading thresholds requires further research.
Should the interlinkage of the above provides a new methodology for sustainability assessment, this paper investigates the systematic view for materials LCA in regional to global scale within the Earth system for the intensive energy materials to aerosol loading in specific time periods. Shifting paradigms with life cycle thinking, towards an extended nexus approach in resource efficiency to aerosol loading while covering all interrelated elements in monitoring the situation towards sustainable development, the main intensive energy materials flows are analyzed in an extended environmental input-output to aerosol loading measurement and

datasets. The discovery of the interplay of disorder and fluctuations in physical systems from atomic to planetary scales provided the essential component of the new sustainability assessment as is proposed in this paper.
The overarching objective of the research is to test a mechanism that proved to be an efficient and transparent way for the environmental impact of material production and consumption to aerosol loading, but this time governing within a replicated methodology entity that would evaluate and provide the core related function in favor of environmental concern. Exploring if examples of good and improved data interpretation resulting from adopting a nexus perspective are promising, a descriptive model of material flows to aerosol loading in parallel to carbon neutrality for GHGs is introduced.
The results will strengthen the idea that life cycle thinking has the power to progress the required paradigm shifts by connecting such activities with a bird's-eye view of the complex systems that contribute nature and human society while considering environmental, social and economic impacts of a product over its entire life cycle.

P-21

A human toxicity assessment in LCA applying a risk-based approach for chemicals

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Although regulatory requirements are in place to ensure the safe use of chemicals in their application, the ambition to reduce the environmental impacts of products along their life cycle is often combined with an ambition to identify and reduce hazards and exposures. As there is currently no methodology available to compare hazard and exposure performance along the lifecycle and identify priorities for improvement, requirements are often based on purely hazard-based lists for priority substances without evaluating their risk in specific applications.
LCA is widely used to quantify the overall environmental impact of products along the life cycle but the models for toxicity impacts are focussing on the indirect impact of chemicals emitted into the environment. As a performance-based indicator for the application in LCA; ProScale assesses hazard and direct exposure potentials from chemicals along their life cycle. It can be integrated in LCA to compare human toxicity potentials of alternatives. Furthermore, Environmental Product Declarations ("EPDs") and Product Environmental Footprints ("PEFs") in life cycle thinking, a risk-based approach for product assessments can be applied.
Several companies from the Industrial Sustainability practitioner network (ISPN) were involved in the method development and applying the method in LCA.
The ProScale methodology is a function of the four parameters (1): Hazard Factor (HF) – Describes the hazard of a substance, reflecting health effect, severity and potency based on hazard statements (also called H-phrases) and acceptable concentration levels (e.g. OEL, DNEL). Exposure Concentration Factor (ECF) – Describes the exposure concentration of a substance based on exposure modelling using the ECETOC TRA Tier 1 exposure model. Person-Hours Factor (PHF) – Number of person-hours of exposure per mass unit of produced product or service. Mass Flow (MF) – Describes the amount of a substance needed per functional unit of a product.

P-22

Can introduction of PVC de-chlorination technology bring circularity benefits? - An analysis using a multi-objective, multi-regional technology choice model

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Typically, mixed plastic wastes are subject to PVC sorting before recycling. The sorted PVC fraction would then be combusted with neutralization or otherwise landfilled. Cl would end up in the ash, which is landfilled or washed and discharged, if not recovered as CaCl2, NaCl, or HClO. Both the Cl and hydrocarbon in PVC are rarely subject to circulation. To improve the circulation of plastics, a novel PVC de-chlorination technology recovering Cl as NaCl by electrodialysis of ethylene glycol/NaOH solution containing Cl leached from PVC was developed. Since NaCl has historically been produced in limited countries having warm and dry climates, current climate changes may affect NaCl production. Therefore, NaCl production by the novel technology would be an alternative way of NaCl supply mitigating the climate change-induced stress on the NaCl supply chain. In this study, the NaCl supply chain and introduction locations of the PVC de-chlorination technology were assessed by developing a multi-objective and multi-regional technology choice model. The benefits mentioned above by introducing the novel technology were analyzed.
The Pareto curve obtained from the preliminary optimization showed that reducing both GHG emissions and the area of salt farming could be achieved by introducing the PVC de-chlorination technology. It was due to utilizing PVC as a NaCl and choosing the countries with low electricity-related GHG emissions and close distance to significant PVC waste generating countries was suitable for the PVC de-chlorination technology introduction. Up to 10.31 ha of the salt farming areas could be reduced by utilizing 7309 kt of PVC waste. Based on the results, when the reduction goal of the objective was set, requirements for the technology energy intensity and each country's electricity-related emission inventory were deduced. Furthermore, considering the influence of carbon circulation by remaining hydrocarbon could promote further analysis.

P-23

Sectoral similarity analysis of production technologies and lifestyles of nations

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To achieve a long-term temperature goal in the Paris Agreement, countries need to efficiently change production technologies and lifestyles toward building a low-carbon society. However, since the production technologies and lifestyles differ from country to country, it is necessary for the government to set a possible CO2 reduction target for 2030 through effective policies implemented by benchmark countries. We use the EXIOBASE3 multiregional input-output table of 44 countries and regions and calculate a similarity matrix for technical coefficients between countries as well as a similarity matrix for household consumption coefficients between countries. The Ward method as a hierarchical clustering approach is applied to the similarity matrices for production technology and consumption. From the results, we find that the countries are classified into several clusters including (i) developed countries including G7 countries, (ii) developing countries (e.g., the BRICS), (iii) countries with higher consumptions of certain consumption items such as health and social work services and real estate services (e.g., the US and Switzerland), and (iv) countries where the item of hotel and restaurant services accounts for a larger share of household consumption (e.g., Spain and Austria). We further investigate household carbon footprints for each group and find that there exists a significant gap in the average carbon footprints of countries that belong to the cluster. We suggest that a country can reduce CO2 emissions through learning from the benchmark countries with similar production technologies and lifestyles founded in this study.

P-24

Effects of environmental labels for packaging on consumer behavior

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We continue to repeat our lives, using the many resources and energy on the earth, producing and consuming large amounts of it. However, the earth's resources and energy are not infinite. Therefore, this lifestyle of mass production and mass consumption places a very heavy burden on the earth. If we continue with mass production and mass consumption, the earth's limited resources will be used more and more, and the possibility that these resources will eventually be depleted will increase. In order to continue to sustain resources while meeting the daily needs of consumers, producers are required to establish production methods that produce higher quality products using fewer resources while protecting the environment and resources, and to reduce energy consumption and waste generation in the production process.
Containers and packaging are essential in our daily lives. However, the production of containers and packaging emits CO2, which contributes to global warming. Since carbon footprints are generally displayed in a manner that includes the contents, it was thought that carbon footprints were not a sufficient source of information to raise environmental awareness regarding containers and packaging. This study will analyze the impact of disclosing LCA results for containers and packaging to consumers on their purchasing behavior. In a simulated shopping experiment targeting parents and children, the influence of environmental information on containers and packaging on purchase behavior will be discussed by displaying products with different containers and packaging and labels showing LCA results.

P-25

Comparative LCA of wood waste treatments - A case in Taiwan

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Agricultural waste and wood waste have been a problem. Traditional treatment such as open burning and burying would cause many environmental problems. At the same time, agricultural waste and wood waste are rich in lignocellulose and have potential to be utilized through biomass technology including gasification, incineration, landfill, pyrolysis to produce electricity and high-value byproducts. Recently, gasification technology has been widely used to treat agricultural waste and wood waste. It can convert wastes into syngas, bio-oil and bio-char. Unlike using energy crops for gasification, using bio-waste can avoid competing for land with food crops and don't need extra fertilizer, water, and cost to cultivate. To evaluate environmental impacts of processes, life cycle assessment (LCA) has been widely used. The LCA result provides important information for decision makers to create commercial strategy or make policy. Taiwan's government set a feed-in tariff (FIT) system to promote renewable energy development. However, biomass technology is still at an early stage of development and only accounts for less than 1% of the energy consumed. Taiwan also produces a lot of agricultural waste and wood waste annually. The stable yields show great potential for waste-based gasification. Recently, Taiwan is trying to import gasification technology for domestic use. However, the environmental performance of biomass

technology is unclear and the potential of using agricultural waste and wood waste as feedstock hasn't been examined. In this research, LCA of three waste wood treatment scenarios (gasification, incineration and landfill) were performed to compare the environmental impacts caused by each treatment. The LCI data is derived from an industrial practice and online databases. The functional unit is one ton of waste wood and the impact assessments were done using SimaPro 9.0 . The potential of waste-gasification development in Taiwan was also discussed in this research.

P-26

Environmental performance of Komatsuna in use of natural impurities adsorbent

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Our research group has been developing the biomass driven hydrogen production system.
In the case of the hydrogen production through the indirect pyrolysis gasification process using urban biomass resources such as sewage sludge, the removal performance and/or the selection of adsorbents for impurities such as hydrogen sulfide or ammonia would be key factors to generally cause voltage drops and degradation in hydrogen-fueled applications.
In the past studies, adsorbents such as metal adsorbents have been investigated as adsorbents for these impurities, but our research group concentrated the use of natural materials, and one of them is a promising candidate of Kanuma Clay. This is widely used as an adsorbent for horticulture, and we are aiming to put it to practical use through the adsorption experiments. The reason for this is that in the hydrogen purification technology, the environmental impacts of the purification system are not necessarily small, even if biomass resource of carbon neutral.
In general, Kanuma Clay is used as a horticultural material. However, we confirmed that the clay has a potential to remove hydrogen sulfide and ammonia. In the hydrogen refinery system, ammonia and other substances are impurities, but they would be important fertilizers for plant growth. Therefore, we investigate the possibility of adsorption of ammonia on Kanuma Clay and using the used adsorbent as fertilizer.
Based on these knowledges, we first execute experimentally and artificially adsorb ammonia into Kanuma Clay and analyzed the possibility of ammonia fertilizer. It is known that the environmental impact of nitrogen fertilizer has some impact on the LCA of agricultural production. In this sense, it is significant to examine the plant growth using the used adsorbent of Kanuma Clay. Here, we chose Komatsuna as a model vegetable, we have discussion on the eco-burdens of the harvesting effects in use of the recycle adsorbent.

P-27

Environmental impact assessment of direct air capture with biogas power plant

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To achieve carbon neutrality by 2050, in addition to reducing CO_2 emissions to the atmosphere, Carbon Dioxide Removal (CDR) technologies that directly remove CO_2 from the atmosphere are required. The large energy consumption during desorption after CO_2 capture is considered an issue. Energy derived from non-fossil resources has been proposed as an energy source to address this issue. In the case of DAC using an absorbent solution, the heat source during regeneration of the absorbent solution is supplemented by methane combustion, so the CO_2 recovered directly from the atmosphere is only 70% of the total CO_2 in the final storage, and studies are needed to improve efficiency. In this study, we proposed the use of wood-derived biogas combustion as a heat source instead of methane combustion and analyzed the effect of DAC efficiency improvement. The impact assessment method used was LIME3. The results showed that the amount of GHGs removed from the atmosphere increased by 10% with the use of biomass compared to methane combustion. On the other hand, the required land modification area was 1.3 times larger, and the occupied area was 600 times larger. The results of the LIME3 integration, which converted the amount of damage into monetary values, indicated that the damage to plants caused by land modification and maintenance may be greater than the GHG reduction benefits of carbon capture by DAC.

P-28

Dynamic substance flow analysis of indium in Japan

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Rare metals are used in many devices such as cell phones, computer memories, DVDs, rechargeable batteries, etc. During the past twenty years, there has been an explosion in demand for many items that require rare metals. The interest in recycling of rare metals is also growing. Substance flow analysis (SFA) is an effective tool for understanding the flow of materials in specific regions. In this paper, we focus on indium and conducted its SFA in Japan. The main use of indium is Indium Tin Oxide (ITO), which is mainly used in

Flat Panel Display (FPD) modules for TVs, mobile phones and others. In this study, the substance flow of indium related to ITO was quantified. In supply stage, the data on primary and secondary production and imports of indium in Japan were obtained from 1999 to 2017. In manufacturing stage, indium demand for ITO and indium content in the products were estimated. In use and disposal stages, indium content in in-use and end-of-life products were estimated by dynamic SFA using time series data about indium content of end-products and their lifetime distribution. The authors also estimated the loss of indium in each process as the recovery potential. As a result, indium input into ITO was 626 t and indium losses in ITO production were estimated to be 81 t, while indium content in end-of-life products was estimated to be 5.2 tons in 2017. Therefore, it can be concluded that process of the ITO manufacturing is the largest recovery potential of indium. On the other hand, it was also suggested that the recovery potential of indium in the end-of-life products has increased during these two decades.

P-29

Evaluating carbon inequality by household type across prefectures in Japan

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Affected by income level, household type, and other factors, the carbon inequality of households is substantially different across prefectures in Japan, which has a profound impact on Japan's sustainable development. Therefore, it is necessary to explore the carbon footprint of different household types within systematic income groups and evaluate the carbon inequality in all prefectures. Based on the multi-region input-output table of Japan for 2005, this study identifies the detailed structures of carbon footprints for different income groups of multi- and single-person households across Japan's 47 prefectures. Moreover, carbon inequalities across prefectures are elucidated through the carbon footprint Gini coefficients of multi- and single-person households. The results show that multi-person households in high gross regional product (GRP) prefectures in the Kanto and Chubu regions have a higher overall carbon footprint, which shows uniform growth in income. In contrast, the carbon footprint of single-person households in high-GRP prefectures is generally lower. In both multi- and single-person households, the income groups with the highest and lowest carbon footprints are relatively concentrated in the low-GRP prefectures, mainly in the Hokkaido, Tohoku, Chugoku, and Kyushu regions. In addition, carbon inequality gradually decreases with the improvement in household wealth.

P-30

Consideration of nitrogen balance between Input and output flow in IDEA

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Atmospheric nitrogen due to population increase and economic growth according to the "Planetary Boundaries" concept has received widespread attention during recent years.

This is due to the use of atmospheric nitrogen, which is released back into the atmosphere and water as reactive nitrogen after it has been used in various processes. Therefore, it is important to analyze the nitrogen flow to reduce the burden on the environment. In existing LCA research, reactive nitrogen has been targeted as elementary flow regarding as environmental burden substance. On the other hand, atmospheric nitrogen has not been targeted as elementary flow regarding as resource or environmental burden substance because atmospheric nitrogen does not affect the environment.

Additionally, technologies which aim to recycle reactive nitrogen into atmospheric nitrogen for reducing environmental burden have been developed in recent years. In this case, we need to analyze environmental burden in total. Hence, we need not only amount of reactive nitrogen as output data, but also amount of atmospheric nitrogen as input data. At the same time, we need to confirm the nitrogen balance between input and output to verify the validity of themass balance entire process because it is significant to reduce the environmental burden in entirety.

Thus, we considered nitrogen balance between input and output flow in IDEA.

P-31

Life cycle assessment for solar panel recycling considering the resources of glass

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The use of solar panels is expanding to achieve carbon neutrality. Similarly in Japan, the expansion of introduction with the start of the Feed-in tariff's for solar power generation surplus electricity in 2009, the amount of waste is expected to increase in the future. This time, we developed a processing technology for used solar panels and aimed to recover cover glass, solar cells, and copper wire. In particular, solar panels with broken panels and broken cover glass are mixed with components, and collecting each material in well-separated glass, copper wire, and solar cells was a challenge in promoting material recycling. Among them, we developed a technology to recover glass with an extremely low amount of foreign matter, which occupies the main component of solar panels. I

will report the results because I conducted a lifecycle assessment on the effect of recycling based on the technology developed here.

P-32

Copper-smelting-related mercury emissions reduced by promoting recycling and introducing countermeasure technology in major copper-smelting countries

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Copper is an important resource, but small amounts of mercury are released into the atmosphere during copper smelting processes. Promoting copper recycling and introducing countermeasure technologies are effective at reducing atmospheric emissions of mercury from copper ore. For this study, we estimated how mercury emissions from smelting are expected to change in response to future changes in copper demand in major countries. We evaluated atmospheric mercury emission effects of copper recycling promotion and countermeasure technology introduction. Results show that (1) total copper demand of the targeted major developed countries in 2050 might be about 7.2 Mt. Copper demand in China was estimated to be about 10.1 Mt to about 6.4 Mt depending on the scenario. (2) Under the business-as-usual scenario, total atmospheric mercury emissions in 2050 of the targeted major developed countries are estimated as about 0.17t-Hg. The atmospheric mercury emissions in China are estimated to be about 1.51t-Hg to about 3.23t-Hg depending on the scenario. (3) The total atmospheric mercury emissions in 2050 in major countries (when China is under the average scenario) were estimated as approximately 1.39t-Hg in a scenario of promoting copper recycling. The figure was estimated as about 0.06t-Hg in a scenario of introducing countermeasure technology for atmospheric mercury emissions, and as about 0.03t-Hg in a scenario in which both countermeasures are taken.

P-33

Feasibility of applying leachate treatment equipment from final disposal sites to methane fermentation facilities after completion of landfill disposal

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In recent years, energy utilization and low-carbon initiatives at waste treatment facilities have become an issue. The Ministry of the Environment of Japan states that the utilization of carbon-neutral waste biomass contributes not only to the formation of a recycling-oriented society but also to the prevention of global warming by reducing greenhouse gas (GHG) emissions, and therefore it is necessary to promote appropriate recycling according to regional characteristics. Methane fermentation facilities are attracting attention as a means of recovering waste energy.
Therefore, in this study, we attempted to analyze the feasibility of using a leachate treatment facility at a final disposal site after the completion of landfill as a water treatment facility for wet methane fermentation, using the plan as a model case.
As a result, the project balance calculated based on a case study of wet methane fermentation using an existing leachate treatment facility showed that construction costs could be reduced by 21.2%, and the payback period could be shortened by approximately 30%.
Furthermore, based on the analysis of 61 facilities based on the information on managed final disposal facilities at certified excellent industrial waste disposers nationwide, the amount available as methane fermentation facilities will increase every year from 2022 to 2032, and approximately 9,800[t/d] will be available for use as methane fermentation facilities in 2032. In terms of electricity sales, approximately 1,000 [MWH/d] of electricity can be sold in 2032. However, by 2053, the amount available for use as a methane fermentation treatment facility will decrease to 3,200[t/d]. The amount of electricity sold will also decrease to approximately 340 [MWH/d].
Most of the facilities with a payback period of less than eight years are located in the Chubu and Kinki regions, suggesting the possibility of utilizing leachate treatment facilities in these regions.

P-34

Cooperation across the value chain – An important condition for resource efficiency

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The increasing world population, sustained economic growth and the fact that industrialization is taking off in many emerging countries have led to a growing demand for materials such as steel, concrete, and plastics in recent decades. The production of these materials requires large quantities of raw materials and energy, which have a large environmental impact. There is consensus that resource consumption and growth must be decoupled in order to preserve the earth.
A key strategy to achieve such a decoupling is an increased resource efficiency. Manufacturing companies can increase their

resource efficiency through technical improvements, reduced inventory or recycling of production wastes. Often, however, they cannot achieve this on their own, but only in cooperation with material suppliers or machinery manufacturers. Also, the application of methods to identify starting points for improving resource efficiency such as Material Flow Cost Accounting (MFCA) require cross-company cooperation and exchange. Likewise, the transformation to a circular economy and climate neutrality cannot be achieved by companies alone, but only together with their suppliers. The former requires the consideration of entire product life cycles and, with regard to the latter, they cannot directly influence their scope 3 emissions.
In the federal state of Baden-Württemberg, the manufacturing industry contributes decisively to economic performance. The local manufacturing companies export their goods and merchandise worldwide. They are part of global value-added chains and dependent on the import of raw materials. In order to remain competitive, an efficient use of materials and energy is elementary for them. More than 100 companies from Baden-Württemberg have provided information on successfully implemented resource efficiency measures. Based on these examples, different types of cooperation within and between companies are identified and presented, as well as the reasons for them. Examples from other federal states are used for supplementation and comparison purposes.

P-35

Analysis of the effect of load leveling on the energy supply function by waste incineration facility

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In recent years, waste incineration facilities have been required to create new value through the effective use of waste heat energy, and one of the examples is Combined Heat and Power (CHP) system. However, there have been few cases in which heat supply projects have been analyzed and evaluated based on the characteristics of heat demand (seasonal and daily fluctuations) for heating, cooling, and hot water supply applications, with commercial buildings as the heat supply destination. Load leveling of heat demand is expected to increase the times when waste incineration facilities could supply large amount of heat (High extraction distribution ratio in condensate turbine power generation system). Therefore, the purpose of this study was to analyze the effect of load leveling on energy management in a city block formed by a waste incineration facility and heat demand facilities.
The facilities adjacent to the waste incineration facility were a gymnasium (heating and cooling), a heated swimming pool facility (heating and cooling, hot water supply), a city hall (heating and cooling), a hospital (heating and cooling, hot water supply), and a nursing home (heating and cooling, hot water supply). In order to determine the appropriate scale of heat demand for a single heat demand facility, a heat supply-demand balance analysis was conducted for several scales of each heat demand facility, and determined the appropriate scale for a heat supply project by a waste incineration facility (60 t/d furnace × 2 furnaces).
Based on the analysis results, a city block energy management model was created, and the energy supply function of each city block model was evaluated using three evaluation indices. As a result, it was possible to quantify the effect of increasing the number of hours when the system can operate at a high extraction allocation rate due to load leveling.

P-36

Effects of showing volunteer-Related movies on children's voluntary attitudes and behavior

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Currently, the world is facing a variety of environmental problems that are becoming more and more serious. Due to the lack of government power alone to solve environmental problems, environmental NPO activities (volunteer activities) are desired to play an active role. Therefore, young children who know nothing about volunteering are led from school to volunteer in activities such as plastic recycling, picking up trash, planting trees, etc. To better understand what volunteering is about, having children watch volunteer movies is an educational aspect. Watching volunteer movies is seen as an education of social responsibility for children, as it clarifies their perception of 'volunteering' and helps them to understand which activities in their daily life count as volunteering activities. The purpose of this study is to investigate the influence of volunteer movies on children's consciousness, behavior and thinking mode, and to enable more children to actively participate in volunteer activities
The Jieyang city in Guangdong Province, China, has environmental problems such as water pollution, air pollution, and marine debris, and although the local government has been focusing on the environment, it is also seeking help on the part of citizens. Therefore, it is hoped that through education on environmental NPO activities, young people will voluntarily participate in environmental protection activities and influence others around them to become active volunteers as well. The study will be conducted in cooperation with Chaqiao Primary School in Jieyang will involve 16 Grade 5 students. The study will use two research methods, an associative survey and a follow-up survey, and the research time will be two months. While observing the children's behaviors before and after watching the volunteer movies, will be recorded, and compared; 16 students will be divided into groups for the associative survey, and the follow-up survey will be conducted once every two weeks.

P-37

Uncertainty of electricity generation efficiency of variable renewable energy power plants: The case of Japanese photovoltaic power plants

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This study analyzed the electricity generation activities of 249 utility-scale photovoltaic (PV) power plants to evaluate electricity generation efficiency. Applying the generic data envelopment analysis (DEA) framework, benchmark values were identified for power generation from PV power plants. The Monte Carlo experiment analyzed the impact of variability in solar irradiance and temperature on power generation efficiency. For our analysis, we considered three inputs—monthly solar irradiance, average monthly temperature, and installed capacity—and monthly electricity generation as the output. The study findings show that seasonality and location of PV power plants affect electricity generation efficiency. It is crucial to increase the power generation capacity of power plants and operate them more efficiently to achieve the roadmap for expanding utilization of renewable energy sources.

P-38

A methodology for assessing mobility revolution with low carbonization

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The development and spread of ICT (Information and Communication Technology) and energy technologies have led to a mobility revolution. Although decarbonization is a vital part of this picture, no academic research has comprehensively assessed the CO2 emissions of transportation systems, technologies, and services. Therefore, this research aims to clarify the conditions and devise assessment methods under which the mobility revolution can achieve low-carbon impact in the short term and decarbonization over the medium to long term.

Firstly, we needed to organize the basic information on next-generation mobility technologies and services. Using evaluation methods established so far, namely the SyLCEL (System Life Cycle Environmental Load) of LCA (Life Cycle Assessment) and ELCEL (Extended Life Cycle Environmental Load), we then constructed an evaluation method for assessing the environmental loads of traffic activities associated with the mobility revolution in the city for achieving low-carbon impact. By applying and evaluating this methodology to actual cities and regions, local governments will be enabled to achieve decarbonization and improve QOL (Quality of life) over the medium to long term.

P-39

Policy driven compact cities: A literature review on the effect of compact city on carbon emissions

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Cities play an important role in greenhouse gas (GHG) emissions. Compact city strategy, characterized by high density and accessibility with fully support of inner-city public transport, is wildly discussed, and practiced by both developing and developed countries all over the world as response to the challenges of sustainable development as well as global warming. This study assesses and sorts the theoretical evidence and practical experiences on the effect of compact city characteristics and policies on urban CO2 emissions. A focused literature search and review using targeted keywords is used to identify key characteristics of compact city and its impact on urban CO2 emissions. Moreover, four case studies are done aiming to identify the empirically important factors of compact city policies including Toyama (Japan), Melbourne (Australia), Vancouver (Canada) and London (Britain). Based on the above, we present a comparative assessment from the perspective of how cities with different urban growth rates adopt different policy practices, and whether these practices contribute to achieving the goal of building a sustainable, low-carbon city. Basically, two types of compact city are divided: 1) aging society, with low urban growth, building a compact city to avoid waste of resources and restimulate urban prosperity, e.g. Toyama city, and 2) fast growing megacity, with high urban growth, aiming to accommodate increasing population levels sustainably, while limiting urban sprawl, e.g. London. Overall, when it comes to how compact city policies contribute to the reduction of CO2 emissions, there is insufficient evidence to draw a clear conclusion. One reason is that there is still not a comprehensive and effective evaluation system in quantifying compact city performance. In addition, leveraging and co-effects need to be considered when connecting different aspects of compact city characteristics to their impact on urban CO2 emissions and these will be our focus of future research.

P-40

Integrated analysis of overseas global environmental impacts induced by Japanese food production activities -Proposal for production and distribution system transformation-

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There are various approaches currently taken by various industries to improve the global environment. As environmental threats, including carbon dioxide emissions, are widely recognized as global issues, industries in various countries are required to take initiatives to reduce them.
In previous studies, in addition to the environmental impact of domestic production on the home country, the indirect impact of imports on other countries had been calculated based on the production value. However, supply chain-based causes had not been examined in detail.
This study focused on Japan's food production activities and developed a methodology to reduce the indirect global environmental impacts caused by foreign countries in the future. Based on this, we can promote the transformation of production and distribution systems in Japan to improve the global environment.
We determined the environmental impacts along the supply chain for each industry in each country and investigated the upstream sectors that had large impact on the respective impacts. We analyzed the spillover and domestic sectors with particularly large environmental impacts, classifying them by impacts and by domestic sector. Then we integrated the impacts indirectly emitted by overseas industries and constructed a comprehensive index of the impacts associated with Japan's food production. Finally, based on projections of future impacts based on climate change scenarios, we proposed methods of production and distribution system transformation that the Japanese food production industry should undertake.
The novelty of this study is that it explored spillover effects outside of Japan, down to the industrial level in each country. Furthermore, by simulating future changes in threats, the results of this study provided an important indicator for each industry to improve consistency with their trading partners in addressing environmental issues. Long term, the results are also useful in setting the direction of each industry's goals based on future economic trends.

P-41

LCA evaluation of freon reclamation and destruction

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Demand for air conditioning equipment continues to increase worldwide. On a global scale, refrigerant-derived GHG emissions are on a scale that cannot be ignored. We quantified the refrigerant recovery and regeneration or destruction process in this case study for multiple refrigerants. We collected primary data from destruction and reclamation companies to conduct the analysis. 2 methods were evaluated for each of the destruction and reclamation processes.
We considered two functional units: 1) Disposal of 1 kg of used refrigerant and 2) Production of 1 kg of refrigerant.
The calculation results showed that avoiding the release of refrigerant into the atmosphere and conducting either reclamation or destruction is essential for reducing GHG emissions.
If it is difficult to reclamation the recovered refrigerant, it can be destroyed. In such cases, chemical recycling can be promoted to recover fluorite resources and reduce the amount of sludge to be landfilled. However, there is a trade-off between fluorite resource recovery and energy consumption.

P-42

Design for fostering life cycle thinking through a speculative scenario picture book about mending with mycelium in a local circular network

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Life cycle thinking has been shown to be useful for fostering environmentally conscious values and lifestyles and has been tested in educational practice. It is effective in understanding the current state, revising daily life behavior, and fostering a commitment to addressing environmental issues. However, extending the present into the future is not enough to overcome wicked problems such as the environmental crisis. Looking solely at present examples also lacks the opportunity for learners to consider emerging technologies' role in life cycle thinking. In this study, we hypothesized that design methods can be useful in future-oriented life cycle thinking education. Design methods have been used to speculate and communicate on possible futures and to stimulate discussion on preferable ones. Therefore, we conducted research using design methods to develop possible future scenarios. Specifically, we created a near-future scenario in which shoes are repaired with mycelium, a method that enables a local life cycle in which materials circulate within a 20 km radius of Kyoto City, and a picture book as the medium to tell the future narrative. The picture book is

intended to be a catalyst for imagining and discussing the future life cycle thinking, especially with children, who will be living in the near future. To ensure the reality of the future scenario we combined various design research methods; scanning material and literature review of biomaterials, prototyping with mycelium material, and field research on local materials of Kyoto City.

P-43

International trade in mercury and its uncontrolled risk

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P-44

Association of air pollution and meteorological variables with COVID-19 pandemic event in DKI Jakarta

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Air pollution due to fossil fuel emissions alone is estimated to cost the global economy upwards of USD 2.9 trillion per year (3.3% of global GDP). The emerging COVID-19 pandemic and the lockdown policy have been said to become one of the prime factors influencing air quality, especially PM2.5. In this study, some of the meteorological variables will be considered to see their associations with the air pollution that occurred in pandemic situations. This study evaluates the air quality data (PM10, SO2, CO, O3, and NO2) and meteorological variables (precipitation, wind speed, radiation intensity, humidity, and temperature) in DKI Jakarta from 2018 to 2020. With the monthly data of the air pollution and meteorological variables above between 2018 to 2020, the study results show that the higher correlation coefficient comes from radiation intensity, NO2, and wind speed for the precipitation, humidity, and temperature, respectively. From the regression analysis, the CO and NO2 concentration showed the same characteristics as the correlation analysis, which negatively correlated with the humidity data. The study also indicates that CO and O3 showed the same characteristics as the correlation analysis, which negatively correlated with precipitation. The results suggest that air quality data may correlate with the meteorological variables and COVID-19 pandemic event. For further study, the following parameters that need to be included are PM2.5 for air quality data, 2021 air quality, meteorological data, and COVID-19 confirmed cases or COVID-19 policy relating to transportation mobility.

P-45

A proposal of multiple indexes in vegetable consumption flow in terms of environmental impacts and nutrition

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This study analyzed freshness, nutrition, and environmental impact of vegetables with the aim of extending healthy life expectancy and contributing to the SDGs (food loss reduction and decarbonization). In its life cycle, vegetables are divided into edible and discarded portions, and portions deemed unnecessary are discarded at the pre-distribution and cooking stages. However, it is generally pointed out that the waste portion of vegetables is rich in nutritional value. For example, the leaves of radish are often discarded at the distribution and cooking stages, but they are rich in minerals, such as containing about 73% more potassium than the root portion. Therefore, consumption of the discarded portion is considered to contribute to insufficient intake of vegetables and extension of healthy life span. In addition, not only the waste portion, but also the edible portion is often discarded due to lack of freshness (deterioration of vegetables). In our research to date, we have proposed optimal food intake methods (cooking menus) according to the degree of deterioration at the cooking stage, and we believe that proposals that take this into account can contribute to the reduction of food loss.

Based on this background, in this study, for vegetables such as daikon (Japanese radish), we divided the vegetable life cycle into three stages: transportation stage, storage stage, and cooking stage, and for each stage, we assumed several consumption paths for edible parts of vegetables, such as daikon with leaves or without leaves. For these pathways, we conducted an evaluation using three integrated indexes: freshness, nutrition, and environmental impact based on LCA. In the future, we believe that making the results of this research available to consumers will contribute to extending healthy lifespans and contributing to the SDGs (food loss reduction and decarbonization).

P-46

Evaluation of secondary aluminum cycles under automotive changes in China

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Because of the penetration of next-generation vehicle and vehicle-lightweight trends, automotive demand for aluminum, especially wrought aluminum alloys, is increasing significantly. Secondary aluminum recycled from aluminum scrap can save 95% of the energy and reduce the environmental impacts compared with the primary aluminum production (Ding et al, 2012). However, the recycling potential of aluminum and the artificial flows of secondary aluminum have not been quantified in China due to the prolonged neglect and complex aluminum scraps. The impacts of the vehicle-lightweight trends on aluminum cycles are not estimated. In this study, we expanded the diagram of secondary aluminum flows in China to estimate the stocks, flows, and metal dissipation of aluminum within its life cycle in 2019 and 2050. This diagram distinguishes wrought and cast alloys so that the chemical composition of each flow is considered. In addition, through introducing the improvement in collection system, dismantling, and sorting for end-of-life vehicles, the recycling potential of aluminum and the reduction in primary aluminum requirement are estimated, with considering the penetration of next-generation vehicle and vehicle-lightweight trends.
Findings include the following: (1) Share of wrought alloys in secondary aluminum production will decrease from 31% in 2019 to 4% in 2050. (2) Total loss rate of secondary aluminum cycles will increase from 21% in 2019 to 30% in 2050. The biggest loss occurs in the end-of-life product collection process due to the underdeveloped waste management system and the lack of legislation in China. (3) Automotive demand for cast and wrought alloys will increase by 2 and 15 times compared with 2019, respectively, vehicle-lightweight trends are more attributable to aluminum demand than penetration of next-generation vehicle. (3) Improving collection system and applying dismantling and sorting for end-of-life vehicles can reduce primary aluminum requirement by 4%-8% in 2019 and 12%-26% in 2050.

P-47

Analysis of the (H)EV permanent magnets recycling trend for rare earth sustainability improvement

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As climate change becomes serious, each country imposes sanctions on internal combustion engines for automobiles, and as an alternative to the de-internal combustion engine policy, the electric vehicle proliferation policy is being promoted. By 2025, it is expected that about 12 million electric vehicles will be sold worldwide, including in China. The permanent magnet of the electric vehicle driving motor is one of the core parts of the product. Therefore, about 2,000 tons of heavy rare earth are needed to manufacture rare earth magnets that will be used in the driving motors of 12 million electric vehicles. China is the only country with a monopoly on the heavy rare earths market, and domestic rare earth magnets are imported from China. However, China produced about 1,400 tons of heavy rare earth in 2019, and it is difficult to more than double the current supply within 10 years, so it is urgent to prepare measures to supply rare earth magnets. Currently, in the United States, Blue Line is promoting the construction of a heavy rare earth separation plant in cooperation with Lynas, an Australian mining company; in Japan, Nissan Motors has developed a technology to recover 98% of the rare earth used in magnets. In addition, Korea's Star Group Ind. Co., Ltd. secured technology to reduce the amount of heavy rare earth use required for manufacturing permanent magnets by more than 70%. Therefore, this study is considered to be a way to improve the sustainability of rare earths by recycling permanent magnets as a measure to reduce the supply of rare earths. Research on the development of recycling technologies should be continuously conducted by country.

P-48

Environmental and social impact assessment of cultural contents considering the economic ripple effect of visits to drama location

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According to a report published by the Ministry of Land, Infrastructure, Transport and Tourism, there is concern about the increasing environmental burden caused by the growing number of tourists, and the need to balance the environment and tourism. Two factors that threaten the sustainability of tourism are cited: "damage to tourism resources" and "deterioration of the living environment." We need to redistribute the wealth generated by the economic benefits of tourism and curb the environmental impact induced by tourism.
Regarding the value of art, film, animation, and other creative works, UNESCO has taken the lead in advocating cultural GDP, and international efforts to visualize the added value generated by cultural activities have been observed. However, while cultural GDP includes values related to the production and exhibition of creative works, it does not include the impact of pilgrimages to sacred places where viewers visit the stage after a film or animation is shown.
Therefore, the objective of this study was to examine the relationship between cultural GDP and LCA by considering the production,

broadcast, and post-airing of a single drama production as a life cycle and evaluating its overall environmental and economic effects. The highest impact was after airing for both environmental and economic effects, with the environmental impact accounting for 80% of the total, and the economic impact calculated to be approximately 13.5 billion yen.
The cultural GDP for this study was 1.2 billion yen, which corresponds to the production and broadcast portions of the study. By including the post-airing period, the cultural GDP was estimated to be 8.1 billion yen, a five-fold increase.
I believe that the inclusion of considerations induced by creations in cultural GDP needs to be reaffirmed as the definition.

P-49

The carbon footprint of Kishiwada Danjiri Festival

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LCA has been used primarily for products and services, but in recent years it has also been used to analyze events. The carbon offsets were implemented on a scale that exceeded the total emissions through collaboration between businesses and local governments. Sharing environmental information at events where diverse stakeholders gather is expected to provide a good opportunity to collaborate on projects. In Osaka, the Osaka Zero Carbon Foundation (OZCaF) was established as a platform to strengthen efforts to realize a decarbonized society through public-private partnerships. The organization's first environmental initiative was to conduct an assessment of the carbon footprint of the Kishiwada Danjiri Festival, one of Japan's most famous festivals. The objectives of this study are to calculate the carbon footprint of Kishiwada Danjiri Festival and suggest GHG emissions reduction proposals to stakeholders.
In this study, we compared the festival carbon footprint in 2013 and 2019. The functional unit is the festival duration of 2 days. The total greenhouse gas emission is about 10,000 tons of CO_2 equivalent during two days. In particular, the largest source of GHG emissions is coming from visitors. In 2013, the GHG emission from visitors is about 6,650 tons of CO2 eq/during 2 days. Whereas, in 2019, the GHG emissions from visitors is about 7570 tons CO2 eq/during 2 days. The difference is around 920 tons. A large portion of visitors' GHG emissions is related to souvenirs, followed by food and beverage. That is mainly because the amount of spending per person in 2019 is higher than in 2013.
According to this study, in order to reduce GHG emissions, we suggest taking actions such as reducing food loss, moreover to increase food consumption from the locals.

P-50

Evaluating the environmental performance of silver nanoparticles syntheses

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Silver nanoparticles (AgNPs) have been actively studied, for AgNPs possess broad applications, including catalysts, medical products, and textile coating. Among the AgNPs production, chemical methods utilize silver ion solutions as a precursor; then reduce the precursor to yield nanoparticles; the particles is stabilized by adding protecting agent into the colloidal system. Aiming at green chemistry, simple production methods are desired. We are developing a one-pot synthesis using polyethyleneimine (PEI) as sole additive for the reductive crystallization that produces AgNPs at a single nanometer scale with narrow crystal-size distribution. PEI, a water-soluble polyelectrolyte, acts as a reducing agent to silver nitrate, and a protecting agent to the silver nanoparticles. The method therefore may involve less energy and fewer hazardous chemicals. To evaluate the prospective environmental performance, we have conducted a cradle-to-gate Life Cycle Assessment (LCA) of AgNPs production. The functional unit was 1 kg of AgNPs with 2.89±0.72 nm diameter. Our preliminary results show that the silver metal production dominates the global warming potential, 78% of the total impact. This is common for most AgNPs chemical methods, thus achieving a minimum loss of silver is crucial to green production. We also find that our PEI method is competitive against the emerging bio-based reduction methods. If the same amount of silver is required, the impact of input reagents and process energy will be important to improve the environmental performance. This study will provide a comprehensive comparison of LCA of AgNPs to highlight the environmental implications of prospective production.

P-51

Ex ante life cycle assessment of synthetic talc production based on supercritical hydrothermal flow process

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Recent efforts in chemistry have led to the development of a fast and continuous process for the production of synthetic talc in a supercritical hydrothermal reactor. This attractive process compatible with industrial requirements leads to advantageous physicochemical characteristics including submicrometer size, hydrophilicity, and high chemical and mineralogical purity. In addition, the high speed of the process and moderate reaction conditions have potential advantages from a viewpoint of the impacts on the environment. To verify environmental advantages and seize further opportunities to improve environmental performance, the current study evaluates the new process using ex ante life cycle assessment (LCA) methodology. A cradle-to-gate assessment considers the production of synthetic talc from di!erent magnesium and reagent acid precursors at di!erent concentrations. The findings suggest high impacts of precursors (65 -94%, depending on their concentration) and low impacts of process energy and water. Substituting magnesium acetate with magnesium sulfate could reduce greenhouse gases from 4.8 to 2.6 kg CO2 and cumulative energy use from 86 to 34 MJ per 1 kg of synthetic talc. Discussion draws on previous LCA studies on the supercritical hydrothermal process and applications of synthetic talc considering its environmental performance and characteristics in comparison to the conventional (natural) talc. Perspectives will provide next steps for further research.

P-52

A concurrent technology development and life cycle assessment of lithium-sulfur battery

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Cathode chemistry is the hotspot of the environmental impact of lithium-ion batteries, particularly the common nickel-cobalt-manganese oxide (NCM) battery that required mining and refining of the metals. The recent development of sulfur-based cathode is a potential solution due to its high energy density and low-material impact—sulfur is a byproduct from petrochemical industries, and it is abundant on earth. We have been developing a high-energy-density lithium-sulfur (Li-S) battery with a positive electrode of lithium polysulfide held by a carbon nanotube sponge in the laboratory. With some promising experiment results, we hereby introduce a prospective life cycle assessment (LCA) to support the development of an environmentally friendlier Li-S battery production. This is a cradle-to-gate LCA, with the functional unit of one 61.3 kWh battery pack intended for electric vehicles. First, we designed the pouch-cells battery pack using BatPaC 4.0. The information on cathode chemistry was based on our Li-S coin-cell experiments. Then, we examined the lifecycle GHG emissions under various battery production scenarios and identified the key improvements. Finally, we compared our results to a graphene-based Li-S battery and an NCM811 battery. The results showed that our proposed Li-S battery pack can achieve 60 kg CO2e per kWh battery capacity, nearly 50% lower than an advanced NCM811 and slightly lower than the graphene-based Li-S. We found that it is not only contributed by the change of cathode materials but also by the change of cathode processes, in which, our filtration method demands far less energy than the conventional evaporation of solvents. Also, the carbon nanotube sponge can avoid the considerable impact of current collectors and binders. Through the practice of concurrent technology development and LCA, we were able to inform some experiment decisions such as the desire for more concentrated dispersions as they are sensitive to the overall impact.

P-53

Mineral resource demands for building power transmission grids associated with wind and solar PV plants by 2050 under the energy transition

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The energy transition not only calls for the employment of renewables to generate electricity but also for massive power transmission networks to integrate renewable-based electricity into existing grids to achieve universal access to electricity. Two types of indispensable transmission grids are usually built for grid-connected wind (both onshore and offshore) and photovoltaic power plants that are anticipated to dominate future renewable electricity. One is infield grid networks, which collect electricity generated by each generator and send it to substations or transformers on the site, and the other is export lines that transmit electricity from power plants to existing grids. The rapid expansion of the power network would inevitably require large amounts of mineral resources for building transmission infrastructures. However, little research has been done on how many metals would be required to build such power transmission infrastructures for wind and solar power and how to mitigate their potential future supply-demand risks. Here we estimate the global mineral demands for electricity transmission grids associated with wind and solar power by 2050, using dynamic material flow analysis based on IEA's energy scenarios and typical engineering parameters of transmission grids for wind and solar projects. Under the Sustainable Development Scenario (SDS), the copper demand for related transmission lines increases rapidly from about 4.3 Mt during 2021-2025 to 11.5 Mt during 2046-2050, and aluminum and steel demands increase from 2.7 and 3.2 to 3.3 and 9.0 Mt, respectively. Under the Net-zero Emission scenario, these related metal demands would be 2 to 3 higher than in the

SDS. Power cables are the most metal-consuming electrical components compared to substations and transformers. In addition, we discuss the decommissioning issue on associated transmission lines and their recovery potentials. Our study would deepen the understanding of the interconnection between energy transition, grid infrastructure, and mineral resources.

P-54

Modelling product loss within the packaging sector

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The current emphasis on recyclability and biodegradability of packaging can potentially reduce the package's functionality to protect the product. In some cases, this can result in higher emissions of the product and package system. Accordingly, for some packages it may be preferable to use materials with slightly higher emissions, if their use leads to lower product loss rates.
A review of published studies on milk packaging shows that product loss is often overlooked as a source of emissions and not included in the system boundary (Desole et al., 2022);(Meneses et al., 2012); (Xie et al., 2011).
This paper uses a case study LCA assessing two milk packages, to discuss the importance of accounting for product loss within the packaging sector. The case study was generated in PIQET, an online streamlined LCA tool for use in the packaging industry.
The system boundary was cradle-to-grave for packaging and includes production and disposal of product wasted, excluding impacts of the consumed product. The functional unit was the protection of 1 litre of milk consumed at the consumer. The first package was a 1L aseptic carton made from LPB. The second package was a 2L plastic bottle made from PET. Product loss at consumer was modelled as 0.5% for the aseptic carton and 0.75% for the plastic bottle, based on the shorter shelf-life of milk packaged in plastic bottles compared to aseptic cartons. All waste from loss was assumed to go to landfill.
The plastic bottle resulted in a 138% increase in GHG emissions compared to the aseptic carton, principally because of product loss in the system. When product loss was excluded, the plastic bottle only had a 34% increase in GHG emissions compared to the aseptic carton. The results indicate that modelling product loss can be critical when assessing packaging emissions.

P-55

Mitigating fossil energy consumption in protected horticulture: Life cycle assessment of a water heat pump system for strawberry production

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Greenhouse cultivations for fruits and vegetables contribute significant CO2 emissions derived from fossil fuel combustion for temperature control. So far, low-carbon technologies, such as heat pumps, have been introduced to reduce these CO2 emissions. Meanwhile, we need to pay special attention to ensure that greenhouse cultivation systems combined with a heat pump increase environmental impacts other than climate change.
Therefore, the current study aims to evaluate and compare various environmental impacts including climate change based on LCA focusing on the following two strawberry cultivation systems: a conventional system using an oil boiler (OB) and a low carbon system combined with the OB and a water heat pump (WHP), which uses the heat from running water in an irrigation canal nearby the farm.
The LCI data was created with the SimaPro software based on the following data. For the conventional system, the materials used (e.g., pesticide, fertilizer, and equipment including oil boiler) and energy consumption during the cultivation phase were collected from farm accountancy data in Tochigi prefecture of Japan. For the low carbon system, detailed primary data was collected for the manufacture and installation on site of the WHP. The amount of oil that would be potentially reduced by the introduction of WHP was estimated from existing studies.
Based on the results obtained, we will compare the environmental impacts containing climate change between OB and WHP in terms of providing one unit of thermal energy and reveal the difference in environmental impacts of the two cultivation systems with and without WHP per kg of strawberry.

P-56

A cradle-to-gate greenhouse gases emission perspective for assessment of CCU technologies - Comparison of process options in non-reductive CO2 utilization for poly-carbonate diol production

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Comparison of process options is one of the domains where LCA can make actual differences in the decisions relevant to the future environmental impacts associated with industrial activities. Here, we explore how such decisions may be supported by LCA, with the

example of an emerging chemical process technology. Non-reductive reaction routes are potentially more energy-saving than other numerous carbon capture and utilization (CCU) routes. Taking the synthesis of polycarbonate diol (PCD) from 1,6-hexanediol and CO2 as an example, two process options to promote the yields in this route were compared from a cradle-to-gate greenhouse gas (GHG) emission point of view, a crucial indicator for designing a CCU process.
First, the process inventories were developed via steady state simulations using Aspen Plus V11. The energy consumption and cradle-to-gate GHG emissions were evaluated for a kg of PCD produced with one of the two dehydration options: dehydrating agent (DA); and gas stripping (GS). The numbers remain highly uncertain, but the characteristics of both process options were better understood through these activities. Choice of DA option leads to significantly higher energy consumption and associated GHG emissions, due to 1) difference in the difficulties separating PCD from the dehydrating agent and solvent/unreacted substrate, and 2) potentially excessive (i.e., 20 times the requirement of reaction stoichiometry) use of the dehydrating agent.
Since energy consumption was the hotspot in the processes, next, exploitation of unutilized heat and use of low carbon energy sources were identified as the key items to elaborate on. A breakeven analysis was designed, and the results indicated that it was actually possible that DA becomes more attractive under some scenarios. LCA, if applied appropriately, can lead to better decisions made, highlighting the need for additional information or assumptions deduced from future visions that affect the choice and the designs.

P-57

Determinants of changes in footprints of crucial environmental indicators for global commons stewardship in China

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There is growing evidence of the state of the Global Commons is worsening. As the second-largest economy in the world, China plays a crucial role in the global supply chain, and its production and consumption structure has changed dramatically over the past decade. There is a need to comprehensively assess the environmental impacts of the changing patterns of China's economy and trade on the Global Commons to develop comprehensive and reliable measures and address unsustainable consumption. Here, we quantitatively evaluate the regional disparity, transmission mechanisms, and driving forces in four broad categories of environmental arenas (Aerosols, GHGs, water cycle disruptions, and nutrient cycles disruptions) that have a significant impact on the Global Commons at the sub-national level in China from 2007-2015. The study is facilitated by the improved international MRIO model with high resolution at the Chinese sub-national level, the approaches of multi-region input-output analysis, structural path analysis, and structural decomposition analysis. Our results highlight the North-South imbalance in the impacts of different environmental arenas in China. The Central and Southwest were considered to be the largest contributors to environmental impacts induced by China's final demand. In general, the decline in China's consumption-based environmental impacts from 2007 to 2015 was mainly due to changes in industrial structure. Growth in per capita final demand was the strongest factor that drove the increase in impacts. As China move into the "new normal" phase, its environmental efforts made significant progress over the period 2007-2015. In addition, unintended negative impacts of determinants on the water cycle are observed in our results, future action will need to further weigh up complex mechanisms between environmental domains.

P-58

Web scraping approach for secondary data collection in life cycle assessment and life cycle cost analysis

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Carbon neutrality has become a trend in many countries in order to achieve a competitive level for various environmental issues including climate change. With the introduction of product-related environmental regulations such as the EU's Product Environmental Footprint (PEF), Carbon Border Adjustment Mechanism (CBAM), and the Buy Clean California Act of USA, it is critical to reduce the carbon fooprint of products. It is important for LCA(Life Cycle Assessment) to collect, verify, and calculate data effectively. In the case of secondary data, the quality depends on the data source, so it is necessary to collect data by identifying the proper pertinent information from various sources. Recently, the application of big data in various fields has become common with the 4th Industrial Revolution. One of the text-mining techniques, web scraping, is an approach that collects necessary information from web pages. This study intends to utilize the web scraping approach to effectively collect a large amount of data required for LCA and LCC (Life Cycle Cost analysis). In particular, since the sources of secondary data vary more than primary data, it is essential to select the most appropriate source. In addition, sources of the LCI (Life Cycle Inventory) database are diverse, and the appropriateness of the database affects the reliability of the LCA results. It is vital to select the most proper one from various LCI databases including databases built in diverse institutions around the world, databases with LCA software, or databases registered in global LCI database

platforms. By classifying secondary data using the web scraping technique, this study aims to facilitate the selection of the most suitable data or databases. In addition, it is expected that web scraping will be useful in forming standard prices for various raw materials and energy in economic allocation and LCC.

P-59

Biodiversity damage assessment integrating carbon and land footprint

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The Convention on Biological Diversity conference will be held in 2021 and 2022.
Accordingly, new biodiversity targets will be set, and quantitative assessments will be required.
In addition, the TNFD will be launched in 2021, and disclosure of corporate natural capital assessments will take place in 2022, among other things. Much of the natural capital to be assessed comes from food, construction, and energy, and these raw materials must be properly sourced in countries where they are shared. Japan has a significant biodiversity impact on the rest of the world, which needs to be taken more seriously.
A multiregional inter-industry input-output table could be very useful in implementing the biodiversity footprint. There are several multilateral input-output tables, but we plan to use the EORA developed by the University of Sydney. To account for climate change and land use, greenhouse gas emissions and land-use area for each sector of the world will be obtained. From there, areas relevant to Japan's trade will be extracted. The impact assessment will be conducted using LIME3, which enables analysis that reflects the environmental conditions of countries around the world. A damage analysis including climate change and land use will be conducted using both. This will allow us to conduct biodiversity footprint through final products and services provided in Japan. It is also envisioned that the results of this study will be used by Japanese companies. With the cooperation of Japanese companies, an attempt will be made to conduct a biodiversity version of SCOPE3 by conducting a footprint analysis of the products of Japanese companies.

P-60

Developing product lifetimes information system

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While the planet is facing various environmental challenges associated with unsustainable levels of material consumption, governments and industries are more frequently considering policies and practices aimed at extending the lifetimes of manufactured products. Nevertheless, it is still quite challenging for eco-minded consumers to navigate across a variety of products looking for more long-lasting brands and models. To meet such consumer needs, the first online platform of its kind has been developed as part of this research (https://lt-platform.web.app/). It collects and stores consumers' reports on use and disposal patterns for various products they have owned. This allows analyzing the harvested data using Markov chains to estimate the durability (time until the first failure) and the total lifetimes (domestic service lifespan) of the different consumer products. Such results are updated live after every new contribution to the platform and are presented back in a user-friendly visual format ranking various products' manufacturers and models according to the estimated lifetimes. Additionally, the structure of the collected data allows evaluating the effects of the different circular behavioural approaches (repair, re-use, recycling, etc.) on the products' longevity that could be of specific interest for researchers and policymakers. As a result, such a platform is the first attempt to collect and analyze products' lifetime and durability data in an open, centralized, and accessible format supporting users in their more sustainable consumer.

P-61

Investigating power generation efficiency of PV power plants in Japan focusing on new market entrants

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In Japan, renewable energy sources supplied 21.2% of the total electricity generation in 2020. The Japanese government plans on increasing this ratio to around 36 - 38% by 2030. In this situation, Photovoltaic (PV) power generation will play a significant roll and a large number of new entrants in the market is expected. On the other hand, it is widely known that electricity generation in PV systems fluctuates depending on factors such as weather conditions, seasonality, and location of the power plant. Moreover, in Japan, where the sites for building PV systems are limited, it is essential to improve and stabilize the power generation efficiency of PV systems at plant levels.
In the light of these research backgrounds, by applying a combined research framework of metafrontier Data Envelopment Analysis

and global Malmquist index to the data on PV power generation in Japan at plant levels between 2017 and 2020, this study investigates the following three questions: (i) When dividing the whole of Japan into three parts (north, east and west), is there a significant regional gap in changes in power generation efficiency during the study period? (ii) Which of 'catch-up' and 'frontier technology shift' effects would mainly affect the changes in power generation efficiency? (iii) How new market entrants would have an impact on power generation efficiency?
During the study period, our results show that power generation efficiency in north, east and west regions is increased by 13.6%, 38.9% and 19.4%, respectively. The catch-up effect is the main driver of the substantial efficiency improvement in the east region, while the frontier technology shift effect mainly affects the changes in power generation efficiency in the north and west regions. Furthermore, new market entrants contribute to increasing the average power generation efficiency especially in the west region.

P-62

Economic and environmental efficiency analysis of medical sector in Japan

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The number of diagnostic imaging equipment such as computed tomography (CT) and magnetic resonance imaging (MRI) mainly used in hospitals has increased by 29.6% during the period between 2002 and 2017 in Japan and thus the capital demand for medical services has grown rapidly due to the aging society. On the other hand, the per capita capital demand (i.e., number of CT and MRI installed in the hospitals per capita) largely varied among prefectures in Japan. This paper focuses on not only economically inefficient operations of the capital equipment in hospitals but also lifecycle CO2 emissions embodied in the capital demand in the medical services. We use a comprehensive hospital database including the number of CT and MRI introduced, the expected number of medical examinations using the CT and MRI, the number of radiology technologists, and the number of radiologists, and the actual number of their medical examinations and estimated the relative efficiency of 47 prefectures of Japan through the data envelopment analysis (DEA). We find that there existed a considerable potential of reducing CT and MRI equipment in some inefficient prefectures such as Fukui and Kochi. Finally, we conclude that the capital efficiency improvements with a focus on the inefficient hospitals can contribute to mitigating lifecycle CO2 emissions from the medical sector in Japan.

Withdrawn P-63

Safe by design in product development through combining risk assessment and life cycle assessment

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The Safe by Design (SbD) concept focuses on ensuring the safe use of chemicals involved in material and product design. SbD is seen as a promising approach to reduce the environmental and human health risks of products throughout their life cycle and calls on the responsibility of product designers to take these risks into account at an early stage. The combined application of a risk analysis (RA) of the chemicals used and a life cycle assessment (LCA) of products is often seen as a valuable methodological approach to SbD. However, practical methods combining RA and LCA for designing new chemicals, materials or products are still largely lacking. We therefore reviewed the state-of-the-art in this field and identified examples from the literature combining RA and LCA for new materials and products. We eventually found ten studies in a product development context and assessed them on several predefined criteria. Our findings show that product designers can perform several relatively simple checks early in the design process, including applying life cycle thinking and consulting lists of known hazardous substances. While applying these simplified approaches and guidelines cannot replace a full RA or LCA, it can help to avoid some obvious sources of risk. Designers can also work with experts in RA and LCA to create a more complete design review to identify health risks across the entire product life cycle. Examples of this collaboration are still scarce. To improve this situation, more experience should be gained with Safe by Design by carrying out more case studies, preferably in the context of a concrete product design as the latter appeared missing in our review findings.

P-64

A framework of environmental risk analysis of chemical accident-induced atmospheric pollution

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Chemical industries have accidental risks that fire, explosion, and toxic release can result in damages to human, equipment, building, environment, and social activity. A lot of accidents occur at chemical plants for many years in the world, and the causes of chemical accidents are collected and analyzed to prevent and mitigate accident. To reduce the risks, risk assessment methodologies are developed, and they are effectively used for decision making to control residual risks as low as reasonably practicable.

Recently, natural disaster such as earthquake and typhoon trigger an increase in chemical accidents, and massive chemicals such as toxic gas and VOC are leaked that cause risks of atmospheric pollution. Although environmental measures against chemical emissions under normal operation are installed in processes based on regulations, chemical accident-induced atmospheric pollution have not been analyzed, and their countermeasures are not investigated based on quantitative environmental impacts caused by chemical releases.
The purpose of this study is development a framework of environmental risk analysis of chemical accident-induced atmospheric pollution. Firstly, we investigated reports of chemical accidents to analyze what kind of chemical are leaked and estimate environmental impacts. Secondly, we developed a framework that consists of accidental scenario identification, detailed chemical reaction, and life cycle impact assessment method based on endpoint modeling. Finally, we conducted a simple case study for an accidental risk of ammonia leak in an ammonia storage tank to establish an effectiveness of the framework for environmental protection.

P-65

Comparison of the externality cost of biodiesel from palm oil, soybean, and rapeseed as renewable fuel by using endpoint analysis

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The external costs obtained from the environmental impacts of biodiesel can be significant to consider a ranking between different feedstock sources for decision making of the policy maker. This research aims to compare the externality cost of biodiesel from palm oil, rapeseed, and soybean in different countries using a life cycle impact assessment method based on endpoint modeling (LIME3). The functional unit is 1 GJ of biodiesel from the various feedstock. The inventory data of the biodiesel system was gathered from the Ecoinvent database as follow: palm oil from Malaysia (MY), rapeseed from Switzerland (CH), and soybean from the United State (US). In addition, palm oil biodiesel from Thailand (TH) was collected from the literature review. The environmental impact based on the LIME Method consists of damage assessment and weighting. Damage assessment covers human health, social assets, biodiversity, and primary production in units of DALY, US$, EINES, and NPP, respectively. The results of the damage assessment showed that damage to human health and social assets of rape oil biodiesel from CH is the highest impact in comparison with others. While damage to the biodiversity and primary production of soybean oil biodiesel from the US is the highest impact due to land use. Based on the weighting factor, this study shows that biodiesel from soybean oil (US), palm oil (MY), palm oil (TH), and rape oil (CH) are 12.5, 9.4, 4.7, and 5.5 US$/GJ, respectively. Biodiesel from soybean oil has the highest externality costs with land use accounting for 78% of the costs. When compared to fossil diesel, the result found that diesel is a higher external cost than biodiesel due to the cost of fossil depletion on social assets except biodiesel from soybean.

P-66

How can LCA contribute to the evaluation of sustainable tourism?

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Before the COVID-19 pandemic, tourist destinations had problems of overtourism due to the number of tourists who exceeded their capacity. In addition, the United Nations World Tourism Organization (UNWTO) is warning about causing environmental problems such as climate change.
Life cycle assessment (LCA) is one of the methods for quantitatively understanding the amount of energy consumed and greenhouse gases emitted in tourism. It is thought that the know-how necessary for conducting LCA and certifying environmental labels will be useful for evaluation of sustainable tourism. On the other hand, the Sustainable Development Goals (SDGs) and the Japan Sustainable Tourism Standard for Destinations (JSTS-D) require not only quantification of total CO2 emissions but also sustainability evaluation and management in a broad sense.
Conventionally, when evaluating tourism in LCA studies, the unit of calculation was "one trip per person." Therefore, trying to reduce total CO2 emissions means reducing the load originating from each component of tourism, which inevitably reduces the value of travel. In addition, increasing the occupancy rate of means of transportation and the occupancy rate of hotels will reduce the amount of CO2 emissions per person, however this is a trade-off with the problem of overtourism.
Recently, new types of tourism have emerged, such as virtual tourism and microtourism. It is necessary to reorganize the value of tourism (that is, the functional unit in LCA) from the perspective of satisfaction and fulfillment, and to appropriately set the scope of evaluation and comparison targets. In addition, workcations and bleisure blur the boundaries between travel, work and everyday life. Examination of the allocation method for LCA implementation is an important theme.
Therefore, in this study, I reexamine the methodology of how LCA can contribute to the sustainability of tourism and the evaluation of environmental impact.

P-67

A mixed recipe choice benefits nutrient cycle closing in a sustainable manner

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Food systems are the key to alleviate global warming and mitigating the negative impact of climatic change. As food consumer, shift of our residential dietary choice are practical and effective strategies for determining the food system's contribution to climate issues. Here, we select 45 typical home recipes and conduct the analysis on both nutrition intake as well as the environmental impact, which further result in recommended dietary habits for population who may have specific nutrient intake demands and simultaneously would like to minimize the associated environment impact. We aggregated listed recipes into five groups that defined by their components, namely beef-, chicken-, pork-, seafood- and vegetable-major dishes. The listed dishes are evaluated according to ingredient supply chain information as well as cooking energy use. The corresponding nutrients provided are later linked with the environmental impact to distinguish whether they are both environmentally sustainable and nutritious. One step further, our recommendations are discussed from both objective insight by establishing multiple nutrition scores and subjective insight involving individual preferences. Results show that despite the emission-intensive nature of animal meat supply chain, the correlated dishes may still a good option considering the real-world dish arrangement. By simulating varied subjective food intake preference, our results also indicate that a mixed dietary choice is found as the 'smartest' choice that meeting all major nutrition requirements with minimal environmental impact. From the dish-specific analysis, we found the mixed dietary habit provides a nutrient-rich food intake in a sustainable manner

P-68

Carbon footprint analysis of food packaging in Brasilia, Brazil

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Currently, the climate change debate is the main topic of the environmental agenda. In 2015, 196 countries adopted the Paris Agreement (PA), compromising the goal to limit global warming to well below 2.0 ºC by 2030. The sixth report of the Intergovernmental
Panel on Climate Change, published in 2022, reveals that although the PA, the Greenhouse Gases (GHG) emissions have increased, and to achieve the PA goals, the reduction of GHG emissions must be even more drastically in the following years. This context deepens the emergency to promote GHG emission reduction opportunities in individuals' lifestyles. This study aims to analyze the contribution of fruit plastic packaging to the overall individuals' food carbon footprint. This analysis's emissions and consumption data represent Brasilia's (Brazilian Capital) population. The footprint calculation considers the intensity of GHG emissions per consumption unit and the consumption amount from individuals. The Lifecycle Assessment methodology was used for carbon intensity quantification, considering the Ecoinvent 3.6 cut-off system model database adapted to Brazil. The fruit consumption amount was obtained by microdata from the Personal Food Consumption Analysis in Brasilia (Brazilian Institute of Geography and Statistics, 2018). The plastic food packaging amount and carbon intensity were estimated to represent the flow of the solid waste management system in the Federal District. Considering the results, a low carbon lifestyle could be proposed, and additional analyses considering the behaviour aspect may improve future research.
The study was funded by Fundação de Apoio à Pesquisa do Distrito Federal - FAP/DF (Scientific Support Foundation of Federal District - Brazil).

P-69

The development of LCIA methodology and damage factors for biodiversity loss with extended impact categories.

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With the COP-15 conference, part one was held in 2021, the heightened interest in promoting biodiversity safety became further clearer. In the near future road map, not only should actions pursue a large tank of the committed funds, but the scientific research promotion should be done as well.
However, the conventional methodology and indicators should be realized on a finer scale. Moreover, the high-interest impact categories should be also incorporated under one evaluation frame. For instance, although LIME3 as a rather completed methodology has already considered the climate change and land use impact to the biodiversity loss, some other highly concerned impact

categories such as eutrophication, acidification and even explore deeper to the sub-categories etc. are essential as well.
In this study, we adopted one of the most widely used ecological methodologies, the species distribution model, binding with the LCIA framework. Aims to dependently assess each category's impacts on biodiversity. The future scenario-based evaluation for biodiversity should be also addressed as the alarm well comprehend the ecosystem.
So far with the preliminary evaluation, it is obvious to see that under the pressure of climate change, where 1-degree Celsius rising will bring an adverse impact to the global biodiversity on an overview. The overall situation shows that the global plant species are most deeply affected by climate change; the bird species are more flexible compared to other species. If we go some precise category occasion, such as the land degradation. The impact of it may lead to over 64% of plants' potential suitable habitat are seems to shrink.
In the next step, we would like to build a large tank for the species record. So as to see the more detailed alteration under the different drivers' scenarios. After that, trying to refresh the characterization factors of the biodiversity.

P-70

Greenhouse gas emission and reduction due to rice husks biochar application: The impact of capital goods production

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Biomass grow by absorbing carbon dioxide from the atmosphere, and the charcoal made from biomass is called biochar. When biomass is left unattended, it is decomposed by microorganisms and released into the atmosphere as carbon dioxide. The carbon contained in biochar is persistent and can be sequestered from the atmosphere by storing it in the soil for a long period of time without decomposition. However, fossil fuels are used in the processes of the life cycle of biochar, such as biochar production and agricultural land application. To quantify the greenhouse gas (GHG) emission reductions associated with biochar application, the GHG emissions from fossil fuel usage must be subtracted from the soil applications benefits. The fossil fuel usage includes the fuel consumption during biochar production and manufacturing of the machinery used in making the biochar. However, no study has assessed the environmental impacts of machinery production in biochar production. Therefore, this study quantified the GHG emissions from biochar production, such as capital goods production, using life cycle assessment technique. Rice husks, which is a biochar material, were selected for this study because they are produced more than they are demanded, and a substantial amount of them are unused now in Japan. Biochar made from rice husks has the potential to reduce GHG emissions in Japan. Results showed that the GHG emission from the production processes of capital goods cannot be ignored when evaluating the GHG emission reduction potential of biochar made from rice husks.

P-71

Air conditioning energy analysis using big data

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It is estimated that two-thirds of the households in the world will have air conditioners installed, and the current energy demand for air conditioning, which accounts for 10 percent of global electricity consumption, will be tripled by 2050. Economic growth in developing countries has allowed their residents who could not have air conditioners installed in their homes to do so. Global warming also increases the demand for air conditioners. The increased demand for air conditioners burdens the electricity systems in many countries as well as boosting the amount of greenhouse gas (GHG) emissions.
In Japan, about 25 percent of the entire residential GHG emissions comes from the use of air conditioners. The country has set a goal to reduce GHG emissions by 66 percent from the 2013 level to achieve carbon neutrality by 2050. One of the problems arises, however, regarding the calculation of assessments, because the data that shows the use of air conditioners in the Tokyo area is taken as a standard value to indicate the data of the entire Japan. Since the Japanese islands stretch from north to south, there is a concern that the assessments may be inaccurate disregarding a variety of diverse in Japan.
In this study, I have looked into big data, i.e., the data that describes actual usage of about 110,000 air conditioners in Japan from 2017 to 2021 to illustrate the discrepancy between actual data and the standard values. I also conducted an energy analysis reflecting the actual usage. I have found that the duration of annual operating hours was shorter and energy consumption was lower in real-life usage than those in the standard values. In my future study, artificial intelligence will be used to estimate location information to show regional difference in energy consumption of air conditioners.

P-72

A new H2 storage scheme for a fuel cell assisted bicycle in uses of exhaust gas and insulator coating

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Metal hydride (MH) is the alloy that reacts with hydrogen gas reversibly and charge/discharge hydrogen into/from it. Though MH has some merits, such as low-pressure hydrogen storage that can contribute to the abatement of environmental impact and high volumetric density that can enhance the operation time per one charge, it is pointed out that MH cannot provide a satisfactory hydrogen release rate at a lower temperature. As a countermeasure against this problem, it is desired to improve the energy efficiency by utilizing the exhaust gas of the fuel cell and coating the exhaust system. In this study, a bicycle system of MH and fuel cell which reuse exhaust gas has been developed. This is known as a fuel cell assisted bicycle (h-bike). So far, the conventional assisted bicycle is launched by a Li-ion battery. In terms of eco-burden mitigation, an h-bike would be beneficial. Simultaneously, the travel distance would be longer, and/or the operating time would be also expanded.
In our previous studies, we designed a cartridge and conducted an experiment to utilize the hydrogen release support of MH by FC exhaust heat. we found the issue of tank configuration, that is, the temperature change aspects at H2 discharge would be extremely impacted in the inner tank. Therefore, we find out a new suitable tank design that could change the number of lays of MH to feed H2 out smoothly. First, we investigated the temperature profile in the cartridge (10 layers) in which 4 tanks are set up as 1 layer. Then, we estimated the heat balance during FC operation. Finally, based on the estimated results, we confirm that the film insulator is promoted to make somewhat improvements. Moreover, eco-burden mitigation would be achieved.

P-73

Life cycle assessment to assess circular economy business models: case of lithium-ion battery remanufacturing

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The purpose of this study is to advance and illustrate how life cycle assessment can assess circular economy business models for lithium-ion batteries. The research compares investment in a new versus a second life battery in terms of environmental sustainability for decision-making support. The expected change due to the choice of business model is assessed, including the crucial effect of the substitution coefficient on environmental impact results.
Primary data from two case companies are applied in the life cycle inventory. These represent two different business models based on the circular economy strategy repurpose. With this new inventory, the authors compare a new lithium-ion battery with a second life battery (from a spent electric vehicle) by performing a complete consequential life cycle assessment. Building on earlier work, a procedure to identify the substitution coefficient for battery assessments is proposed. The primary qualitative data and literature review reached a consensus on a crucial technical- and a market factor influencing the potential for avoided production.
Environmental impacts from second life battery remanufacturing and installation are low compared to production of a new in both circular business model cases. However, the quality and price of second life batteries is essential for the results as these factors can hinder the ability of a second life battery to avoid production of a new: The remaining capacity (in kilowatt hours) and the selling price.
Two factors should be considered to inform an environmentally sustainable battery investment decision: Firstly, the spent batteries applied in circular economy business models must have sufficient (technical quality) original capacity left after its first life and secondly, the market price should be comparable with a new battery (not significantly lower). In these instances, substitution can be included in life cycle assessments of batteries.

P-74

Carbon footprint of stationary type water server

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Currently, the main methods of consuming drinking water range from the use of plastic containers to the use of ceramic containers. It is necessary to evaluate which method has the least environmental impact when consuming an equivalent amount of water. The amount of material consumed differs significantly, especially when drinking beverages from disposable drinking water containers and when drinking from an installed water dispenser. In this context, it is necessary to consider means of supplying water with lower environmental impact. In this study, a comparison of greenhouse gas emissions between water supplied by a direct water supply (WS) and bottled water was conducted for public places when all water was used for drinking purposes at 20 L/day.

P-75

Life cycle externality cost of battery electric vehicles, hybrid vehicles, and conventional gasoline vehicles in Thailand based on end-point impacts

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The external costs are the cost of environmental impacts in terms of monetary value and can be easily communicated to the public. It can help in cost-benefit analysis, by comparing the negative impacts and environmental benefits of public policy such as the promotion of electric vehicles. This study compares the externality costs of battery electric vehicles (BEV), hybrid electric vehicles (HEV), and conventional gasoline vehicles (CGV) of an average mid-size car based on the cradle-to-grave approach. The results help the decision makers with complementary and in-deep interpretation using the life cycle assessment (LCA) technique. The impact assessment was based on the LIME3 method. The power generation scenarios considered in the analysis consist of the present grid mix of Thailand and a plan to increase renewable energy sharing. A life cycle model of vehicles with a service life of 150,000 km was carried out. The results showed that the BEV has less greenhouse gas emissions than that of the conventional gasoline vehicle for the present electricity mix and depends strongly on the national electricity portfolio. The externality costs are 5.18 US$/100 km for the CGV, 3.73 US$/100 km for the HEV, and 3.89 US$/100 km for the BEV. The CGV has the highest externality costs with fossil depletion damage on social assets accounting for 65% of the costs. At the same time, the HEV and BEV generate insignificant different external costs. The trend of the results has also been examined for future energy mixes: the electricity and gasoline mixes for the year 2030 have been investigated for the use phase modeling of electric and conventional gasoline vehicles.

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Modeling the relationship between life cycle environmental impacts of ripened peach and food loss reduction induced by transportation packaging

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Food loss is a menace to food security and global warming. Thus, the target 12.3 of the Sustainable Development Goals works on food loss reduction. Peach is one of the most susceptible fruits to damage against shock and vibration during transportation, causing food losses. Some studies have analyzed packaging conditions for peaches, but fewer studies assessed the food losses from environmental perspective. The current study conducted a modeling of the relationship between environmental load and food loss reduction by packaging and discussed the method to environmentally optimize the packaging condition. Functional unit was 1 kg of ripened peaches without damage at retail sector. System boundary was from cultivation and package production to waste of them. A food loss ratio was determined based on the damage degree on peach surface after a simulated transportation test. The transportation distance was assumed from 100 km to 2000 km. Background data used were IDEA V.2 and LIME2 was adopted for life cycle impact assessment. Climate change, urban air pollution, and resource consumption impacts were assessed. Relationship between the environmental load and food loss ratio was predicted by a linear equation and showed a negative correlation in the result of resource consumption impact, indicating that food loss reduction doesn't decrease the impact. A relationship between transport distance and slope of the linear equation presented that the environmental loads increased with the distances. This result was obtained at a distance from 300 km. Therefore, a packaging condition having high potential for food loss prevention is recommended at 300 km or longer. By contrast, the packaging condition with lower environmental loads attributed to its production is suitable within 100 km. This study provides valuable knowledge for sustainable food supply chain from both aspects of environmental impact and packaging condition.

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Environmental and social impacts assessment caused by the growing demand for electric vehicles

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Transportation accounts for about 16% of global greenhouse gas emissions.Passenger cars occupy the main part of the CO2 emission of transportation. As many countries start to regulate the CO2 emissions of gasoline vehicles, electric vehicles (EV) become a key measure of curbing greenhouse gas emissions, and the wave of EV shift has grown internationally. Rare metals such as cobalt, nickel, and lithium are essential for electrification. Demands for rare metals will increase, but the gap between demand and supply may not be filled up. In particular, more than half of cobalt is produced from the Democratic Republic of Congo (DRC), and there are

big concerns that social impacts such as child labor might be worse due to the increase of exploitation with low wages. Although the number of papers on EVs and social impacts has been increasing since around 2015, there is few studies to properly assess environmental, social, and economic impacts.
The purpose of this study is to examine the future environmental impacts of the EV shift and the associated social impacts, represented by child labor, using E-LCA (E-LCA) and S-LCA (S-LCA) methods.

P-78

Analyzing variable factors of water supply-demand balances derived from food production and consumption

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Freshwater resources are necessary for food production and consumption to sustain human activity. Water supply-demand balances could increase due to extending water requirements for food production and consumption in the future. This study aims to elucidate the contribution factor to the variation in water supply-demand balances due to changing water requirements for food production and consumption. The production- and consumption-based water requirements are defined to quantify water requirements for food production and consumption, respectively. The former is evaluated by assigning water requirements for food production to producing countries, whereas the latter is evaluated by assigning water requirements for food consumption to consuming countries. Water footprint is adopted to estimate both water requirements considering green and blue water. The blue water requirement is evaluated as the amount of water withdrawal by considering irrigation efficiency. Time series changes in food production, consumption and trade are taken into account by estimating food trade balances and food supply-demand balances for each year. The food trade balances are adjusted to meet that the sum of import quantities is equal to that of export quantities for each item and year on a global scale. The food supply-demand balances meet that the sum of production and import quantities is equal to that of domestic supply and export quantities. The difference between the two is defined as stock variation. The water supply-demand balances are defined as the ratio of production-based blue water requirements to available water resources. Complete decomposition analysis is applied to the water supply-demand balances and consumption-based water requirements to analyze multiple contribution factors of variation. In addition, the production-based water requirement is also compared with the consumption-based water requirement to analyze the variation in water supply-demand balances associated with food production and consumption changes.

P-79

Economic and environmental consequences of the COVID-19 pandemic through foreign tourists demand in Japan.

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Foreign tourists demand in Japan has increased from 1 trillion (JPY) to 3.5 trillion (JPY) in the three years from 2012 to 2015 in and thus it has considerably contributed to the Japanese economy. The government estimated that the foreign tourists demand will increase by a factor of 15 from 2012 to 2030. However, the COVID-19 pandemic has contributed to rapidly shrinking the inbound demand since December 2019. On the other hand, it is true that the slowdown of economic activity due to the COVID-19 pandemic reduced CO2 emissions in 2020 and it contributed to climate change mitigation. To the best of our knowledge, the economic loss and the environmental benefits in a country are still poorly understood. In doing it, we propose an environmentally-extended, semi-closed input-output model that incorporates endogenous final consumptions of a nation as well as exogenous final consumptions of the foreign tourists. Based on the analysis framework, we found that the COVID-19 pandemic led to the economic loss of 1260 billion yen and the emission reduction of 16,517 kt-CO2 in 2020 in Japan. Tourism and restaurant business activities had the biggest direct economic loss, whereas they indirectly contributed to considerably reducing CO2 through reducing electricity demand. This study suggests a counter-measure against COVID-19 pandemic. The government should not only give financial support to higher priority industries (i.e., heavily-damaged industries) identified in this study but require them submit a report on how their production activity environmentally improves through the financial support.

P-80

Life cycle assessment of photocatalytic reduction of CO2 to methanol

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The increase of CO2 concentration in the atmosphere is a main driver of climate change. Despite international efforts, the progress

of CO2 reduction is slow globally. To counteract this problem, it is of particular importance to further investigate technologies to capture CO2 from the atmosphere followed by subsequent binding or conversion. The photocatalytic reduction of CO2 to fuels such as methanol is one potential solution. The core idea is to enable the reduction of CO2 to methanol by direct activation of a catalytic system via sunlight. To estimate the future potential of the photocatalytic reduction of CO2, a life cycle assessment (LCA) was conducted.
In this project, two different technologies for the photocatalytic reduction of CO2 to methanol were investigated, namely the reduction using carbon dots and carbon nitrides as a photocatalytic system, and the reduction using ZnO in ZIF-8 encoded nanoparticles as a photocatalytic system. The materials, solvent systems and energy quantities required for both processes were estimated based on our own experiments and literatures. We modeled the lifecycle greenhouse gas emissions supplemented by the background information from Ecoinvent database. Technology improvements were modeled through four criteria, increased stability of the catalytic system, higher production rate, lower amounts of solvent needed, and the commercialization of renewable energy sources.
Considering the technological improvements, the ZNO/ZIF-8 photocatalytic system produced 28 kg CO2 equivalent per kg methanol output, significantly less than the carbon dots/carbon nitride system with 110 kg CO2 equivalent, but both methods were considerably more impactful than the commercial methanol production, 0.66 equivalents 110 kg CO2 equivalent.

P-81

Analyzing the carbon foot print of IT display products

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The paradigm of display technology has moved from CRT to LCD in the past, and is now moving to OLED. The outward direction of display technology is getting larger, slimmer and lighter. And in terms of picture quality, it is evolving to express vivid and rich colors. Recently, due to the influence of ESG, social expectations for eco-friendly products are increasing, and it is especially becoming important to analyze the carbon foot prints in order to practice the carbon neutrality. In this study, the environmental impact of IT display products was assessed through carbon based LCA. Based on the results, the carbon foot prints were analyzed for the life cycle of products and for main display functions. Furthermore, eco-friendly product strategies in terms of carbon foot print were discussed for IT display.

P-82

Case study of applying smart & safety solution using DT/AI

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1. Purpose of the study
70% of industrial accident fatalities occur in the construction industry and manufacturing sites, and the causes of death include collapse, fall, jamming/crushing, bumping, fire/explosion, etc. This study intends to study various smart environment/safety solution application cases for accident prevention, rapid response, and post-history management by utilizing ICT technologies such as 5G communication, Big Data, AI, and Digital Twin.Through this, workers who work at the manufacturing site protect their health in a safe and comfortable environment, and companies themselves identify risk factors to remove or replace them in advance and establish an integrated safety/environmental management plan to systematically improve industrial safety and health. We want to be able to respond to health.
2. Scope of the study
Data generated in equipment / people / environment / safety areas in device industries such as displays, secondary batteries, and petrochemicals, which require continuous large-scale investment, and assembly industries, such as home appliances, construction, and shipbuilding, which require a lot of manpower. We want to analyze a solution that can collect and monitor in real time through a wireless network, automatically control when an abnormality occurs, or detect an abnormality in advance.
3. Content of the study
The types of data generated at industrial manufacturing sites are: ① Numeric/character data collected through PLC and smart sensors ② Audio/video data collected through CCTV and smartphones ③ Location data of people and products collected through Beacons and GPS. By using above data : ① monitor what you want to see and know in real time ② analyze big data to diagnose abnormality and normality ③ use AI to give an alarm in advance when an abnormality occurs or before an abnormality occurs ④ remotely control. This study is application cases of smart environment/safety solutions were analyzed / researched

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P-83

Life cycle assessment of alcoholic beverage produced by highly refined Japanese rice

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Tokyo city university, Japan

Many Life Cycle Assessment (LCA) studies on agricultural products have already been international. Alcohol products such as wine and beer have also been evaluated in recent years, As Japanese food becomes popular overseas, the value of Japanese rice wine exports is increasing year by year. However, no LCA studies have been conducted on Japanese rice wine yet as far as we know. Therefore, we carried out an LCA case study on Japanese rice wine to examine measures for the reduction of its environmental impact. The calculated result of Japanese rice wine was compared with those of wine and beer, and we discussed their environmental characteristics considering the differences in raw materials and production methods. Japanese rice wine can be classified with the rate of polish in general. This study concentrated on the assessment of highly refined Japanese rice wine, with shaving rice down to 18%. The functional unit was 720ml (1 bottle). We visited a Japanese rice wine brewery to collect raw data and reflected them to calculate the carbon footprint.
The total amount of carbon footprint result was 2.6kg -CO_2eq, greatly affected by the production of brown rice and packing stages. The water footprint result was 3085 liters, mostly affected by the production of brown rice. Compared to other alcoholic drinks showed that red wine, Japanese rice wine, and craft beer, in that order, had the greatest impact on climate change. Therefore, we found that these key parameters affecting the totals are different from alcohols.

P-84

Evaluation of greenhouse gas emissions from bagasse-derived clothing

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The apparel industry has been pointed out as an industry with a large environmental impact due to the energy consumption associated with manufacturing and the short life cycle, which has become an international issue. Therefore, clothing and shoes that are friendly to the global environment are being developed. As one of them, we calculate the environmental impact of Jeans and Kariyushi shirts using bagasse as part of the material. Bagasse is a fibrous pomace of sugar cane most of them are discarded. By manufacturing Japanese paper yarn using powdered bagasse and Manila hemp pulp as raw material, it is possible to replace the new production of cotton yarn. We are conducting a hearing survey of process data in each process of fiber, yarn, dyeing, fabric, and clothing. In the future, I will conduct a field survey to understand the manufacturing process. Then, using the SimaPro LCA software, we compare them with the literature values and evaluate the validity. Kariyushi shirts are also considering developing a sharing service for tourists. It will be handed over at partner hotels, and after wearing it, it will be washed by a cleaning company. Therefore, it is considered that the life of the product will be longer than that of general use. In the disposal process, carbon storage is performed by manufacturing biochar from used clothing. In addition, I will also evaluate the environmental impact of improving the yield of sugar cane by applying biochar as a soil improvement material.

P-85

Life cycle assessment of imported jackets

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In 2019, the United Nations Conference on Trade and Development <UNCTAD> referred to the apparel industry as "the second-largest environmental polluter industry in the world”.
Products are managed in a complex and long supply chain of raw material extraction, processing, material production, finished product assembly, and transportation. Their carbon emissions, water use, and waste are factors that have a profound environmental impact on the climate crisis and biodiversity. The linear economy of "take, make, consume, and dispose of" is a value system that permeates modern society, and clothing is no exception. The value of "getting one new thing after another" is further accelerating its impact.
In recent years, many of the clothing sold in Japan has been imported after undergoing much of the production process overseas. The Ministry of the Environment has explicitly stated data that 98% of clothing sold in the Japanese retail market is sourced, spun, and dyed overseas. However, it is difficult to collect reliable data in LCA implementation for jackets imported through overseas production processes because of the diversity of stakeholders and lack of transparency.
In this study, LCA will be conducted for imported jackets used in outdoor sports, covering the entire process from procurement of raw materials, manufacturing, transportation, sales, use, and product recovery (circulation) after use. In collecting data for this study, primary data will be collected as much as possible based on interviews with companies to conduct a highly reliable analysis. Through these studies, responsible product manufacturing will also be mentioned.

P-86

Estimation of greenhouse gas emissions from mercury-contaminated municipal solid waste

treatment in Japan

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Spent fluorescent lamps and dry cell batteries contain mercury. Most local governments in Japan collect these wastes separately and recycle mercury from them. The Japanese government set a goal of net-zero greenhouse gas (GHG) emissions by 2050. Quantification and reduction of GHG emissions is also an essential issue in the waste treatment sector. Therefore, this study aims to estimate GHG emissions and discuss GHG reduction measures on the recycling activities of spent fluorescent lamps and dry cell batteries collected by local municipalities. More than 70 local governments answered our questionnaire regarding the treatment of mercury-contaminated municipal solid waste, such as fluorescent lamps and dry cell batteries. The questionnaire includes the amount of collected-fluorescent lamps and -dry cell batteries, collection methods, disposal methods, outsourcing companies, etc. Further, as primary data, fuel consumption during the recycling process was obtained from mercury recycling plants. Based on these surveys, we modeled the recycling system of these wastes in Japan, and GHG emissions were estimated using the life cycle assessment technique. The results showed that GHG emissions from the transportation of the spent fluorescent lamps were high. This is due to the small number of recycling plants in Japan. In addition, it was found that a large amount of GHG is emitted when fluorescent lamps are transported without being crushed. Indirect GHG reductions associated with the recovery of resources such as zinc were significant regarding dry cell batteries, and GHG emissions from transportation were small.

P-87

Factor decomposition analysis of changes in CO2 emissions from container operating companies

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CO2 emissions from international shipping were estimated as 1056 million tonnes-CO2, accounting for 3% of the global anthropogenic CO2 emissions and there is an urgent need to decarbonize the sector. To the best of our knowledge, there are few previous studies that attempted to estimate the CO2 emissions from the maritime sector of countries and regions. Based on the microdata of IHS Markit, this study estimated CO2 emissions from container ships owned by major seven operating companies (Maersk, Mediterranean Shipping Company, COSCO SHIPPING, CMA CGM, Hapag-Lloyd, Ocean Network Express, Evergreen) that occupy a large portion of fuel consumptions in maritime transport. Based on the CO2 emissions at company level, we develop a new factor decomposition framework to identify driving forces of the changes in the CO2 emissions from container ships. The results show that (1) CO2 emissions of each company increased by 3.5% on the company average from 2018 to 2019, however Maersk, Mediterranean Shipping Company, Hapag-Lloyd, and Ocean Network Express reduced CO2 emissions during the COVID-19 period (2019-2020); (2) the main reason for this reduction in CO2 emissions of the companies during the COVID-19 period was port calls (i.e., demand-side change factor); (3) the change in CO2 emission intensities in ton-CO2 per ton-miles of container ships (i.e., supply-side change factor) was marginal for all the companies. The environmental and business strategy shown in the sustainability reports provided by the companies has not yet been fully reflected in the major change factors identified in this study. Looking at the marginal contribution of the supply-side factors to CO2 mitigation, the operating companies should put more efforts on improving supply-side factors of size and speed of their vessels to reduce carbon intensity.

P-88

Latest practices and issues with avoided greenhouse gas emissions by ICT contributing to Green Transformation

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FUJITSU LIMITED, Japan

The Fujitsu Group aims to reduce greenhouse gas(GHG) emissions throughout the Fujitsu Group to zero by 2050 and contribute to achieving carbon neutrality and adapting to climate change. To contribute more aggressively to the resolution of environmental issues confronting humanity, Fujitsu revised its emissions reduction targets for its business sites in FY 2030 from 33% to 71.4% below FY 2013 levels.In 2021, these were validated as 1.5 ℃ aligned targets by the Science Based Targets initiative. In addition, Green Transformation(GX) has become important that contributes to the reduction of GHG emissions in line with digital innovation in society. With the introduction of its products and services, Fujitsu has promoted its contribution to avoided GHG emissions by ICT. We are contributing to GX through Artificial Intelligence, quantum-inspired Digital Annealer technology, cloud services, and high performance computing. Using the EcoCALC-GX internal system, which measures avoided GHG emissions, we are re-building an internal system and promoting skill transfer so that employees in the solutions & service development, and sales departments who

deal with business communication can measure the amount of the avoided GHG emissions by themselves and visualize the effect so that they can communicate their contribution to customers. At WG 17 of IEC TC111, the definition of avoided GHG emissions is currently being discussed. Fujitsu has also joined the National Committee as a member, introducing Fujitsu's efforts to date as a case study and actively participating in discussions on international standardization. In this presentation, we will introduce the latest practices of GX, introduce the amount of contribution we have made in avoided GHG emissions, and report on future issues. From now on, in order to make the world more sustainable, in 2021 we launched the new brand, Fujitsu Uvance (Universal + Advance), and would like to accelerate its realization together with our customers.

P-89

Greenhouse gas emission reduction potential of vehicle-to-grid technology: A case study in Kyushu, Japan

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Solar and wind power generation depend on the weather. Power output suppression control for reducing solar and wind power generation is introduced at a time of low electricity demand. An order of this control appeared in 2018, and the frequency of this order has been increasing in Japan, especially in Kyushu area. Vehicle-to-Grid (V2G) is a technology that utilizes electric vehicle (EV) batteries as a means of adjusting the supply and demand of electricity and avoiding wasting electricity derived from renewable energy sources. In general, the EV batteries are charged during the sunny daytime and discharged at night when electricity is dependent on fossil fuel-based generation. However, EV users expressed concerns about V2G, such as battery degradation, low battery storage when they use their EV, and restraint of parking time. Therefore, the purpose of this study is to identify users with a high affinity for V2G and to estimate the greenhouse gas (GHG) reduction potential. Data on the power output suppression control is based on Kyushu area from FY2018 to FY2021. Hours of use and charge are modeled by classifying EV users into three groups: commuting, daily use, and business. As a result, it is found that people who use EVs for business have a high affinity for V2G. They rarely use EV on day-offs while they use it daytime on weekdays. Therefore, it is possible to charge at a time when electricity tends to be excess. This study also demonstrated that adopting V2G can reduce GHG emissions. It is recommended that companies introduce EVs with V2G technology to reduce their emissions.

P-90

An environmental impact and economic analysis of palladium recovery in low concentration spent catalyst solution

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Recently, to realize carbon neutrality, the economic structure leading to the existing 'massive production - mass consumption - mass disposal' has been shifted to a circular economy that reduces the use of primary mineral resources and pursues a virtuous cycle of resources. In December 2021, the government established Korean K-Circular Economy Implementation Plan for carbon neutrality to invigorate the recycling of metal resources, such as rare metals. In this study, the project feasibility was evaluated from an economic point of view for the palladium recycling process in a low concentration spent catalyst solution, and the environmental effect was quantified adopting a Life Cycle Assessment technique.
As a result of the study, 1) The cost-saving effect of palladium recycling is estimated KRW 3.6 billion every year. 2) Advent, as a result of the B/C analysis, assuming that there is no scrap value of the facility after the 5 year project period, the total cost was KRW 103.13 billion and the total beneficial cost was KRW 121.43 billion, and the B/C was 1.18, indicating that it was a recycling process with high marketability and profitability.
3) As a result of LCA, it was found that fine dust emissions were reduced by 9 tons per year, and greenhouse gas emissions were also reduced 384 tons CO2-eq per year.
Finally, it was found that there was an employment inducement effect of 28 people through the creation of direct and indirect employment, which can be converted into a labor cost of KRW 108.82 billion. The research results showed that the palladium recycling in low-concentration spent catalysts solution has sufficient positive association effects with the local community in three aspects: environment, economy, and job creation.
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P-91

Efficient utilization of palm oil residue as material / energy products

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Biomass materialization / energy conversion contributes to issues such as the prevention of global warming and the achievement of a sustainable society, and thus active promotion of its utilization is strongly required. To date, however, the research fields related to unused biomass, such as leftover materials and agricultural crop residues, have not yet fully progressed. Therefore, for the new utilization of unused biomass, we focused on the oil palm (Elaeis guineensis) residue generated in large quantities after palm oil production, and conducted research on its materialization and energy conversion. Palm oil is mainly used for food, but its demand is expected to grow in the near future as a raw material to replace petroleum-derived plastics and as a chemical product. On the other hand, empty fruit bunches (EFB), which remain after palm oil collection are residues and increase with increase in palm oil production because they are generated in almost the same amount as the production of palm oil. The disposal method of EFB has been mainly incineration, but since the main component of EFB is cellulose, which is a renewable biomass, there is room for studying more effective utilization methods. Until now, regarding the utilization of biomass, studies have been conducted to convert biomass into solid materials or solid fuels individually, but there is no studies comparing the efficiency of the both at the same time.
The purpose of this study is thus to clarify the sustainability of EFB as solid fuel / solid material. First, flowcharts of each product including partly-finished product produced from oil palm were prepared, and the production ratio was calculated by applying the Markov process model. Next, LCA of each product was studied to determine which production process is significantly responsible for GHG emission.

P-92

Comparison of disassembly and assembly works using optical motion capture for circular economy

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End-of-Life assembly products such as smartphone and home appliance have played an important role for circular economy because they include recyclable metals and plastics. In contrast, most of the End-of-Life products are not reused and recycled. For instance, two-thirds of renewable resources are wasted in the United States, and 57% of large-sized home appliances in Japan are still at home. One of the reasons is that higher costs bring manufactures for recycling by disassembly. Hence, not only assembly but also disassembly works are required to take materials from the End-of-Life products in reuse and recycling. However, manual disassembly is still necessary due to assembly complexity which brings higher labor costs. Therefore, disassembly motions should be analyzed and improved. Thus, motion capture systems are expected for analyzing and improving them. This optical motion capture enables us to measure 3-dimensional coordinate data for workers with high accuracy. Toshiba Corporation (2018) has introduced the motion capture for the purpose of more effective guidance and skill transfer at the work site using 3-dimensional sensors. Kawane et al. (2022) analyzed worker's motion using motion capture and deep learning software. However, disassembly works were not treated. This study measures, analyzes and compares the motion data for disassembly and assembly works obtained by optical motion capture for circular economy. First, the motion data for disassembly and assembly works is obtained by optical motion capture. Next, the data preprocessing is conducted. Finally, the pre-processed motion data for the disassembly and assembly works are analyzed and compared.

P-93

Quantification of the environmental impacts associated with human labour

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The contribution of human labour is not usually included in the environmental assessment of products and processes. This omission may constitute an unfortunate bias, resulting in leaking of environmental effects and, thereby, systematically misinformed decision-making. This is especially true for those products and processes where the role of manpower is relevant, i.e. in labour intensive sectors.
Therefore, in this study, we propose a methodological framework to give an answer to the question "how could the contribution of human labour to the environmental assessment of products and services be evaluated"? To this aim, the following contributions are included in the framework: the energy spent at work and that spent in driving to/from the work, and the corresponding food quantity burned to get that energy; worker transports; use of workers facilities (toilets and shelters); personal safety devices; handheld tools.
The proposed methodological framework has been applied in a life cycle assessment (LCA) study where a traditional demolition is compared to a selective one. A selective demolition includes a series of sorting operations into homogeneous fractions, using machinery and equipment, with the primary goal of maximization of reuse and recycling of the construction and demolition waste.

Selective demolition is usually perceived as essential for a sustainable built environment since it aims to maximise the valorisation of constituent building materials and components giving them a new life. At the same time, a selective demolition requires many more man-hours than traditional demolition. And this difference should therefore be included in the LCA study to evaluate how it influences the environmental impacts of the two practices and so the comparative assessment. This is possible under the proposed framework that can also be adapted for other labour intensive services and products.

P-94

Analysis of material flow in mercury recovery process for determining the characteristics of mercury behavior

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Mercury has an addictive and highly toxic effect on humans. An example of mercury damage case is Minamata disease caused by methylmercury.
The international community's perception of mercury has changed and the mercury convention has been discussed. In 2013, the "Minamata Convention on Mercury" was adopted by UNEP. Korea participated in a party to the 2020 Minamata Convention and implement the agreement. By 2027, a mandatory standard has been established to recover more than 70% of the mercury.
In this study, the behavioral characteristics of the mercury recovery process of the waste mercury lamp are identified for the purpose of systematic management of mercury.
The mercury recovery process consists of input, crushing, heating, and condensation processes. Mercury in the waste lamp is heated to 600℃ or higher. It is then recovered through a condensation process. Glass and iron, which are by-products of mercury-removed lamps, are recycled. In addition, Cyclone, Bag filter, and activated carbon adsorption facilities are installed in each process step.
In order to understand the behavior of mercury in the entire process, it was set based on the amount of waste lamps put into the process for one year. Mercury input, recovery, disposal, content in by-products, and air emissions were identified, measured, and analyzed. Based on this, a material flow chart was created.
The results of a study, Mercury recovered from the facility was found to be 89.73% of the input. the disposed mercury through air pollution prevention facilities was found to be 7.26% in the crushing process and 2.07% in the heating process, 0.79% of air emissions, and 0.16% contained in by-products.
This work was supported by Korea Environmental Industry & Technology Institute(KEITI) grant funded by the Korea Government (Ministry of Environment)(The Knowledge-based Environmental Service Specialized Graduate School Program).

P-95

Carbon-circularity-based evaluation of recycling process with dynamic MFA approach

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Toward the realization of carbon neutrality, waste plastics (WP) recycling is a crucial activity to prevent carbon release from WP. Although several modes of WP recycling have been studied so far, consideration of recycled products' lifetimes and circularity tended to be lacking. Without tracing mid- or long-term carbon circulation, a truly effective WP recycling system for carbon neutrality can not be developed. This study modeled carbon circulation through WP recycling activities by applying the MaTrace approach considering product lifetimes and distributions varied with recycling modes. The dynamic material flow analyses of ten resin types (e.g., polypropylene, polystyrene, and polyethylene) were conducted and subsequently integrated into the carbon cycle. Focused on resins newly entering the country in 2011, the state transitions (in use, export, and dissipation) after t years ($0 < t < 50$)were traced. The amount of total recycled carbon for 50 years per initial input (S_50) and the year in which carbon becomes one-fourth of the initial carbon (τ_0.25) were considered as the indicator of carbon cycle efficiency. Three scenarios were considered: the current recycling practice in Japan, mechanical recycling (MR) only, and chemical recycling (CR) only. MR and CR only scenarios are cornerstones, set for clarifying the maximal potential of the recycling modes. In CR only scenario, sub-scenarios varying with/without self-supply of produced oil as a heat source were considered. While the current practice could utilize the carbon almost only once (S_50=1.07), MR only and CR only with self-supply scenarios had higher S_50 (~1.20) and τ_0.25 (~16). CR only without self-supply had the highest values (S_50=1.63, τ_0.25=30). A comparison of the results of two CR scenarios suggested the energy with an emissions intensity of 0.0738[kg-CO2eq/MJ] could work CR without self-supply in both avoidance of GHG emissions and recycling carbon.

P-96

LCA experts training graduate program supported by the Korean government

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Since the Paris Agreement, declarations of carbon neutrality by the international sector is gaining steam for combating the climate crisis, and carbon neutrality is quickly becoming the global standard. In order to achieve efficient carbon neutrality it is not only important to consider the scope 1 and 2 emissions of GHGs from sources but also the scope 3 indirect emissions during the product value chain. Also, as the carbon reduction impact of LCA is recognized, the demand for LCA-applied carbon footprint information is increasing. For example, restrictions in international trade due to the carbon emissions factor is on the rise as is evident from the EU's PEF(Product Environmental Footprint), CBAM(Carbon Border Adjustment Mechanism) and the Clean Buy Act by California of the U.S. Therefore, assessment and management of scope 3 GHG emissions and reductions based on LCA have become necessary due to the fast-moving trends in international environmental issues. However, there is a lack in the number of experts who specialize in global environmental regulation response related to products. This is especially true in the case of sustainable design and LCA. To this end, the Korean government selected 4 universities starting in 2021 to support LCA related graduate programs for 3~5 years. Each university program should produce about 20 experts every year and it is anticipated that they will be utilized in the fields of LCI database, carbon footprint, eco-design, and responding to global environmental regulations. Our KU-LCA program in the Konkuk University Graduate College was one of the programs and it is offering an integrated curriculum involving several departments. The KU-LCA program offers: L(Leadership & Training – basic, intensive and applied levels of education); C(Company & Cooperation – interaction various industrial sectors through on-site field training; and A(Action & Application – opportunities to apply their obtained knowledge through internships.

P-97

Environmental impact assessment for polyester T-shirts -Prospective LCA for chemical recycling

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Purpose of this study is to evaluate the greenhouse gas (GHG) reduction effect of chemical recycling that can recycle resources into materials with the same composition, the same quality, and the same performance. Life Cycle Assessment (LCA) shows the environmental impact of polyester T-shirts manufactured from recycled PET using chemical recycling and manufactured from virgin material.

The system boundary of evaluation is the flow of T-shirts which is manufactured in China, sold and used in Japan, carried out chemical recycling in Japan, manufactured T-shirts in China again, sold and used in Japan, and then discarded.

The calculation was processed mainly for primary data for manufacturing process and store process, and the inventory database used the overseas version of IDEA2.

This calculation results show GHG emissions from PET manufacturing, chemical recycling, store and consumer process are large. As a result of comparing the GHG emissions of 10% chemical recycling/90% material recycling (circular economy scenario) within the range used as commercially available recycled products, and incineration (linear economy scenario), the circular economy scenario was able to reduce GHG by about 10%.

Furthermore, this study attempted the prospective LCA, which is expected to reduce the environmental load in the production scale rather than the research and development scale. Although this chemical recycling was carried out with a small-scale demonstration machine, it was confirmed that 50% chemical recycling/50% material recycling by increasing the scale of chemical recycling to the scale of existing commercial machines are almost the same as the above 10% chemical recycling/90% material recycling.

Based on the above, in apparel industry, chemical recycling has the potential to become a technology that has the same quality as virgin materials, has little impact on climate change, at the same time, that realizes a circular economy which does not deplete resource.

P-98

Analysis of treatment and resources circulation for marine litter

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It is estimated that plastics accounted for 80%(±18%) of the global marine litter. In addition, Metal (7%±7%), glass (5±6%) and fabric (3±3%) accounts of the global marine litter. The amount of plastic waste entering the aquatic ecosystem is expected to triple from 11

million tons in 2016 to 29 million tons by 2040. Marine Litter can be a potential risk not only to marine organisms but also to humans. That why efforts such as prevention of occurrence, collection, treatment of these marine litter risks are required. Also, the collected marine litter contains many components such as salinity and foreign Materials. Therefore, the rate at which most marine litter is incinerated, landfilled, treated or recycled is low. In this study, we dealt with the treatment status of marine litter and the case of resource circulation. It also suggests ways to implement a resource cyclical system for marine litter.

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