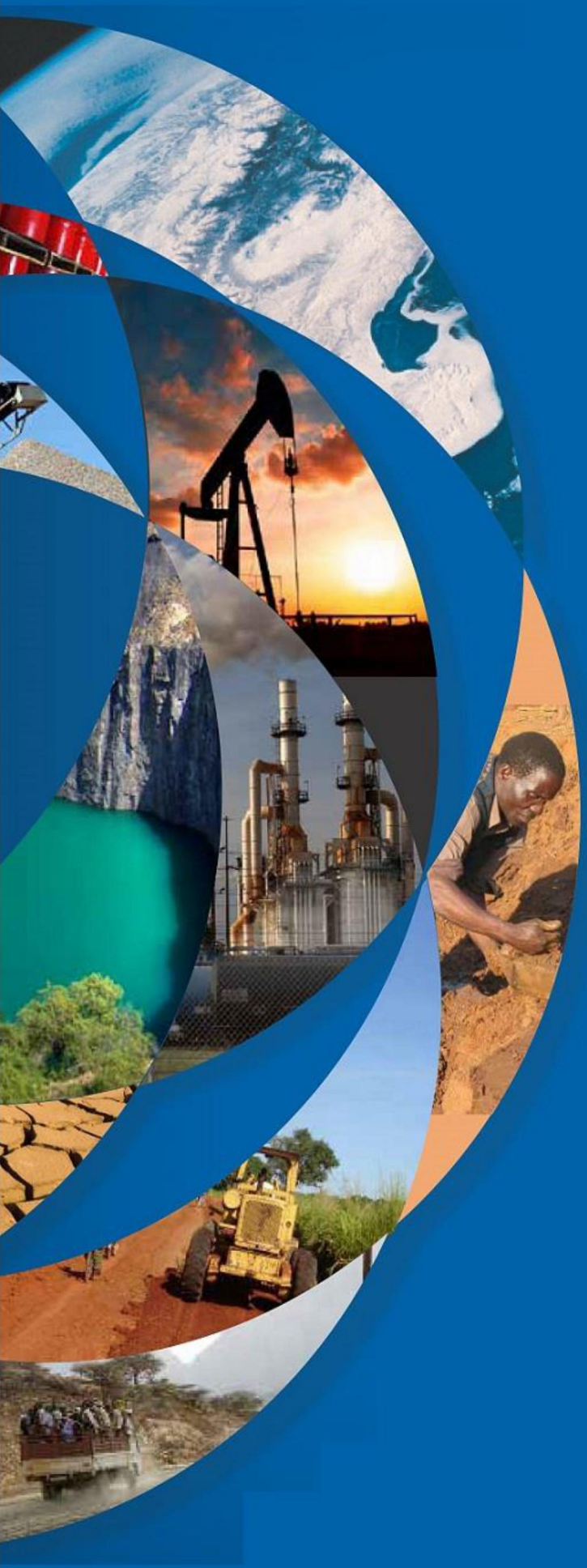
# icRS 2022



## 2022 International Conference on Resource Sustainability

**August 1-4, 2022**
**All Virtual**

**www.icrsconf.com/icrs_2022.html**

UNIVERSITY OF MICHIGAN

# Contents

# Welcome to icRS 2022

August 1-4, 2022, Virtual
www.icrsconf.com/icrs_2022.html

## 2022 International Conference on Resource Sustainability (icRS 2022)

**Welcome to icRS 2022!**

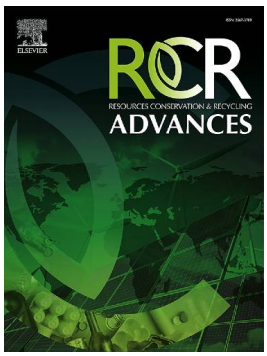
The sustainable development of human society depends on resources. Addressing critical societal challenges, such as climate change, resource depletion, and environmental protection, requires sustainable management of resources using interdisciplinary approaches.

The International Conference on Resource Sustainability (icRS) series serve as an international platform for researchers and practitioners around the world with diverse background and expertise to share the most recent ideas, outcomes, and practices on resource sustainability.

Although COVID restrictions have been eased in many countries, there are still critical challenges for many to travel due to health and cost concerns. At the same time, environmental impacts caused by large in-person events have been extensively debated for concerns such as substantial carbon footprint. Therefore icRS 2022 will be held completely **online** to accommodate attendees who cannot travel and help reduce our footprint on the environment.

icRS 2022 is sponsored by the flagship journal in sustainable resources management *Resources, Conservation & Recycling* (RCR; 2021 Impact Factor: 13.716) and its companion journal *Resources, Conservation & Recycling Advances* (RCRADV; 2021 CiteScore: 14.5). The conference will include keynotes speeches and oral presentations. High quality papers presented at icRS 2022 will be recommended to special issues in these journals as well as other supporting journals.

**We are looking forward to meeting you.**


**Prof. Ming Xu**

**icRS Conference Chair**

# Keynote Speakers

**Prof. Veena Sahajwalla**
University of New South Wales

**Date:** 2:10-3:10pm (Beijing), August 1
**Zoom link:**
https://umich.zoom.us/j/92625430717

## A smart vision for a sustainable future: SMaRT technologies and MICROfactories™ creating sustainable materials and products from waste resources

Professor Veena Sahajwalla is an internationally recognised materials scientist, engineer, and inventor revolutionising recycling science. She is renowned for pioneering the high temperature transformation of waste in the production of a new generation of 'green materials' at the UNSW Sustainable Materials Research and Technology (SMaRT) Centre, where she is Founding Director. Professor Veena is the inventor of polymer injection technology, known as green steel, an eco-friendly process for using recycled tyres in steel production. In 2018, Veena launched the world's first e-waste MICROfactorieTM and in 2019 she launched her plastics and Green Ceramics MICROfactoriesTM, a recycling technology breakthrough. Veena is the director of the ARC Industrial Transformation Research Hub for 'microrecycling', a leading national research centre that works in collaboration with industry to ensure new recycling science is translated into real world environmental and economic benefits.

**Prof. Wilson W.S. Lu**
The University of Hong Kong

**Date:** 2:00-3:00pm (Beijing), August 2
**Zoom link:**
https://umich.zoom.us/j/96785802694

## Developing a Waste Trade Organisation (WTO) to Boost Construction Waste Material Sharing in the Guangdong- Hong Kong-Macao Bay Area

Dr Wilson Lu is Professor in the Department of Real Estate and Construction, Faculty of Architecture, the University of Hong Kong (HKU). His research interests focus on Construction Management with two directions: *Construction informatics* (Building Information Modelling, smart construction, and big data, and blockchain) and *Construction waste management* (Management, economics, and public policies). Prof. Wilson Lu is the leader of research grants worth HK$40+ million from various prestigious funding regimes. He is the author of more than 180 books, book chapters, and journal papers. He has a Google Citation > 10,000 and H-index > 57. He has been ranked as one of the Top 1% Scholar by Clarivate Analytics since 2017. He was the receiver of HKU Outstanding Young Researcher Award 2014-15, HKU Faculty Knowledge Exchange (KE) award 2018-19, and HKU Faculty Research Output Prize (ROP) award 2018-19. Prof. Lu is the Director of iLab@hku, Prof. Lu has been the Associate Dean (Research) of Faculty of Architecture (FoA) since March 2016. He is the President of the Chinese Research Institute of Construction Management (CRIOCM)environmental and economic benefits.

# Keynote Speakers

**Prof. Gang Liu**
University of Southern Denmark

**Date:** 2:00-3:00pm (Beijing), August 3
**Zoom link:**
https://umich.zoom.us/j/97548697901

## Moving beyond carbon tunnel vision with a resource sustainability perspective resources

Gang Liu is a professor of Industrial Ecology at SDU Life Cycle Engineering, Department of Green Technology, University of Southern Denmark. His research interests evolve around mapping and informing societal circular, low carbon, and just transition based on characterizing material and energy stocks and flows and their environmental consequences in a systems context. His work has been published widely in high-profile journals such as Nature Climate Change, Nature Food, Nature Communications, and Environmental Science & Technology, and covered by domestic and international media. He has been awarded the Robert A. Laudise medal by the International Society for Industrial Ecology and the James J. Morgan Early Career Award by Environmental Science & Technology. He is co-Editor-in-Chief of the Journal of Industrial Ecology and serves as an editorial board member for several other journals in the sustainability field.

**Prof. NANSAI Keisuke**
National Institute for Environmental Studies, Japan

**Date:** 2:00-3:00pm (Beijing), August 4
**Zoom link:**
https://umich.zoom.us/j/91397190001

## Material budgets towards a net-zero carbon society

Keisuke Nansai is Research Director of the Material Flow Innovation Research Program (mfi.nies.go.jp) and Head of the Global Resource Sustainability Research Section at the Material Cycles Division at the National Institute for Environmental Studies (NIES), Japan. He is an adjunct professor at the Graduate School of Environmental Studies at Nagoya University in Japan. He is also a panel member of the International Resource Panel (IRP) of the United Nations Environmental Program. He is serving as an editor of Resources, Conservation & Recycling (Elsevier). Keisuke's expertise is environmental systems analysis based on life cycle thinking, and he has mainly applied input-output analysis, life cycle analysis and material flow analysis to sustainability assessments. Keisuke's current research interest is the nexus of planetary health and sustainable material use, such as material criticality regarding climate change mitigation/adaptation, human health impacts via material consumption, and global material trade harmonised with the planetary health.

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# Abstracts

## DAY 1 Session 1

### Unevenly Distributed CO2 And Its Impacts on Terrestrial Carbon Uptake

Xiangzheng Deng1,2,3, Wei Cheng1,2, Sijian Jiang1,2,3
Organization(s): 1: Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; 2: Key Laboratory of Land Surface Pattern and Simulation, Chinese Academy of Sciences, Beijing 100101, China; 3: University of Chinese Academy of Sciences, Beijing 100049, China

**Abstract**
Increases in atmospheric carbon dioxide (CO2) concentrations is the main driver of global warming due to fossil fuel combustion. Satellite observations provide continuous global CO2 retrieval products, that reveal the nonuniform distributions of atmospheric CO2 concentrations. However, climate simulation studies are almost based on a globally uniform mean or latitudinally resolved CO2 concentrations assumption. We reconstructed the historical global monthly distributions of atmospheric CO2 concentrations with 1° resolution from 1850 to 2013 which are based on the historical monthly and latitudinally resolved CO2 concentrations accounting longitudinal features retrieved from fossil-fuel CO2 emissions from Carbon Dioxide Information analysis Center (CDIAC). And the spatial distributions of nonuniform CO2 under CMIP6 Shared Socio-economic Pathways and Representative Concentration Pathways scenarios were generated based on the spatial, seasonal and interannual scales of the current CO2 concentrations from 2015 to 2150. Then, the spatial distribution of CO2 concentrations was introduced into the coupled Beijing Normal University Earth System Model (BNU-ESM) to study the responses of temperature, surface energy balance, and terrestrial carbon uptake to non-uniform CO2 distribution. Relative to the uniform CO2 simulation, global annual mean surface air temperature increases by 0.44 ± 0.03 ℃ over 2071-2100 when forced with non-uniformly distributed CO2, in the Arctic by 1.63 ± 0.28 ℃ and by 0.67 ± 0.08 ℃ in northern midlatitudes. The non-uniform CO2 simulation increases global surface energy by 0.68±0.06 W m-2, principally due to a 0.73±0.08 W m-2 increase in net downward surface longwave flux. Results showed that, in the mid-high latitudes, the non-uniform CO2 leads to a 0.1 Pg C year-1 reduction in terrestrial carbon uptake. The changes in surface energy fluxes and terrestrial carbon uptake imply reduced time and emission space for greenhouse gases before running into scientific and politically flagged temperature limits.

### Verifying The Synthesized Effects of Intensive Urban Land Use on Quality of Life, Ecology, And Urban-Land-Use Scale in China

Bingqing Li, Zhanqi Wang, Ji Chai
Organization(s): China University of Geosciences, Wuhan, China, People's Republic of

**Abstract**
Intensive urban land use has been proposed as a method to promote sustainable development in the context of rapid urban sprawl. However, a consensus has not been reached on whether this approach is beneficial for ecology and compatible with suitable living conditions. Exploring this issue in China will help promote high-quality development. Extant research has mainly explored the effects of intensive urban land use on quality of life, ecology, and urban-land-use scale separately, while a synthesized analysis in this regard is lacking. In the light of this, we establish an analysis framework by which to verify the effects of intensive urban land use on the three aspects, using data from China spanning 2005–2019, subjected to structural equation modeling. The results show that intensive urban land use has varying degrees of positive effects on quality of life, ecology, and urban-land-use scale. It had no strong effect on the three items initially, while quality of life was significantly optimized by 2010, and ecology was markedly improved from 2015. However, there was a trend toward shrinking living space and sprawling urban areas. The corresponding suggestions are formulated for policy makers to improve intensive urban-land-use policy.

## Research on the Synergy of Grain Productivity Improvement and Its Carbon Reduction in China

Yifei Wang
Organization(s): INSTITUTE OF GEOGRAPHIC SCIENCES AND NATURAL RESOURCES RESEARCH，Chinese Academy of Sciences, China, People's Republic of

**Abstract**
Food security threatened by climate change is one of the most severe global challenges of the 21st century. The agricultural sector has great potential to reduce emissions. In China, a win-win strategy to achieve food security and carbon peaking and carbon neutrality goals is an urgent need for agricultural modernization development. In this study, we described the spatial-temporal characteristics of China’s grain productivity in the past 20 years based on the ESAP model. Then we identified the synergistic state of provincial grain productivity improvement and its carbon reduction using the General G statistic, and further explored the driving effects of production factors, resource utilization efficiency, agricultural management practices, and socio-economic development on the synergistic state using the spatial econometric model. The study showed that grain productivity of China showed a trend of first decline and then recovery, with an overall increase of 9.7%. The spatial pattern of high in the south and low in the north gradually was weakened. High-yield areas of grain (middle and lower reaches of the Yangtze River Plain, the Pearl River Delta Plain, and North China Plain) showed a synergistic trend of grain productivity improvement and carbon reduction. Northeast China is a key area for alleviating the pressure of agricultural carbon emissions under the northward shift of grain productivity in China. It is necessary to increase technical investment to improve crop varieties while maintaining arable land productivity, and reduce the risk of non-carbon dioxide emissions. Conservation tillage is an agricultural management practice that can effectively promote the synergy of grain productivity improvement and its carbon reduction (DEcons=0.018*). Our

research provides a reference for the optimal layout of grain production in China under climate change. It helps to achieve a win-win strategy constrained by food security and carbon peaking and carbon neutrality goals.

## Weakening in Terrestrial Carbon Uptake in A Carbon Reduction Climate

Wei Cheng, Xiangzheng Deng
Organization(s): Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, China, People's Republic of

**Abstract**
Carbon dioxide emissions will need to decrease substantially in the future if 2 ℃ target relative to pre-industrial is to be met. Here we examine the responses of terrestrial carbon uptake to the carbon emission reduction. Globally averaged terrestrial carbon uptake (TCC) becomes weak under carbon emission reduction scenario relative to business as usual, with the 101.9±6.7 Pg C (51%) reduction in the accumulate TCC during 2040 to 2100. Changes in TCC are highly associated with reduction in atmospheric CO2 concentrations and the resulting climate change, which contribute to about 59% reduction in TCC. While the rest part of reduction in TCC could be due to enhanced human and natural disturbances mainly from crop harvesting, deforestation, land-use change and fires. These results imply that weakened disturbance effects and more aggressive carbon reduction will be needed for carbon neutrality target when considering the adjustment in terrestrial carbon sink.

## Spatio-Temporal Changes of Historical and Scenario-Based Methane Emissions from Rice Field in Black Soil Region of Northeast China

Zhihui Li, Yifei Wang, Xiangzheng Deng
Organization(s): Institute of Geographic Sciences and Natural Resources Research, CAS

**Abstract**
Methane emission from rice fields is a major source of agricultural methane emission in China. Black soil region of Northeast China is the largest grain production base of the country. Greenhouse gas emission reduction of agricultural sector is a critical part to realize sustainable utilization of black soil. In this study, we comprehensively applied remote sensing data and the methane emission process model to quantify the total amount of methane emission and the emission level from rice fields in black soil region of Northeast China. The spatio-temporal distribution characteristics of methane emission and the impact of rice production on methane emission connecting with cultivated land distribution and rice allocation were further analyzed. Additionally, we predicted methane emission potential in the future till 2035 based on scenario analysis of climate change, food security, and agricultural management practice. Our study found that, the spatio-temporal distribution of total methane emission was consistent with that from rice fields in the black soil region of Northeast

China. Increasing rice production has significantly increased the total amount of methane emission from black soil. Methane emission from rice fields was estimated to increase by 18% - 64% in 2035 compared with that in 2018 approximately. Implementing effective policy and field management measures can alleviate methane emission from rice fields. Our study provided a theoretical basis for agricultural emission reduction and natural resources management in black soil region of Northeast China

## The Impact of Land-Use Land Cover Changes on the Ecosystem Services and Food Security in Afghanistan- An Investigation of The Past and Future

Omaid Najmuddin1, Li Zhihui2, Rabnawaz Khan1, Weiqing Zhuang1
Organization(s): 1: School of Internet Economics and Business, Fujian University of Technology; 2: Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences

**Abstract**
Due to limited industrial growth, ecosystem services in Afghanistan remains the primary source of livelihood and food security. National food security is largely dependent on the local food production provided by the ecosystem. The livelihood of more than 70% of the population is directly or indirectly supported by agricultural and other supporting land-uses. Ecosystem has, however, lost its productivity due to the four decades of continuous instability in the country. The crisis grows as rapid population growth and deteriorating climatic conditions further add the pressure on ecosystem. Of the identified ecoregions in Afghanistan, 38% areas are currently classified endangered while another 61% is in a vulnerable land category. During the past two decades, with the support of international donors, some efforts are made to restore the food production to its pre-war statues. Unfortunately, sufficient information of the rates of ecosystem services changes and food production capacity in Afghanistan is still missing. Therefore, this study attempts to communicate the ecosystem capacity change during the past two decades and provide an assessment of the future prospective of food production capacity in Afghanistan. For this, land-use change based ecosystem valuation was used as a simple method to investigate the ecosystem services changes. However, this study do not only account the supply changes, but it also accounts the simultaneous changes in demand of ecosystem services and the quality effect of land-use on ecosystem services. The ecosystem services assessment is followed by the development of various scenarios of population growth, economic development and environmental conservation policies. The flow of ecosystem services, particularly food provisioning, is estimated under the given scenarios and compared with the respected expected demand in future. Upon the comparison of demand and supply of ecosystem services, the study will conclude providing concrete policy recommendations while focusing food security in Afghanistan.

## DAY 1 Session 2

## Proliferation of Waste Treatment Facilities in Chinese Cities: Patterns And Influencing Factors Revealed By Recent Data

Xiao Li1, Yanan Ren2, Xuezhao Chen1, Yang Li3, Marian Chertow4
Organization(s): 1: School of Public Policy and Administration, Xi'an Jiaotong University, PRC; 2: School of Environment, Tsinghua University, PRC; 3: Growth Lab, Harvard Kennedy School, Harvard University, USA; 4: Center for Industrial Ecology, School of the Environment, Yale University, USA

**Abstract**
Driven by rapid economic growth and urbanization, cities in emerging economies such as China generate soaring quantities of municipal solid waste (MSW) soon accompanied by a proliferation of waste management facilities. The development of MSW management infrastructure is a result of combined influences based on a variety of socio-economic factors. The literature has provided some baselines for understanding development pathways and driving forces. It remains unclear, however, how much these theoretical baselines can explain the real-world situation in China, as reflected by the debate over the development paths of MSW management infrastructure. Our paper aims to track the development history of MSW management infrastructure across Chinese cities with detailed data and to uncover important patterns and trends. We find that the development patterns have been significantly shaped by the imbalance of development levels and endowments among regions in China. More focused attention is needed to update construction guidelines and regulations and to provide support for building the technological and managerial capabilities to improve MSW treatment infrastructure

## Can Industrial Agglomeration Increase The Wood Resource Efficiency?

Chang Yu, Chenlu Tao
Organization(s): Beijing Forestry University, China, People's Republic of

**Abstract**
Wood is the only biodegradable, renewable, and recyclable material among the four major raw materials (i.e., wood, steel, cement, and plastics). The use of wood resources would replace high-energy-consumption materials such as steel and plastics, which can achieve the goal of sustainable resource utilization and climate change mitigation. China is the major wood processing country with a complete upstream and downstream industrial chain. For instance, in the wood-based panel industry cluster in Linyi, Shandong Province, the regional annual production capacity has reached more than 30 million tons, a leading position throughout the world. Therefore, China's efficiency in wood resources has a crucial influence on the global wood utilization.

This study aims to explore the impact of industrial agglomeration on wood resource efficiency and evaluate the possibility of improving the efficiency of wood resource use by expanding wood

processing clusters. We analyzed the spatial-temporal evolution of total factor productivity of Chinese wood processing enterprises. Furthermore, we discussed the relationship between spatial agglomeration and wood resource efficiency from the perspective of heterogeneity. The results show that the average total factor productivity of Chinese wood processing enterprises achieved the largest improvement from 1998 to 2007. We also found that the spatial agglomeration of China's wood processing industry has a significant positive impact on total factor productivity. From the perspective of enterprise types, the spatial agglomeration of state-owned wood processing enterprises has a significantly greater positive impact on total factor productivity than private enterprises. The spatial agglomeration of the wood processing industry in eastern China has a greater positive impact on total factor productivity than in western and central China. The productivity of China's wood processing industry has reached a relatively high level, which can provide lessons for emerging countries in terms of industrial cluster allocation and development models.

## The Driving Factor Analysis and Prediction Research on The Amount of Municipal Solid Waste in China

Wei Yan1,2, Shu le Liu1, Zheng fang Wu2, Qing xian Gao1, Hai bo Du2, Zhanyun Ma1
Organization(s): 1: China Academy of Environmental Sciences, Beijing 100012, China; 2: Northeast Normal University, Changchun 130024, China

**Abstract**
With the rapid development of social economy in China, the amount of municipal solid waste (MSW) is increasing yearly. Therefore, it is important to accurately predict the amount of MSW for subsequent treatment and disposal. Based on an analysis of the historical emission trends of MSW production in China (2000-2020) and its nine driving factors. Using the auto regressive moving average (ARIMA) model and the multiple linear regression analysis method, a prediction model for MSW generated is established, which realizes the different research scales of the production of urban domestic waste in regions, cities, and climate zones from 2021 to 2035. The results show that: GDP, urban population and urban built-up area are the main drivers of MSW generation in China. The spatial distribution of MSW generation at each stage and waste treatment has a strong directional consistency and shows an increasing trend. The MSW generated in 2000, and 2020 was mainly distributed in the gradient range of 0.78-250 thousand tons and 25-500 thousand tons. It is expected that the amount of waste generated in China will continue to increase gradually in the next 15 years. Compared with the central and western regions, the eastern region has a faster growth rate. It is significantly higher than that of megacities. The waste production in the temperate continental climate zone and the temperate monsoon climate, subtropical monsoon climate and tropical monsoon climate region shows an opposite decreasing trend. It is estimated that by 2035, waste production will reach 323.17 million tons.

## Housing Vacancies Assessment in Shandong Peninsula Urban Agglomeration Based on Multi-Source Remote Sensing Data

Dong Yang1, Bing Xiao1, Xuexiu Jia2, Lingwen Sun1, Feng Han1, Feng Shi3
Organization(s): 1: Institute of Science and Technology for Development of Shandong, Qilu University of Technology (Shandong Academy of Sciences), Jinan 250014, China; 2: Sustainable Process Integration Laboratory – SPIL, NETME Centre, Faculty of Mechanical Engineering, Brno University of Technology - VUT Brno, Technická 2896/2, 616 69 Brno, Czech Republic; 3: School of Environmental Science and Engineering, Qilu University of Technology (Shandong Academy of Sciences), Jinan 250014, China

**Abstract**
As the urbanization rate in the world has increased rapidly, the housing vacancy problem has become serious and attracting more attention. Calculating and analysing vacant housing will also help reduce the wasteful use of resources. This paper measures the housing vacancy rate and housing vacancy stock in Shandong Peninsula urban agglomeration using night-time lighting data and land use data. The results show that the average housing vacancy rate in the Shandong Peninsula urban agglomeration rose rapidly from 14.7% in 2000 to 29.7% in 2015, and then slowly declined to 29.5% in 2020. As urban population growth is lower than the housing construction rate, the average annual housing vacancy stock growth in megacities exceeds 3 million square meters between 2000 and 2020, and the average annual housing vacancy stock growth in large and medium-sized cities is 1-2 million square meters, the vacant housing has caused a lot of waste of housing resources. In addition, the LMDI decomposition method is used for the decomposing analysis of the housing vacancy stock, and the driving factors of the housing vacancy are analysed. Results indicate that the economic development level has a positive influence on, and is also the most significant driving factor in the vacant housing stock. The value effect of unit floor areas is the major driving factor inhibiting the growth of vacant housing stock, and the decline of unit floor area value is conducive to the reduction of vacant housing stock.

## Comparing Industrial Linkage of Water Footprint between Developed and Developing Country

Wenjun Xia1,2, Xiaohong Chen1,2
Organization(s): 1: Center for Water Resources and Environment, Sun Yat-sen University, Guangzhou, China; 2: School of Civil Engineering, Sun Yat-sen University, Zhuhai, China

**Abstract**
Industrial structure affects the consumption of water resources. It not only affects the environmental quality through sewage discharge, but also affects the water consumption of other industries from the supply or demand side. There are differences in industrial structure and water pressure between developed and developing countries, so it is essential to compare the industrial linkages of water

footprint between developed and developing countries for the adoption of adaptive water-saving strategies. Previous studies focused on individual country and ignored the embodied environmental impacts of industrial drainage. This study takes developing country-China and developed country-the United States as the research objects, and uses the absolute weighted measurement method (AWMM) to estimate the backward and forward linkage of blue water and gray water footprint from 1995 to 2014. The results show that agriculture and food & beverage sectors are the largest water consumers for blue water from demand side. In China, agriculture is obviously the significant driving sector, followed by the secondary industry, while food & beverage has the highest pull from the demand side in the United States, followed by the tertiary industry. Moreover, agriculture, petrochemical and mining sectors, which are upstream resource groups, have a great driving effect of water consumption on the supply side. In terms of grey water, the tertiary industry is a strong driver in the United States, while metal manufacture, thermal power and other industries play a dominant role from the supply side in China. Besides, fixed effect model shows that economic linkage has the greater impact on industrial linkage of water footprint than environmental indicator. Therefore, to promote water saving, it's essential for developing countries to control high water consumption sectors, especially agriculture and secondary industry, and developed countries should focus on improving water efficiency of the tertiary industry.

## The Decoupling between ICT Sector Output, Energy Consumption and Carbon Emissions: A Global Value Chain Perspective

Bo Ren1, Huajiao Li1,2, Jianglan Shi3, Huijun Ren4, Ning Liu5
Organization(s): 1: China University of Geosciences (Beijing), China, People's Republic of; 2: China International Economic Exchange Center; 3: Hebei University, School of Management; 4: China National Coal Research Institute; 5: Shandong University of Technology and Business, School of Economics

**Abstract**
The information and communications technology (ICT) sector is a key sector that promotes economic development and sustainable development. At the same time, it also brings environmental problems that cannot be ignored in the process of development. In order to qualitatively and quantitatively analyze the environmental effects of the ICT sector, this paper takes the global value chain (GVC) as the carrier, and divides the global value chain of the ICT sector into "high-position" countries and "low-position" countries according to the GVC-Position. Studying the evolutionary trends and decoupling of their output, energy consumption and carbon emissions. Results show that from the perspective of climate change and sustainable development, the "high-position" countries should be the focus of attention. The period from 2012 to 2016 was a special period for the global value chain (GVC) of the ICT sector. During this period, the decoupling relationship between output and energy consumption and carbon emissions in "high-position" countries deteriorated, while the decoupling relationship in "low-position" countries was more optimistic. In addition, the values of the decoupling elasticity index (ep) of energy consumption and output and the index (cp) of carbon

emissions and output indicate that carbon emission reduction technologies in both “high-position” and “low-position” countries need to be further improved. “High-position” countries focus on the design of technological products, while “low-position” countries focus on the process of production, transportation and sales. In conclusion, attention should be paid to sustainable development issues in the development of global value chains (GVC) in the ICT sector. The necessary way is the cooperation and alliance of “high-position” countries and “low-position” countries, so that it can achieve both the increasement of product added value and sustainable development.
Keywords: ICT sector; global value chain (GVC); Tapio decoupling; sustainable development

## DAY 1 Session 3

### Comprehensive Measures Are Required to Deal With Global Waste Issues

Zhe Liu
Organization(s): Xi'an Jiaotong University, China

**Abstract**
With rapid population growth and current urbanization trends, annual global waste generation is expected to rise from current 2.01 billion metric tons to 3.40 billion metric tons by 2050. Inadequate management of waste have consequences for ecosystems and human health and contributes to GHG emissions. Circular economy has been considered as part of the solution to transition to net zero and achieving SDGs. However, from a global perspective, nations are not at the same page in terms of the ability to deal with waste from a circular perspective. Circular economic development and implementation in waste management is still limited to advanced countries. In this regard, global nations are still facing challenges when dealing with waste. In particular, for most of mid-low income countries, basic waste infrastructures for collection and treatment of waste are inadequate and investment to build them is insufficient. Developing the CE globally requires to radically increase global waste treatment and recycling capability across the globe to deal with current increasing volumes of waste and to maximize recovery. To advance CE development globally, developed nations and developing nations need to cooperate and create alliances to establish a suitable global system to respond global waste challenges.

### Recent Wildfire Impacts and Countermeasures in Vietnam

Tien Hung Le1,2, Takaaki Kato1
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**Abstract**

Population increases and climate change are considered as the factors of the increasing trend in the burnt areas due to wildfire in Vietnam. Controlling wildfire is imperative to protect the biodiversity of forests and the livelihood of rural citizens. This study aimed to review the literature and government documents and summarized the information on wildfire prevention and mitigation in the country It also intended to provide suggestions for future policy.
First, the trends of wildfire cases and burnt areas were summarized from the statistics by the Vietnam Fire Prevention and Rescue Police Department and the studies using satellite imagery. It showed a fluctuation in wildfire impacts between rainy and dry years, but it showed an increasing trend in the size of burnt areas possibly reflecting an increase in the frequency of dry years due to climate change. Second, the method of forest management in the country was summarized. A risk-based approach using Nesternop's fire risk formula was adopted by the forest management authority and this method helped the authority to effectively allocated their limited human resources and equipment. Third, the method and organizations for emergency responses to mitigate wildfire were summarized. The tactics for dealing with wildfire cases were reviewed and the ways of coordinating government and other stakeholders were assessed.
Through the above-mentioned literature survey, policy recommendations for the forest management authority and emergency management organizations are stated

## Global Supply Chain Drivers of Water Use in India

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**Abstract**
India is categorized among water stressed regions, and increasingly growing consumption-based water use exacerbates the water scarcity stress. Consumption-based accounting of water use could provide the insights for allocating regional responsibility and sustainable management of water resources. This study combined environmentally extended multi-regional input-output (EE-MRIO) model with structural path analysis (SPA) to identify the critical regions and sectors that direct and indirect drove India’s water use from a consumption perspective during 1995-2021 in global supply chains. Results show that domestic final demand was the main driver (driving about 87%~98% of the total); the main foreign drivers are the rest of Middle East, the rest of Asia and Pacific, and USA. Moreover, the major contributors of water use in India are the food related sectors and “Trade and service” sector. This study identified the hotspot areas and sectors affecting water use in India, which provides a theoretical basis for the formulation of water use policies based on demand-side management.

## Multiple Accounting and Driving Factors of Water Resources Use: A Case Study of Shanghai

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**Abstract**
Previous research papers on urban water resources accounting were confined to the perspectives of production and consumption, ignoring the perspective of income. This paper proposes a systems framework to analyze the income, production, and consumption-based water uses and underlying driving forces of a city based on the methods of multi-scale input-output analysis and structural decomposition analysis. A case study is performed for Shanghai as a megacity. The results show that the income, production and consumption-based water uses of Shanghai had decreased from 5.70 billion m3, 10.85 billion m3 and 28.45 billion m3 in 2007 to 2.80 billion m3, 6.20 billion m3 and 24.10 billion m3 in 2017, respectively. Domestic imported primary inputs had emerged as an important virtual water supplier of Shanghai and its share of total supply-side water use had increased from 23.92% in 2007 to 42.95% in 2017. Meanwhile, about 46% and 40% of Shanghai's total consumption-based water use had been imported from other Chinese regions and foreign countries in 2017, respectively. It is revealed that trade played an important role in relieving water use pressure in Shanghai. The factors that had increased the uses of water resources in Shanghai include population, per capita value-added, per capita output, final consumption structure, and per capita final consumption. The factors that had reduced the water uses in Shanghai include technology, value added mix, output structure, value added structure, domestic import, commodity mix, and foreign import. It is suggested that in addition to curbing urban water use from the production side, more targeted water-saving measures should be devised from the supply (e.g., restricting loan to heavy water-consuming enterprises) and consumption sides (e.g., encouraging residents to buy low-water products).

## Greenhouse Gas Emissions of Meat Production in China: A Provincial-Level Quantification

Ying Wei1, Yuan Chang2
Organization(s): 1: Central University of Finance and Economics; 2: Central University of Finance and Economics

**Abstract**

Climate change has become a threat facing humanity, and the transition of agriculture sector toward a low-carbon direction is tremendous and urgent. Animal husbandry sector contributes to nutrition security by supplying animal products, but the sector also has significant greenhouse gas (GHG) emissions due to resource use as well as livestock's rumination and manure. Driven by continuous rising household living standards, China's meat consumption will keep growing, exerting GHG mitigation pressures on the country. This study employed the process-based life-cycle inventory (LCI) modeling approach to quantify the province-level GHG emissions of meat production in China in 2018. Four major livestock products (including beef, mutton, chicken, and pork) with four feeding scales (i.e., cage-free, small, medium, and large scale) were considered. The results show that the GHG footprint of per kilogram (kg) meat products widely varies in China, i.e., beef has the highest value (19.7 kg CO2e), followed by mutton (10.2 kg CO2e), chicken (4.7 kg CO2e), and pork (3.9 kg CO2e). Besides, the GHG intensity of meat production significantly varies by region. Specifically, the northwestern region, where ruminants (beef and mutton) are mainly produced, has high GHG intensity (E.g., Tibet present the highest value of 10.5 g CO2e/kcal), while the central and eastern regions mainly produce pork and chicken, resulting in a low GHG intensity (E.g., 1.3 g CO2e/kcal of Shanghai). For the GHG emissions associated with meat production in 2018, Shandong (43.8 million tons CO2e) is the top emitter, while Shanghai (0.5 million tons CO2e) bottoms the ranking. The 31 provinces in China were categorized into four groups by the GHG intensity and production of their meat products, and provinces with "high intensity-high production" (such as Jiangsu, Hubei, Hunan, Guangdong, and Guangxi) are targets for decarbonizing the meat production in China.

## The Strategic Importance of Key Metals in China's Carbon-Neutral Future

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**Abstract**
Achieving carbon neutrality requires profound transformation in a country's energy structure. Rapid transition from carbon-intensive fossil fuels to renewable energy and large-scale electrification are key in this process, which would potentially alter the strategic importance of different resources.

As one of world's largest importers of oil and natural gas, China's energy supply is heavily shaped and affected by external geopolitics, posing concerns over its energy security. Although China's carbon neutrality commitment could largely alleviate its dependency on oil and natural gas import, the demand for battery-related mineral resources such as lithium, cobalt, and nickel are projected to experience rapid growth with increasing deployment of electric vehicles and electrochemical energy storage, making them potentially the "new strategic resources". The demand-supply pattern of and the geopolitics associated with these resources could play a key role in determining the feasibility and cost of achieving carbon neutrality in China by 2060.

To evaluate the strategic importance of the battery-related resources, this study examines China's demand, supply (including domestic production and recycling), import, and export of lithium, cobalt, and nickel to assess China's foreign dependency of these resources in its carbon-neutral future. Estimations for resource demand are made under different growth scenarios of consumer electronics, electric vehicles, and electrochemical energy storage that are powered by lithium-ion batteries (LIBs) – the most widely used type of batteries today. Estimations for resource supply are based on different projections for domestic production and recycling of LIBs. Foreign dependency rates of battery-related resources under different scenarios are compared with that of oil and natural gas to evaluate the level of their strategic importance.

## DAY 1 Session 4

### Material Footprints Embodied in Global Value Chains with Multinational Enterprises

Meng Li
Organization(s): Shanghai Jiao Tong University, China

**Abstract**
Extraction and processing of natural resources is essential to the sustainable development of all nations. The world has witnessed an unprecedented growth in extraction of materials and natural resources in the past few decades, especially in developing economies. To what extent are these natural resources extracted in each country to fulfill final demands of consumers globally? To what extent the material footprints are re-distributed around the world by trade and by overseas foreign direct investments of multinational enterprises? What drives the rapid increase of the material footprints, is it growth in consumption or investments? To answer this set of questions, this study first uses multi-regional input-output table (MRIO) with explicit information on multinational enterprises, and employs an Environmental Extended MRIO approach to trace the embodied material flows along different global value chains, including trade-related routes, investments-related routes, and trade-and-investment-related routes. Then, this study uses the index decomposition method to analyse the drivers of the surging extraction of natural resources. The results show that both the outsourcing of production process by trade measures and the overseas investments by large multinational enterprises contribute to the surging material extraction in developing countries. The results also highlight the role of capital formation as an important source of final consumption that drives the increase of the material footprints. As the global production network becomes more complex, it is more difficult for policies targeting sustainable development implemented by a single country to be effective. The sustainable development goals call for cooperation of all nations, especially large multinational enterprises.

### An Economic Complexity Tool to Analyze Circular Economy Capability

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**Abstract**
Circular economy (CE) represents a new industrial paradigm aimed to overcome the traditional "take, make, dispose" economic model and to promote more sustainable resource consumption patterns and production processes (Kirchherr et al., 2017).

To support transition to CE, firms are called to develop and implement effective CE initiatives and employ different strategies, generally classified by the so-called "R" frameworks (Sihvonen and Ritola,2015; Van Buren et al.,2016; Potting et al.,2017). To be effective in this process, they need decision-making tools helping them select the most appropriate CE strategies having a high likelihood to be successful implemented.

In this paper, we address this research aim by adopting a capability-based theory approach (Teece et al., 1997) and resorting to complexity economics (Hidalgo et al., 2007; Hidalgo and Hausmann, 2009). First, we argue that CE strategies require specific CE capabilities to be successfully implemented. Then, we use economic complexity tools to capture the CE capabilities. Economic Complexity has been recently applied to propose novel measures of country' green production capabilities. Fraccascia et al.(2018) developed the green product space by identifying green products with the highest growth potential in a given country by capturing the country green production capabilities. Similarly, Mealy and Teytelboym(2020) designed the Green Complexity Index (GCI), which aims to capture the extent to which countries are able to competitively export green, technologically sophisticated, products.

In particular, we develop an economic complexity tool to measure country's capabilities related to the "R" CE strategies (mainly, recover, recycle, reuse). In doing so, we refer to the data in EXIOBASE3 available on Zenodo. EXIOBASE3 provides a time series of multi-regional input-output (MRIO) tables for 49 countries and 163 industries.

The analysis provides a clear picture of country's CE capability as well as the most effective CE strategies to be implemented by companies in different economic sectors.

## Multiple Perspective Accountings of Cropland Soil Erosion in China Reveal Its Complex Connection with Socioeconomic Activities

Keke Li1, Ling Wang1, Zhen Wang1,3, Yuanchao Hu2, Yi Zeng4, Hua Yan1, Baodong Xu1, Cai Li1, Huwei Cui1, Shuxia Yu1, Zhihua Shi1

Organization(s): 1: College of Resource and Environment, Huazhong Agricultural University, Wuhan 430070, China; 2: School of Resource and Environmental Sciences, Wuhan University, Wuhan 430079, China; 3: Interdisciplinary Research Center for Territorial Spatial Governance and Green Development, Huazhong Agricultural University, Wuhan 430070, China; 4: State Key Laboratory of Soil Erosion and Dryland Farming on the Loess Plateau, Institute of Soil and Water Conservation, Northwest A&F University, 26 Xinong Road, Yangling, Shaanxi Province 712100, PR China

**Abstract**

Cropland soil erosion is a major threat to global agricultural sustainability. Compared with the well-studied natural factors of soil erosion, socioeconomic factors have just begun to be considered. The major obstacle is that the soil erosion of different croplands has not been accounted for and connected with socioeconomic activities. In this study, we adopted the revised universal soil loss equation (RUSLE) and the environmentally extended multiregional input–output (EE-MRIO) model to account for soil erosion on cropland from the production, consumption, and income perspectives at the provincial and sectoral levels in China. Our results showed the major responsible agents in a synthetic view. Our results indicated that accounting from multiple perspectives could inform the better management of cropland soil erosion from more comprehensive perspectives. To the best of our knowledge, we are the first to consider the accounting of cropland soil erosion in China from multiple perspectives. Tailored packages of measures should be established based on different patterns of those areas with serious cropland soil erosion.

## Allocation Mechanism of Urban Carbon Mitigation Responsibilities Considering Both Carbon Dioxide Emissions and Natural Carbon Sinks: A Case Study of Cities in Pearl River Delta (PRD)

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**Abstract**

Allocation of carbon responsibility considering equity, efficiency as well as forest carbon offset is a key step of achieving carbon peaking and neutrality. However, for Pearl River Delta (PRD) region, how socio-economic development and forestry carbon sinks affect responsibility allocation has yet to be studied. Our study accounted for production- and consumption-based carbon emissions by utilizing multi-regional input–output (MRIO) analysis and assessed forest carbon sequestration using biomass emission factor (BEF) in 11 cities of PRD. Considering multiple factors including carbon leakage, forest carbon sink and socio-economic development, we developed 12 principles of assigning carbon responsibilities. Future carbon emissions and responsibility allocations in three typical cities under different scenarios were also forecasted and analyzed through the Low Emissions Analysis Platform (LEAP). Results show that differences of carbon mitigation responsibilities

among the 11 cities have narrowed during 2005-2019. The responsibility of Hong Kong is particularly high because it takes up over 42% of total emission from a consumption-based perspective. Under the production-based principle, the mitigation responsibilities in Guangzhou, Foshan, Dongguan were comparatively large. When considering the effectiveness of natural carbon offset, forest carbon sequestration in some less-developed cities (such as Zhaoqing) play an important role although its ability of offsetting total emission in GBA was also limited. A more fair and transparent mechanism of carbon reduction quota considering both emissions and sinks would be important in achieving carbon peaks and neutralities in cities.

## Finding the Best Approach for the Road Transport Sector to Synergistically Reduce CO2 and Air Pollutant Emissions

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**Abstract**
The road transport sector is one of the most important sources of CO2and NOx emissions. In this paper, we use the structural path decomposition (SPA) method to analyse in detail the direct and implicit emissions caused by final consumption in the road transport sector. And 33 specific emission reduction technology options related to passenger cars, light trucks and heavy trucks have been constructed. A thorough analysis of the direct emissions and emission reductions of the technology options in the production phase and use phase, as well as the indirect implied emissions and emission reductions passed through the supply chain, was carried out. It was found that the direct emissions caused by the road sector are much higher than the implied emissions. This is because most of the direct emissions in the production phase are associated with road freight transport. The expansion of the transport sector will lead to the development of industries such as metal products, which in turn require transport support for their production. This can create a vicious circle that leads to more emissions. It is therefore crucial that the road transport sector itself reduces its emissions. All technology options, while leading to some additional emissions in the production phase, can be offset by the emission reductions in their use phase, resulting in net CO2 and NOx reductions. Pure electrification technology for passenger cars is exceptional as it leads to the highest additional emissions in the production phase, but has the greatest NOx reduction potential and the second highest CO2 reduction potential after hybrid technology for heavy trucks. Overall, new energy technologies, including pure electrification and hybrids, have the highest emission reduction potential.

## Carbon Emission and Energy Consumption Parsing of Iron and Steel Industry in China: A Multi-Region Input-output Analysis

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**Abstract**
Steel industry is one of the industries with high carbon emissions and high energy consumption. With the development of steel industry, energy consumption and CO2 emissions are bringing pressure to global resources and environment. Through input-output analysis, the economic relationship of steel industry in each province will be transformed into the relationship between carbon emissions and energy consumption. Based on the 2017 multi-region input-output table and carbon emission and energy consumption inventories, this study analyzed the carbon emission and energy consumption of the steel industry in 31 provinces of China, explored the spatial characteristics and differences of carbon emission and energy consumption, as well as the transfer of CO2 and energy consumption caused by China's steel import and export, and clarify the transfer of carbon footprint and energy consumption among different regions in China caused by the economic flow of the steel industry, and divided the green steel production grade of 31 provinces and cities by using entropy weight method. Suggestions on energy conservation and emission reduction for different levels of regions were put forward. Based on the multi-region input-output analysis of carbon emission and energy consumption of steel industry of China, the sustainable development suggestions of energy saving and emission reduction are put forward, which is beneficial for China to adjust the development of steel industry in different regions under the carbon peaking and carbon neutrality goals, and provide a decision-making basis for the development of energy saving and emission reduction measures and the realization of green steel production.

# DAY 1 Session 5

## Uncovering The Dynamics of Household Water Footprint in Response to COVID-19: The Hysteresis Effect of Economic Disruption

Shaoqing Chen, Yuanhong Gu
Organization(s): Sun Yat-sen University, China, People's Republic of

**Abstract**
The socioeconomic disruption of COVID-19 has strong implications for water management. However, it remains unclear how water use related to urban and rural household consumption responded to the pandemic. Taking 15 provincial regions in China for a case study, we quantified the

pandemic-induced variations of household water footprint and tracked the interregional virtual water flows and control relationships in the first–third quarters of 2020 through a parallel comparison with the simulated "no-COVID-19" scenario. We assessed how the water footprints driven by various categories of consumption expenditure responded differently to the pandemic. We found in many regions, the most drastic change occurred only a quarter after the major outbreak, when the average water footprint of urban and rural households decreased by 13% and 9%, respectively, especially those related to food, education and health, indicating the presence of a hysteretic effect of disruption to expenditures. The urban–rural water footprint gap first decreased by 6%-26% because of a stronger hit in highly-populated urban areas and then regrew when economy recovered. Up to 19% pandemic-induced change of interregional virtual water flows and control relationships also reshape the water resources distribution, calling for a precautionary water management in face of crisis.

## Life-Cycle Carbon Emissions by Pilot Zero-Waste City Technologies in China

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**Abstract**
While the construction of Zero-waste City is promoted in a lot of countries, the environmental costs of the Zero-waste City technologies (ZWTs) is barely known. This study provides a system accounting framework for estimating the life-cycle carbon emissions of the ZWTs. It is based on the hybrid method as a combination of the process analysis and the input-output analysis. The indicators of CEWT (carbon emissions in waste treatment), CRWT (carbon emissions reduction in waste treatment), and ACWT (adjusted cost of waste treatment) are proposed to evaluate the environmental efficiency of the ZWT. Based on the detailed input and output inventory of the ZWTs and the carbon emission intensity database of China, case studies are carried out to calculate the life-cycle carbon emissions of the pilot ZWTs in China. These technologies are divided into four categories as the TS (to treat sludge), the TM (to treat mixed waste of sludge and kitchen waste), the TD (to treat domestic waste), and the TC (to treat construction waste). The results show that most of the pilot ZWTs have co-benefits of mitigating climate change while reducing MSW. Among them, the dry anaerobic fermentation technology (TS), the cement kiln co-processing technology (TD), and the in-situ disposal of construction waste technology (TC) are shown superior to similar technologies in terms of carbon emission reductions. After integrating the carbon emission reduction benefit to the economic cost, the sludge resource treatment technology (TS), the grate domestic waste incineration technology (TD), and the in-situ disposal of construction waste technology (TC) are revealed cost less. Finally, the potential life-cycle carbon emissions reduction of rolling out the pilot ZWTs all

over China is estimated as 90 Mt CO2-eq, accounting for 87% of official direct carbon emissions released by China's waste management in 2014.

## Mapping Storage Infrastructure for A Circular Economy

Ling Min Tan, Charles Gillott, Will Mihkelson, Danielle Densley Tingley
Organization(s): Department of Civil & Structural Engineering, The University of Sheffield, United Kingdom

**Abstract**
The construction, operation, and maintenance of the built environment accounts for over 40% of the UK's carbon footprint and 62% of its total waste in mass. A shift to a circular economy (CE) is thus urgently required to limit primary material demand, increase reuse of construction waste and reduce associated embodied carbon emissions. Despite this, there remain critical barriers to the widespread implementation of CE in the manufacturing, construction and waste sector due to the lack of infrastructure necessary to store bulky and heavy building materials. Otherwise, most of the materials reclaimed from building demolition are downcycled into products of less value. This project therefore aims to address the key barrier to the adoption of CE in construction in terms of storing material for future reuse, in order to prolong their use cycles. In this work, we survey major infrastructure providers in the UK to identify sites with potential to be used as storage hubs or temporary deports for reusable materials. These include their existing infrastructure assets such as material handling depots, redistribution centres and minor stocking points. From the responses we received, how much space may be provided for the storage of different material groups is also considered, as well as the ease with which each storage site may be valorised. By overlaying storage hub locations and sizes with the national road and rail networks on a geographic information system (GIS), a trial network analysis is applied to optimise the number and location of material storage hubs required across the country. As such, transport distances, emissions and economic costs are minimised, while promoting material reuse and reductions in raw material extraction, waste generation and associated embodied carbon emissions.

## Scenario Analysis of Household Food-Energy-Water Nexus Based on System Dynamics for Resilient Melbourne (Australia)

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**Abstract**
Household is the basic unit of food-energy-water consumption. Clarifying the nexus between the three resources and formulating corresponding management strategies are essential for the

construction of resilient cities. Based on system dynamics, this study establishes a household food-energy-water nexus model, taking Melbourne as a case. Three regulation measures, including appliance, behavior and price intervention are analyzed to evaluate water, energy and carbon saving effects. Results show that compared with the BAU scenario, reducing the use frequency of the dishwasher to 3.5 times per week brings the best water saving effect, followed by using the 4 star shower heads. Extending residents' water-saving and energy-saving behaviors retention to four years brings the best energy-saving effects. Adjusting the proportion of meat and dairy in residents' diets can only reduce carbon emissions in the short term. Specifically, residents' behavior adjustments are the most significant in reducing resource consumption, and the effects of replacing appliances and resource price adjustments are weak. The insights achieved in this work may support policy makers in guiding households transition to sustainable behaviors and to pay attention to carbon emissions in the food sector.

## Analysis of the Life-Cycle Environmental Impact, Economic Cost, and Sustainability for The Energy Pathways of New Energy Vehicle

Ji Feng, Yadong Yu
Organization(s): East China University of Science and Technology, China, People's Republic of

**Abstract**
The deployment of new energy vehicle (NEV) is vital for the decarbonization of the transportation sector. While the energy infrastructure is regarded as a critical factor for the deployment of NEV, it is still unclear which energy pathway of NEV is the most sustainable and should be prioritized, thus restricting the development of relative energy infrastructures. Against this, 27 major energy pathways for NEV and one energy pathway for conventional internal combustion engine vehicle are designed and their sustainability level which incorporates both the environmental impacts and economic costs are evaluated and compared with each other. Specifically, the Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model (GREET), the techno-economic model, and the reference point approach are comprehensively applied. The results show that the pathways with energy acquisition from renewables are with lower emissions and lower economic costs, which is contrary to the pathways with fossil-based energy. Among the 28 pathways, the battery electric vehicle powered by nuclear electricity is most sustainable. Although most of the hydrogen pathways for fuel cell vehicle are less sustainable due to their more complex technological process, a higher share of renewables in the total electricity generation would lead to a higher sustainability level of electrolysis hydrogen in the future. Thus the hydrogen pathway with renewables could potentially be the most sustainable one with the decrease in the cost of renewables.

## Modeling Spatial Diffusion of Decentralized Water Technologies and Impacts on The Urban Water Systems

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**Abstract**
Decentralized water technologies (DWTs) such as rainwater harvesting (RWH) and greywater recycling (GWR) are emerging as promising alternatives, helping reduce water withdrawal from centralized infrastructures and enhance water security. Social preferences and choices are critical to promoting DWTs in cities. Past studies evaluated the critical socioeconomic and technical factors explaining household preference. However, there is a limited understanding of the spatial adoption and diffusion of DWTs driven by the market and their impacts on urban water systems. To fill this gap, we first developed a spatial agent-based model (ABM) to simulate the adoption of RWH and GWR by single-family households in Boston (U.S.). We used a system dynamic model (SDM) to evaluate the impacts of decentralized water supply on reservoir water availability, hydropower generation, and carbon emission of water and wastewater services. The change in carbon emission was modeled to influence household adoption choices in the spatial ABM. We validated our model integration by comparing the simulated reservoir elevation with historical records in the reference year and comparing where early adoptions emerge with the reported installations. Our ABM results reveal the adoption of RWH is much higher than GWR. The diffusion of both technologies starts from north downtown to southern suburban in the city, but the diffusion of RWH starts much earlier. Our SDM results show water availability increases in reservoirs with the adoption of DWTs. However, hydropower generation from water supply becomes less as water transfer between reservoirs decreases. Utilization of the increased water availability should be explored to produce more hydropower. Moreover, we did not find a significant reduction in carbon emission in the urban water system due to the high carbon intensity of GWR. Overall, our integrated framework can provide systematic solutions for planning and evaluating the DWTs at the nexus of human-infrastructure-environment.

## DAY 1 Session 6

### Quantification of The Material Flow from The Modal Shift of Motorcycle Electrification under Climate Change Adaption Policy in Taiwan

Hsin-Tien Lin, Kuo-Che Weng, Falk Schneider
Organization(s): National Cheng Kung University, Taiwan

**Abstract**
Motorcycle is a major means of transportation in many Asian economies, including Taiwan. However, motorcycles are significant contributors of air pollution and carbon emission in cities. Modal shift into electric motorcycle (or e-scooters) is a potential solution to pollution problems. CO2

emission mitigation may be expected when electric motorcycles replacing conventional motorcycles, but corresponding End-of-Life (EoL) motorcycle generation and resource requirement in motorcycle production cannot be neglected. This work presents the dynamic material flow analysis of modal-related resources from motorcycles under the Climate Change Adaption Policy in Taiwan in 2021-2050. The change of motorcycle numbers are estimated by population balance model with the lifespan distribution function obtained based on primary data. The material composition of motorcycle is acquired form disassembly of the most popular conventional motorcycle and electric motorcycle models in Taiwan. The penetration rate of electric motorcycle and the energy mix for the CO2 emission calculation are based on the Climate Change Adaption Policy. Our result showed that electric motorcycle ownership ratio will achieve 44% in 2050 under the policy, resulting in a 48% reduction of CO2 emission comparing to 2021. However, due to the different material composition of conventional motorcycle and electric motorcycle, the material stock of copper and aluminum in motorcycles will increase while aluminum and plastic will decrease. The material input for new sales and output for EoL motorcycles have a more significant change due to the sharp rise in the electric motorcycle numbers. This work presents essential primary information for the estimation for the material flow related to motorcycle and it can be utilized to analyze the resource consumption and recycling potential in Asian countries. The system developed in this work can be applied to the prediction of waste flow in detail and planning of the recycling policies.

## Pollutant Emission and Congestion Analysis Based on Floating Vehicle Data

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Organization(s): 1: Beijing Key Laboratory of Traffic Engineering, College of Metropolitan Transportation; 2: Centre for Transport Studies, Imperial College London

**Abstract**
Urban transportation is an important source of greenhouse gas emissions, particularity, as the increase of the number of vehicle, traffic congestion is becoming increasingly severe, which leads to the aggravation of urban air pollution.

Currently, many studies related to congestion and pollutant emissions estimates are based on floating vehicle data, but the literature tends to focus on specific roads rather than all urban roads, so the results are not very accurate. Based on the floating vehicle data of Shenzhen, this study attempts to identify and analyze the positions of the vehicles based on the point data, and matches these identified position with Shenzhen, which are rasterized based on the proposed algorithm, so as to more accurately identify the congestion and pollutant emission areas of the city and explore the relationship between them.

In the study, a congestion index is introduced to assess the traffic state over time, and the calculated index data are classified by K-Means Clustering algorithm. The congestion level of roads in different time periods is investigated and analyzed. We select COPERT model to combine with the current

vehicle pollution emission standards and the characteristics of the ground climate in Shenzhen for the calculation of the emission factors. Then the pollutant emissions in different time are obtained. The results demonstrate that traffic is more congested during the day than at night, and the pollutant emissions in the congested areas during the morning rush hour are significantly higher than that in other non-congested areas. In addition, the average speed of vehicles in congested areas during morning and evening rush hours is lower, which also leads to higher emissions. Therefore, the frequency of public transport in the daytime is suggested to increase, and travelers are also encouraged to choose public transport for commuting in the rush hours

## A Scaling Approach for Sustainable Water-Carbon Coupling Management of Urban Green Infrastructures：Evidence at China's City Level

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**Abstract**
Urban green infrastructure (UGI) has become increasingly important in maintaining human well-being equity of city dwellers. However, the expansion of UGI consumes scarce water resources and increases fossil-fuel carbon emissions during maintenance, especially in rapidly urbanizing developing countries. To date, few studies on UGI identified the differentiated demands for water-carbon coupling management from the perspective of UGI growth at city level. In order to evaluate the growth trend of UGI under different climatic conditions and propose policy implications on water-carbon coupling management, we took 287 cities in China as a case study to investigate the scaling of UGI from 2000-2019 based on a scaling law model. Our results reveal that: (1) The area of UGI grew super-linearly with the city population under all climatic conditions; (2) The growth rate of UGI relative to the city population showed a U-shaped curve with the economic level and carbon emission efficiency. Cities with low economic level and low carbon emission efficiency presented greater UGI growth rate; (3) Most underdeveloped cities are located in the arid regions of China, where the contradiction among the expansion of UGI, water scarcity and carbon inefficiency is prominent. Our study put forward an effective scaling approach to the planning of UGI across different climatic conditions, which can be applicable in sustainable water-carbon coupling management of UGI. More specifically, our study proposed that policy makers should pay attention to alleviating the pressure of UGI growth on water saving and carbon reduction in arid cities. Measures like precision irrigation, biomass utilization for bioenergy and improvement in urban vegetation structure are recommended for sustainable water-carbon coupling management of UGI in China and other rapidly urbanizing countries.

## Resource Intensity of The Transportation System Considering The Infrastructure Development: Japan as A Case Study

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**Abstract**

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 transport sector, in the first place, it is important to estimate the amount of natural resource currently used. Although the transport infrastructure associated with transportation system is essential for moving of transportation means, most of existing studies have separately analyzed the resource use of transportation means and the transport infrastructure. Thus, the integration of transportation means with the transport 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 modes, the resource use is indicated in the form of resource intensity as a functional unit. The resource intensity of transportation means and transport infrastructure was calculated based on the inventory data for each transportation modes. The four transportation modes including roadways, railways, aviation, and waterways were considered, the lifecycle stages of manufacturing, operation, and maintenance for both transportation means and transport infrastructure were analyzed. The framework for the transport infrastructure was also developed, covering a location for stop of transportation means (referred to node), a structure linking between nodes (referred to link), structures which supplementarily support as a support for link, a facility for the fuel supply, and a fuel storage.

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 transport infrastructure accounts for a significant share in resource intensity of high-speed railway and automobiles.

## Assessing and Improving The Carbon Emission Efficiency of China's Transportation Industry

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**Abstract**

The transportation industry has proven to be one of the major contributors to energy-related carbon emissions in China. It is therefore perceived as a new priority in efforts to improve carbon emission efficiency. The aim of this paper is to assess the static and dynamic carbon emission efficiency of transportation industry (TICEE) and provide improvement strategies. By using the panel data of 30 provinces in China from 2010 to 2019, a super slack-based measure model is applied to assess the static TICEE, inefficiencies and improvement potentials. The global Malmquist-Luenberger index is adopted to examine the dynamic TICEE and its driving factors. The improvment strategies are provided by coordinating the "static-dynamic" efficiency. The results indicate: (1) severe carbon emission inefficiency of the transportation industry in China, particularly in western, central and northeastern regions; (2) a slow downward trend in the static TICEE due to the decelerating technology innovation; (3) high energy-saving and emission reduction potentials in those provinces that fall into the "inefficient-deterioration" category.

## Are Electric Vehicles Really The Optimal Option for Transportation Sector to Approach Carbon Neutrality Goal in China?

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**Abstract**
Profound worldwide fleet electrification has been thought to be the primary route to achieving carbon-neutral or net-zero carbon targets. However, when and how promoting electrification can really help mitigate carbon emissions in the transport sector remains unclear. Herein, we quantified the overall life cycle environmental impact and carbon saving range of two typical A-class electric vehicles (EVs) and internal-combustion engine vehicles (ICEVs) in China. The results show that EVs outperform ICEV in terms of total environment after 39,153 km and carbon emission after 35,526 km. ICEVs are only more carbon-friendly if they drive less than 3,553 km per year. Taking into account the 150,000 km full-life mileage, the average lifecycle environmental impacts of EV and ICEV were calculated as 8.6mPt/km and 17.5mPt/km, respectively, while EV has 2.3 times higher impacts than ICEV in the production phase. The results indicate that EV unit carbon emission is 166.8 g/km, 37% lower than ICEV. Three potential reduction scenarios were discussed, including cleaner power mix, energy efficiency, and battery recycling, contributing 17.6%, 12.5%, and 7.33% of emission reductions. However, China still faces great challenges in achieving carbon peak and neutral goals, unless turning from fossil fuels to renewable energy.

## DAY 1 Session 7

## Factors Affecting The Adoption of Water Reuse Technologies: Evidence from An Italian Case

Enrico Cagno, Paola Garrone, Alessandra Neri, Andrea Matteo Rizzuni
Organization(s): Department of Management, Economics, and Industrial Engineering, Politecnico di Milano

**Abstract**
Water reuse is a fundamental step toward the circular economy, and a necessary action to relieve pressure on freshwater natural resources. The adoption of water reuse technologies plays a crucial role in the water reuse strategy. Water utilities and potential final users are key stakeholders in the investment decisions in water reuse technologies Their decision-making process is complex and is influenced by several factors, particularly, barriers and drivers - factors recognized to respectively hinder or foster a decision-making process. However, extant literature has not focused on barriers and drivers perceived by water utilities and potential final users. To provide technology adopters with adequate support in their decision-making process, barriers and drivers must be properly evaluated.

To shed light on the issue, we performed an embedded case study in a relevant Italian water utility, considering 8 water reuse plants as sub-units of analysis, for a total of 14 interviews with 17 informants. The case selected is relevant for the adoption of water reuse technologies and processes due to water scarcity and degradation of aquifers in the region. Adopting an inductive approach, we determined the most relevant barriers and drivers for the context investigated. Community acceptance and a limited market for water reuse, together with past technological and unfavorable location-related choices emerged as relevant barriers, while policy instruments, coordination among different institutional and operational levels, and the perception of water scarcity can support the adoption of water reuse technologies. As the sub-units of analysis, although in the same context of the investigation, differ for the management of the reclamation and distribution processes, capacity, and final reuse of water, we provided a preliminary evaluation of the moderating impact of these contextual factors on the relevance of barriers and drivers. Additional research is needed to compare the obtained results with other contexts of investigation.

## Towards The Development of A Comprehensive Methodology for Product Circularity Assessment

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**Abstract**

Due to the increasing global population and high natural resource consumption, the current generation is facing inevitable crises such as resource shortages, increasing waste, and environmental concerns. As such, the linear model with a 'take-make-dispose' approach is no longer suitable. The evolving concept of circular economy (CE) is frequently proposed as a strategy to address limitations of the linear model. Thus, it is vital that products are designed based on the CE concept. However, the description and attributes of the CE remain ambiguous. There are also no clear explanations of what makes a product circular and how to measure its circularity. Therefore, a clear understanding of the CE and core constituent attributes of a circular product is imperative to evaluate its performance. This presentation demonstrates preliminary work to address the above gap with the goal of developing a comprehensive methodology for product circularity assessment. This effort begins by carefully analyzing the definitions and key features of the CE through an extensive literature review. The results are synthesized to attain the description and attributes of a circular product which will become the fundamental inputs to develop the methodology. Based on this outcome, preliminary observations about the existing product circularity assessment tools are conducted. The findings indicate the CE must consider both the technical and biological elements while accomplishing the closed-loop material flow. In addition, the CE descriptions show a lack of emphasis on stakeholders as enablers. The attributes of a circular product derived from the CE domain analysis are presented. Shortcomings of existing evaluation tools are also identified and shown as important factors to consider in the methodology. The outcomes of this project will inform the development of a comprehensive methodology for product circularity assessment and contribute to improving the circular product design process, thus leading to a more sustainable world.

## Shaping the Relationship between Digital Technologies and Circular Economy through Dynamic Capabilities

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**Abstract**
The implementation of the circular economy paradigm and the adoption of digital technologies within industrial firms are hot topics in current academic, political, and managerial debates. Although being separated topics, digital technologies are largely recognized to potentially support the industrial circular transition, fostering the implementation of related practices. The relationship is currently mainly studied in terms of the direct support that digital technologies offer to the implementation of circular economy practices, with overall contrasting results, limited empirical evidence and unclear indications for practitioners. Latest developments suggest the non-linearity of the relationship, meaning the support offered by digital technologies might be actualized by the generation of dynamic capabilities. To shed light on the issue, we conducted explorative multiple case studies. Based on inductive logic, we investigated 11 Northern-Italy industrial firms,

understanding the transformations occurring within the firm owing to the adoption of digital technologies and how these transformations might support the implementation of circular economy practices. Results suggest that different digital technologies – alone or combined, can enable specific dynamic capabilities, that - alone or combined, can support the implementation of circular economy practices. Digital technologies emerging as the most promising for enabling capabilities relate to information exchange, such as the Internet of Things and Big Data Analytics. The most common digital-enabled capabilities are sensing and transforming ones. Among the microfoundations identified, those related to knowledge generation, changes in processes, and traceability seem to provide the strongest support to the circular economy practices implementation. Unfortunately, digital-enabled capabilities appeared to still support mainly the implementation of practices related to production efficiency. The study provides a first-of-a-kind investigation; overall results imply that the main role in supporting the industrial circular transition is not directly related to the number or types of digital technologies adopted, but rather to the set of digital-enabled dynamic capabilities.

## Filtration of Roof-Top Harvested Rainwater: Present Scenario, Prospects and Challenges

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**Abstract**
One of the serious challenges that many nations are struggling with is lack of water. Due to rising standards of life and population expansion, water demand is escalating. Global water shortage is caused by a mismatch between the amount of freshwater needed and the amount available. Reducing that problem may be as simple as looking into and making use of rainwater. A well-known technique for gathering and storing rainwater for later use is known as "rainwater harvesting." The majority of recent studies concentrated on successful rainwater harvesting techniques to lower the demand for mains water. There are several advantages and disadvantages to implementation of rainwater harvesting system (RWHS). Rainfall may be collected and used for potable and non-potable purposes. Alternative water resources like RWHS have been available since decades, but implementation has been restricted owing to low public acceptability. Future obstacles in deployment of RWHS include achieving competitive cost, widespread use of commercial buildings, cost-efficient treatment system, effective execution and public perception improvement. Roof-top rainwater collection happens to be the most common approach and is becoming more and more prominent as a realistic method to deliver drinking water to an ever-increasing population, particularly in developing nations, as strain on water supplies increases globally. Roof-top runoff does have some quality problems, though. Numerous investigations have found chemical and microbiological pollution that are substantially beyond national and international

standards,endangering the health of consumers. In order to implement efficient harvesting systems on a larger scale it is necessary to have a suitable experimental set-up where filtration and suitability of harvested water through roof-tops can be analysed. This paper presents a glance of fundamentals of such techniques which have been used globally to arrive at an optimum possible solution of filtering and hence treating roof-top harvested rainwater.

## Spatial Optimization and Interpretation of Citywide Sustainable Promotion of Building-Based Decentralized Water Technologies

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**Abstract**
Decentralized water technologies (DWTs) such as rainwater harvesting (RWH) and greywater recycling (GWR) are emerging as alternative solutions to reduce freshwater withdrawal from the centralized infrastructure and improve water security. The benefits of DWTs effectively arise when they are widely implemented, requiring an appropriate sustainability assessment of economic and environmental impacts on urban water systems. However, existing decision-supporting tools remain inadequate regarding 1) evaluation of the trade-off between environmental benefits and costs, and 2) interpretation of variations in the optimal selection of locations as the financial support increases. To fill this gap, this study presents an integrated analytic framework combining multi-objective optimization and interpretation to facilitate the citywide sustainable promotion of building-based DWTs. We selected single-family households in Boston (U.S.) as the target users and applied our framework to study the promotion of building-based RWH and GWR. We used genetic algorithm to generate a set of optimal solutions (i.e., Pareto-fronts) by evaluating the trade-off between the energy saving for water uses and the required investment cost. Our spatial optimization suggests RWH is more applicable than GWR for single-family house communities in Boston. In the interpretation phase, census blocks were grouped into two clusters with distinct selections of the prioritized locations for investing in RWH and GWR given different investment levels. One cluster located in the southern part of the city demonstrates a higher priority for installing RWH. We created a random forest classifier to analyze the critical features of the cluster to interpret why it is prioritized, including a longer distance from centralized facilities, higher non-potable water demand, and larger rooftop for collecting rainwater. Overall, our framework can be an additional supporting tool to direct the sustainable citywide promotion of DWTs.

## Emergency Sensor Placement Model for Emergency Response in Water Distribution System

Haidong Yang, Aihua Wang
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**Abstract**
Rapid and accurate response to water contamination emergencies is of key importance to ensure the water safety of the population. However, due to limited information, source identification models can yield multiple possible contamination scenarios, and multiple possible contamination scenarios can seriously affect the development of emergency response plans. To address this problem, the paper proposes an innovative approach to reduce the influence of possible contamination scenarios on the development of emergency response plans by using the idea of exclusion, based on which an emergency sensor placement model is constructed with the objectives of the earliest end time of emergency response, the largest number of possible contamination scenarios excluded and the smallest number of emergency sensors placed to obtain information. The model was solved using a hierarchical sequence approach considering the different levels of importance of each objective and simulated on an example network (i.e. Network 3 of EPANET). The results show that the longer the time spent for emergency monitoring sensor placement, the fewer possible contamination scenarios can be ruled out and the fewer sensors need to be placed; the time required from the development of the emergency response plan to the completion of the emergency response has a phased effect on the change in the model target values.

## DAY 1 Session 8

### The Environmental Impacts of E-Commerce: A Literature Review

Sara Toniolo, Ivan Russo
Organization(s): University of Verona, Italy

**Abstract**
More consumers are purchasing through their preferred online channels and companies in every sector are facing unprecedented pressures related to e-commerce. In 2020, the main web shops witnessed an important increase in web visitors and web traffic grew significantly compared to pre-Covid 2019 situation. According to Statista, it has been estimated that nearly 25000 million units of parcels were distributed worldwide in 2020. In line with European Statistics, e-shopping is growing steadily, with the biggest increase among young internet users. However, a delivery of a parcel to a recipient’s address generates costs of customer service and environmental pollution.

The objective of this study is to explore what aspects of the e-commerce contribute the most to the environmental impact and what solutions can reduce the associated emissions from a life cycle perspective. This study presents a review based on 34 articles published between 2002 and 2022 in international journals and conference proceedings, available in the ISI Web of Knowledge database.

A descriptive analysis was carried out to evaluate the main features of the articles; then the articles are classified considering the aspects analyzed and the possible solutions proposed to reduce the environmental impacts. This study highlights that the environmental burdens associated with e-commerce are still underexplored from a life cycle perspective and presents the elements that can be addressed to reach a higher level of sustainability.

## The Gap between Supply and Demand of Cobalt Resources in China and Analysis of Its Recycling Potential

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**Abstract**
In the past decades, carbon emission reduction has become the common goal of the world, and thus energy-saving and emission reduction technologies have attracted increasing attention. The development of low-carbon technologies cannot be separated from cobalt and other critical minerals. However, as the largest CO2 emitter, China's cobalt reserves only accounted for 1.1% of the world's total reserves in 2020, and the raw material of cobalt is highly dependent on imports. Here, we take each cobalt site as the object to establish a high-resolution global cobalt sites database in 2020, and evaluate the supply of cobalt mines containing Chinese capital from 2020 to 2030. Based on the stock-driven model and scenario analysis, we evaluate the demand and recycling potential of cobalt resources in China from 2020 to 2030. By comparing the total supply and demand in the future, we explore the gap between the supply and demand of cobalt and the degree of external dependence before 2030. The results show that the supply of cobalt mines containing Chinese capital will increase firstly and then decrease during 2020-2030, reaching the maximum between 2023 and 2024. The supply gap of cobalt resources in China from 2020 to 2030 can be alleviated to some extent by developing low and cobalt-free batteries and increasing the recovery rate, but it is still inevitable to face the risk of a shortage of cobalt. Our results are of significance for ensuring the sustainable supply of cobalt resources and promoting energy transition in China.

## Digital Product Regeneration for Lifetime Extension

Hong Yee Low, Lynette Cheah, David William Rosen, Pablo Valdivia y Alvarado
Organization(s): Singapore University of Technology and Design, Singapore

**Abstract**

Global waste generation is expected to grow faster than population growth by 2050 (Kaza et al., 2018). Effective recycling, reuse and remanufacturing have been limited to a limited number of applications so far. As products become more complex, traditional recycling and remanufacturing are becoming much more challenging. In line with circular economy ideals to promote product life extension, the objective of this paper is to propose and discuss a novel concept of product regeneration. Digital product regeneration is a data-driven product lifetime extension strategy that uses product intelligence to continually maintain and upgrade the product. In the information age, digitally designed and manufactured products have digital blueprints that not only contain information about their components and geometry but also their materiality. Intelligent products that can make use of sensors and electronics to monitor their use and functioning can potentially acquire in-field performance data, offering an unprecedented opportunity to pursue product regeneration. To realise this vision, there are a few requirements. Firstly, new design capabilities are needed to design products for upgrading and regeneration. Secondly, the realization of intelligent products requires the ability to collect and make sense of product performance data. Finally, the intelligence must be translated into informed decisions about product regeneration needs. By enabling product regeneration, the useful lifespans of suitable products can be continually extended, reducing waste and contributing to a circular economy.

## Unfolding the Evolution of Carbon Inequality Embodied in Inter-Provincial Trade of China

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**Abstract**
The mismatch between carbon transfer and economic benefits embodied in inter-provincial trade generates carbon inequality among provinces. Exacerbating carbon inequality would diminish the effectiveness of carbon policy, thereby challenging the realization of carbon neutrality target in China. Combining the network analysis and multi-regional input-output (MRIO) analysis, this paper depicted the unbalanced relationship between carbon transfer and value-added flow embodied in inter-provincial trade of China during 2012-2017 to shed light on the evolution features of trade-attributed carbon inequality from a multi-dimensional perspective. The research findings reveal that the carbon inequality embodied in inter-provincial trade in China has increased significantly during the study period, as the correlation coefficient of carbon transfer network and value-added transfer network decreased from 0.772 in 2012 to 0.634 in 2017. Different environmental regulation intensities and economic development levels among provinces are the main factors triggering trade-attributed carbon inequality. During the surveyed years, some provinces such as Beijing, Tianjin and Jiangsu have changed their roles from the drivers of carbon inequality to the leaders of green trade. Whilst some provinces located in the Northwest China which include Ningxia, Gansu and Inner Mongolia are placed in inferior position in trade, and remain as the victims suffering from carbon

inequality. The research findings urge the need to shift from local carbon reduction to collective governance of carbon reduction, and provide supportive references for Chinese governments to develop integral solutions and tailor-made policy instruments towards equitable and sustainable development.

## New Patterns on Socioeconomic Drivers if China’s CO2 Emissions from 2010 to 2020

Zijun Deng, Qiumeng Zhong, Sai Liang
Organization(s): Guangdong University of Technology, China, People's Republic of

**Abstract**
Affected by the deepening of supply-side structural reform in 2018 and COVID-19 pandemic, great changes have taken place in China's production structure and consumption structure in recent years. Such transitions would have an effect on CO2 emissions. However, few studies uncover socioeconomic drivers of CO2 emissions in China after 2018. Besides, China revised statistics from 2014 to 2017, and the data of economy and energy changed. Therefore, it’s necessary to re-assess the role of socioeconomic structure transition in China’s CO2 emissions before 2017. Here, we investigate the relative contributions of socioeconomic factors to China’s CO2 emissions by applying structural decomposition analysis during 2017-2020. We also quantify socioeconomic drivers influencing CO2 emissions from 2010 to 2017. Results show that changes in production structure and final demand structure are the factors contributing to CO2 emission reduction during 2010-2017, while these drivers lead to emission growth from 2017 to 2020. The finding indicates that there are potentials for CO2 emission reduction in the optimization of structural factors. We also find that socioeconomic factors (e.g., energy efficiency) of CO2 emissions during 2012-2017 are different compared with existing studies. During 2012-2015, the change in energy efficiency is the driver contributing to CO2 emissions reduction, while the situation reverses during 2015-2017 due to the increase in energy consumption per output from smelting and pressing of metals. We further provide recommendations related to structural factors (e.g., product structure optimization) for China’s CO2 emission reduction in the post COVID-19 pandemic era.

## Recycling Chains of HDPE Packaging: Insights from A Global South Circular Economy System in Southeast Brazil

Nathalia Silva de Souza Lima Cano1,3, Emília Rutkowski1, Costas Velis2
Organization(s): 1: University of Campinas, Brazil; 2: University of Leeds, UK; 3: University of Pittsburgh, USA

**Abstract**
Resource recovery from waste refers to establishing processes wherein waste generated at all stages of production and consumption value chains is recovered and maintained in the system to achieve a sustainable circular economy. Recycling value chains in middle- and low-income countries are complex to map due to diversified plastic material composition, high level of informality and high number of agents involved. Research that maps and characterizes agents in recycling chains and quantifies their material and monetary flows are incipient, especially for middle- and low-income countries. This research aims to uncover the complexities of a plastics recycling chain in Brazil, using polymer type High-Density Polyethylene (HDPE) as a case study. No other published study has assessed in depth a recycling value chain case study using HDPE packaging plastic waste. Starting from a sorting center in a small Brazilian city, investigating intermediaries until reaching reprocessing companies, this work provides a crossover analysis by combining three other tools, i.e., 1) Complex Value Optimization for Resource Recovery (Iacovidou et al., 2017), 2) Solid Waste Technical Network (Fiore and Rutkowski, 2017) and 3) Waste and Recycling Cost-Benefit Analysis Tool for Inclusive Recycling (Velis, Rutkowski and Rutkowski, 2016). Results include a thorough description of seven nodes of the technical network in the territory and eleven agents, their roles and activities. Mass-based material flows were quantified using Material Flow Analysis, furthermore, monetary and information flows were detailed. Complex value for four agents were assessed using 20 indicators in environmental, social, economic and technical domains. A comparison with a case from Egypt was performed to deepen the analysis and finally, policy recommendations were suggested to improve the Brazilian system. With this, we will contribute to improve decision making for plastics waste management, therefore increasing to the knowledge base required for advocating efficient policies, in Brazil and other countries.

## DAY 1 Session 9

### Charging Infrastructure Development Strategies for Escaping The “Chicken-Egg” Dilemma: An Agent-Based Simulation Study

Luo, Tanxiaosi; Li, Guijun; Song, Yanqiu
Organization(s): School of Management Science and Engineering, Central University of Finance and Economics, China, People's Republic of

**Abstract**
Providing effective charging infrastructure is a prerequisite to achieve mainstream uptake of electric vehicles (EVs), which is crucial for mitigating air pollution caused by conventional fuel vehicles and combating climate change. However, as with other infrastructure-dependent technologies, the market diffusion of EVs generally faces the “chicken-egg” dilemma, in which consumers are unwilling to adopt EVs without adequate charging availability and businesses are reluctant to invest in infrastructure without enough adopters. Previous studies have employed a game theoretic approach to investigate how to address this issue through policy mechanisms, which ignores the reality that

social networks and charging accessibility have a significant impact on consumer purchase decisions. Therefore, this study establishes an agent-based model to explore the effects of various infrastructure development strategies for escaping the dilemma, with a more realistic simulation of the charging behaviors and the reciprocal effects between EV purchases and charging infrastructure. In the case study, the simulation estimates both the EV adoption rates and economic costs of charging infrastructure roll-out under various scenarios, considering the effect of charging accessibility on EV driver comfort and how it influences their willingness to purchase via social networks. The model results can provide insights to policymakers on how to accelerate the positive feedback between charging infrastructure and EV adoption, hence encouraging EV uptake with limited infrastructure investment.

## Potential Impacts of Emerging Technologies on Agricultural Food-Energy-Water Nexus

Zhuang, Jie
Organization(s): University of Tennessee, United States of America

**Abstract**
The nexus of food, energy, and water (FEW) systems represents complex system science. The nexus underlies the sustainable development of agriculture while confronting increasing complexity and challenges brought about by emerging technologies (such as sensors, artificial intelligence, and automated machines), supply chain deglobalization, and environmental change. Far less understood are the FEW outcomes for future generations if the emerging technologies are widely applied to agriculture. The outcomes will influence resource allocation and decision-making on future agriculture practices from local to regional to global scales. These impacts on FEW resources and policies become increasingly complex as environmental change and unpredictable economic, social, and political consequences emerge. In this presentation, we discuss the increasing challenges as a consequence of emerging technologies for agriculture while identifying key knowledge gaps and technological tradeoffs. Synthesis of various information and perspectives indicates that development of a systems approach is a prerequisite for developing sustainable solutions to potential negative impacts of emerging technologies on agricultural FEW nexus.

## Environmental Footprints and Mitigation Strategies of Domestic Plant Food Loss and Waste in the United States

Sun, Huihui; Sun, Yanchen; Zhuang, Jie
Organization(s): University of Tennessee, United States of America

**Abstract**

The United States (U.S.) aims to reduce half of food loss and waste (FLW) by 2030. To achieve this goal, the public, academic, and political attentions on FLW have been increasing, and a series of actions have been implemented. However, the actions lack consideration on the categorical priority of FLW mitigation in relation to environmental footprints. In this article, we compare the FLW of three U.S.-based main plant food categories (i.e., grains, vegetables, and fruits) and their footprints of blue water and carbon dioxide emissions during the period from 1970 to 2017. The FLW of vegetables doubled during the period, reaching 3.39 × 1010 kg in 2017, which was approximately 5- and 2-fold higher than the FLW of grains and fruits, respectively. Vegetables, grains, and fruits contributed 29%, 47%, and 24% to the total wasted blue water footprint associated with the FLW. The total carbon dioxide emissions generated by plant FLW came from vegetables with 50%, grains with 31%, and fruits with 19%. Canonical correspondence analysis indicates that the FLW of vegetables had a higher positive correlation with urbanization, household incomes, gross domestic product, and high-income population than the FLW of grains, whereas the FLW of fruits was not influenced by these socioeconomic factors. Therefore, we suggest that the FLW mitigation should be prioritized on vegetables. Specific strategies include local food sourcing, shortening food miles, building food belts, and developing controlled-environment agriculture. Our data-based comparisons provide valuable insights into food policy improvement for achieving the 2030 reduction goal of the U.S., but the insights could be improved by considering the influences of foods imported from other nations.

## Synergizing Pollutant Removal and Carbon Emission Reduction in Wastewater Treatment Plants: Perspectives on Water-Energy-Carbon Nexus

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**Abstract**
As typical urban facilities of resource interaction with multiple forms, wastewater treatment plants (WWTPs) consume chemical agents and electricity to remove pollutants with large amounts of greenhouse gases (GHGs) emitted. In 2020, there were 55.73 billion $m^3$ of wastewater treated in China with about 18.4 billion kWh electricity consumed. The GHG emissions from wastewater sector accounted for approximately 1% of the whole society. So far, it is urgent to reveal the mechanisms of water-energy-carbon nexus in WWTPs, so that resources can be effectively transformed to achieve synergetic control of pollutants and carbon emissions. To achieve this, 719 daily operating data of an individual WWTP in Jiangsu, China, from 2016 to 2017 were put into use. Data envelopment analysis (DEA) was applied to evaluate the index of water-energy-carbon nexus with daily operational status set as the decision-making unit (DMU). In detail, energy consumption

and chemical usage were set as inputs while the amount of pollutant removal as desirable output. The carbon emissions were quantified and set as the undesirable output. The results showed that 11.54% of DMUs was the benchmark. Based on the data analysis, the water-energy-carbon nexus curve was simulated to reveal the dynamic balance among pollutant removal, energy consumption and carbon emissions in the WWTP. Meanwhile, a sensitivity analysis based on tailored approach was performed for indirect emissions from the chemical usage. It was found that the carbon emissions from chemical usage accounted for 4.90~22.89% of total carbon emissions, with an average value of 12.10%. In addition, the most significant effects of pollutant removal and chemical usage on the water-energy-carbon nexus in a WWTP were observed in this study. By reasonably setting the discharge standards and optimizing the chemical usage, the synergistic effect of pollution reduction and carbon emission can be expected to realize.

## China’s Greenhouse Gas Emissions from Food System Linking to Supply Chains and Trade Network

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**Abstract**
Abstract： Food systems are responsible for a third of global anthropogenic greenhouse gas emissions, and there has been an ever-increasing focus on food-system GHG. However, limited attention has been paid to emissions along with supply chains and regional trade network. This study develops a MRIO-based hybrid LCA model and attempts to trace China’s food-system GHG emissions from production to consumption, including processing, transport and packaging. China’s food system emitted 203.8 Mt CO2-eq GHG in 2019, with the three types of GHG contributing 48.1% (CO2), 47.3% (CH4), and 4.6% (N2O), respectively. The production is the primary GHG emission source (taking a share of 47.0%). There are great differences in emission structure and sources among provinces. For example, the share of CO2 is large for Beijing, Tianjin, and Shanxi, while the share of CH4 is larger for Guangxi, Gansu, and Qinghai. We also reveal that GHG from production and that from waste are weakly correlated. Further analysis indicates that the differences among provinces caused by the separation of food production and consumption. People living in wealthier coastal and central regions consumes food from western and northeast regions. GHG emission is high for major regions of agriculture, but large amounts of food end up being consumed in other regions. In fact, provinces that take agricultural production as a dominical part are poorer and have limited ability to cope with climate change. Therefore, the government should consider inter-regional synergy when developing strategies to reduce GHG emissions from food systems.

## The Current Status, Energy Implications, and Governance of Urban Wastewater Treatment and Reuse: A System Analysis of The Beijing Case

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**Abstract**
Wastewater treatment and reuse is an important means of addressing water scarcity and protecting the aquatic environment in urban areas but comes at the cost of energy consumption and greenhouse gas emissions. However, the issue of governance and provincial-scale research have largely been ignored in current urban wastewater treatment and reuse studies. Taking Beijing as a case study, this paper summarizes the current status of 175 wastewater treatment plants (WWTPs), explores energy-intensive processes, energy consumption ratios, and the overall energy intensity of WWTPs, and maps the structure of urban wastewater treatment and reuse governance. The results indicate that most WWTPs in Beijing are medium or small in scale, treating less than 200 thousand tons of wastewater per day. Treatment capacity among districts in the ecological preservation area (e.g., Mentougou, Yanqing, Huairou, Miyun, Pinggu districts) largely depends on their largest WWTP, which constitutes more than 75% of the district treatment capacity. Then, five energy-intensive subprocesses are identified, including pumping, blowing air, stirring and sludge recycling, filter feed pumping, and sludge dewatering. The energy intensity of WWTPs in Beijing varies by treatment capacity and use of membrane bioreactor treatment technology. Furthermore, the current coordination group for wastewater treatment and reuse and related policies were mapped and can be used to define the boundaries of wastewater governance. Finally, inconsistent data, reductions in energy consumption and the normalization of the governance structure are discussed, and policy suggestions are proposed. The results in this paper complement recent work on national wastewater treatment and reuse and provide foundational knowledge and a useful framework to sustain wastewater treatment and reuse in Beijing and other areas.

## DAY 1 Session 10

### Domestic Plastic Packaging Material Metabolism in China Based on The Bottom-Up and Top-Down Approaches

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**Abstract**

Plastic packaging is closely related to people's life, and the environmental pollution of plastic packaging waste has attracted global attention. Especially, the environmental omission of plastic packaging has become the main source of marine plastic pollution. In this study, a data collection approach has been established, combining bottom-up consumer behavior questionnaire survey and top-down macro data analysis. A metabolic model of domestic plastic packaging materials has been proposed in two dimensions of urban and rural areas at the sub-provincial scale in China, including the plastic packaging consumption and distribution, waste generation, and different treatment and disposal. The recycling potential, treatment and disposal of different types of plastic packaging have been analyzed, revealing the quantitative characteristics of the path and flow of plastic packaging for urban/rural residents in China. The results show that the consumption intensity of domestic plastic packaging in urban areas in China is higher than that in rural areas. The overall difference in the recycling rate of plastic packaging by province is not large, but there are significant differences in the amount of recycling. In 2018, the main category of domestic plastic packaging waste accumulated by urban residents in China was about 14.17 million tons. Heilongjiang, Jilin and Xinjiang are the provinces with high environmental risk of omission of urban domestic plastic packaging waste. The environmental omission of plastic packaging waste in China mainly comes from rural areas, and the provinces with high environmental risk of omission are Henan, Yunnan and Hebei. The probability of environmental omission of domestic plastic packaging waste in rural areas is about 36.6%. This study identifies key control areas and links to reduce environmental emissions from plastic packaging waste in China. This study provides scientific method and data support for the refined management of plastics.

## The Impact of The Covid Pandemic in The Use of Disposable Nonwoven Fabrics: Case Study on The Francesc The Borja Hospital

Alberto Quintana Gallardo, Ignacio Guillén-Guillamón, Romina del Rey
Organization(s): Universitat Politècnica de València, Spain

**Abstract**
In the context of the current coronavirus pandemic, many hospitals are transitioning from using cotton fabrics for medical gowns and other products to nonwoven fabrics. The medical equipment made of nonwoven fabrics is often highly regarded by doctors, nurses, and other hospital workers. Disposable nonwoven fabrics are convenient for the medical staff and provide advantages in sterilization and safety.

However, this tendency has some potential drawbacks environmentally-wise. Hospitals generate huge amounts of nonwoven residues daily. This paper focuses on studying the evolution of nonwoven waste generated in the Francesc de Borja Hospital (Spain) over the last years and its relation to the COVID-19 pandemic. The main objective is to identify the most impacting pieces of nonwoven equipment in the hospital and to analyze possible solutions. The carbon footprint of the nonwoven equipment is studied through a Life Cycle Assessment. The results show an apparent

increase in the carbon footprint in the hospital from 2020. Also, due to the higher annual volume, the simple nonwoven gown used primarily for patients has a higher carbon footprint over a year than the more sophisticated surgical gowns. After finishing the study, it can be concluded that developing a local circular economy strategy for medical equipment could be the solution to avoid the enormous waste generation and the carbon footprint of nonwoven production.

## Plastic Characterisation of Four Internal Combustion Engine Vehicles

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**Abstract**
This paper analyses and classifies the plastic content of 4 vehicle models from SEAT manufacturer, which have been selected, taking into account representativeness factors concerning the total sales of the brand, different equipment levels and different models covering a wide period of production years. Our results show that plastics make up an average of 230 kg, 18 % of the car's total mass. The following car parts are especially relevant considering their plastic contribution: bumpers, fuel tanks, floor linings, door panels, trunk linings, engine mounts, headlights, dashboard, centre console and front compartment. Considering the polymers analysed, 7 categories (PP, NR, PA, PU, PE, EPDM, PET and SBR) account for 63.5 % of the mass of plastics. Among them, the contribution of PP stands out with 18.5 % of the total mass.

## Tracking The Patterns of Materials Stocks and Flows for Circular Economy in Eastern Europe, 1990-2019: An Integration of Economy-Wide Material Flow Analysis and Dynamic Substance Flow Analysis

Wensong Zhu, Kun Sun, Ciprian Cimpan, Agate Veipa, Gang Liu
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**Abstract**
Economy-wide material flow analysis (ew-MFA) is widely applied to explore pathways towards sustainability across scales, but it ignores the crucial role of material stocks of manufactured capital. Dynamic substance flow analysis (SFA) can fill this gap by tracking the stocks and flows of a particular substance or material over time, whereas it also leads to narrow material coverage. Integrating ew-MFA and SFA paves the way to simultaneously cope with the stock dynamics and narrow material coverage and further facilitates comprehensive understanding of socioeconomic metabolism and circular economy (CE) monitoring. Moreover, previous studies at national scale

have focused on industrialized countries, eastern Europe countries received much less attention. Herein, we integrated the CE monitoring framework for economy-wide materials and the material inputs, stocks, and outputs (MISO) and applied to the case of four eastern EU countries (Bulgaria, Croatia, Poland, and Romania) from 1990 to 2019, aiming to provide national profiles of material use and dematerialization, and further to identify barriers and enabling conditions for future CE implementation. The results show that the productivity indicating by domestic material consumption and material footprint delivers distinct performance, but they both reveal the gaps for these countries to meet the benchmark of EU-27 and other developed countries. The per capita in-use stocks have reached 384 t/cap (Bulgaria), 380 t/cap (Croatia), 236 t/cap (Poland), and 296 t/cap (Romania) in 2019, dominating by concrete and aggregates. Both material flows and stocks tend to be relative decoupling with GDP while the elasticities of material flows show diverse trends but that of stocks keep increasing among all countries. Improving country-specific parameters, statistical reporting and the quality of wastes would benefit to assess stocks and circular performance. Developing specific collection system and recycling facilities takes the priority to address the increasing stocks of packaging materials and future demand of metals.

## Material Stocks in Highways: A Case Study of Remote Sensing Capability

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**Abstract**
Global material stocks (MS) increased 23-fold over the 20th century and are predicted to have an increasing trend in the future, which causes waste and growing greenhouse gas emissions, surpassing the planet's regeneration ability. Therefore, better design, utilisation and management of in-use stocks are required to minimise the expected increases in resource demand for economic development. Though our understanding of material stocks is continuously improving, their detailed characterisation remains time-consuming. The bottom-up approach (the preferred methodology for detailed MS characterisation) is indeed data- and time-intensive as it quantifies MS by inventorying all items containing a specific material and multiplying this inventory by the item's material intensity. This study investigates ways to automatise the creation of built environment assets inventory. More specifically, we explored the potential offered by remote sensing (RS) data, using highways in London and Leicestershire as case studies. We used image classification to extract the highway dimensions from high-resolution aerial photographs provided by EDINA national data centre. The object-based image analysis (OBIA) can permute the remote sensing images into factual information, which can be exploited to conjure different Geographic Information System (GIS) data sets. The OBIA method in Quantum GIS (QGIS) 3.16.14 and ArcGIS pro 2.9.1 have been used to capture highway dimensions from 25cm resolution aerial images. The results of highway dimensions extraction show ArcGIS pro provides more accurate results in areas with a higher number of shadows and shaded regions, while QGIS works better in images with a low shadow rate

environment. This study shows that RS images and GIS provide a cost and labour-efficient method to extract dimensional information on highways, as opposed to on-site surveys and manual count. Future work will investigate the potential of RS data for the inventory of other infrastructures (e.g., car parks), and for integrating a temporal understanding.

## Decision Analysis Framework to Assess SDG Targets within the Context of BSC Perspectives in Supply Chain Networks

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**Abstract**
This research aims to develop a framework for implementation of the Sustainable Development Goals (SDGs) in supply chain network organizations. An in-depth research about the SDGs and related targets is provided in order to align them with networks through a decision matrix. A systematic literature review based on the Methodi Ordinatio methodology ensures the scientific robustness of the theoretical basis, providing a survey of general indicators to monitor implementation progress. By honing the theory with this research's objective, the SDG Compass guide, which provides implementation guidelines business strategy, was analysed. The mathematical part was based on the decision-making method MACBETH (Measuring Attractiveness by a Category Based Evaluation Technique), which allows to evaluate options on a multi-criteria basis. The result is s structured framework based on those perspectives, guidelines and actions taken from the methodology development, aimed to monitor the implementation of SDGs in supply chain network organizations.

Keywords: Sustainable Development Goals, supply chain network, Balanced Scorecard, MACBETH.

# DAY 1 Session 11

## Interventions Improving Household Recycling Behavior: A Spatial Analysis

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**Abstract**
The United States (US) generates 42 million metric tons of plastic waste each year – the most of any country – of which less than 9% is recycled. This waste represents an estimated loss of $7.2 billion, and 3.4 EJ embodied energy per year. Moreover, plastic waste contaminates the earth's ecosystems,

which is increasingly drawing concerns about its potential impacts on wildlife and human health. The application of Circular Economy (CE) strategies such as reducing, reusing, and recycling could mitigate the environmental impacts of plastic waste. However, making informed policy and research decisions within this space can be challenging given the diverse range of available solutions. Some of the most critical barriers to overcome are increasing the quantity and quality of collected plastic waste and improving recyclates' value.

Regarding collection, the highly context-specific effect of factors affecting household recycling behaviors means that tailored interventions more effectively increase recycling behaviors than 'one-size-fits-all' solutions. In this presentation, we analyze a series of different interventions aiming at improving the quantity and quality of collected polyethylene (PET) bottles (e.g., enhanced producer responsibility or cart-tagging programs) for different US states through agent-based modeling (ABM). The model simulates households' recycling behaviors in detail and explores various interventions' effects on those behaviors. The ABM uses data from the Census Bureau and various academic and grey literature to provide a spatially resolved estimation of the collection rate from the Census block group to the state level. Results show that breaking households' habits is crucial to adopting recycling behaviors. Moreover, doubling households' recycling knowledge within communities (e.g., through a cart-tagging program) augments the collection rate by 0-9%, depending on the state. A possible next step for this research is to find the combination of interventions that best suit each state: minimizing costs while maximizing plastic waste collection.

## Public Land Conversion in Macroeconomic Policy Uncertain Times

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**Abstract**
Globally, local governments manage substantial public land and face the trade-off between environmental and economic use. However, there is little understanding of how this trade-off responds to macroeconomic policy uncertainty caused by the central government. In this paper, we develop a simple model to incorporate local governments' land conversion decisions with macroeconomic policy uncertainty. Also, we provide an empirical evidence from prefecture-level governments in China to support our theoretical result: macroeconomic policy uncertainty significantly expands the scale of public land conversion for urban development. The analysis highlights the role of local economic stabilization in shaping patterns of public land-use change in economic policy uncertain times.

## How The Incentive Policy Affects Enterprises' Innovation in Renewable Energy Industry:A Quasi-Natural Experiment Based on China's Micro-Data

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Organization(s): Beijing Forestry University, China, People's Republic of

**Abstract**
Under the context of developing the low-carbon industry, incentive policies are helpful to promote enterprises' innovation and development. Based on China' s 13th Five-Year Plan for Renewable Energy Development, this paper builds the quasi-natural experiment using difference-in-difference model (DID) with data on Chinese A-share listed enterprises in renewable energy industry from 2012 to 2020. We empirically analyze the impact of this incentive policy on enterprises' innovation and the moderating mechanism of market power on the incentive effect. Then, we investigate the differences in the mediating effect of R&D investment on different innovation behaviors. The results show that: (1) The policy promotes the innovation of enterprises, but there are still strategic innovation behaviors in the innovation process, which is prone to the pursuit of quantity of innovation rather than quality; (2) Market power has a strong positive moderating effect on the policy to promote innovation; (3) The direct effect on R&D investment in the policy that encourages enterprises' substantive innovation is not significant, while the indirect effect on R&D investment in the promotion of strategic innovation is small in proportion; (4) The policy significantly promotes enterprises' substantive innovation in photovoltaic and wind energy industry segments and those enterprises located in the upstream and midstream of the industry chain.

## The Influence of Personal Characteristics, Environmental Attitude, and Knowledge on The Use of Toxic Substances in Handicrafts Businesses in Mexico.

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**Abstract**
The use of toxic substances in the manufacture of pottery handicrafts has generated a problem for many years that can be analyzed from three aspects: 1) the handling of dangerous substances in the varnishing process of the handicrafts, which leads to health problems for the craftsman, 2) when the clay pieces are fired, smoke is emitted, generating exposure by inhalation and, 3) chemical reactions when the finished product comes into direct contact with acidic foods, so there is a risk for those who ingest food prepared or served in these products. In this work, the use of toxic substances in pottery businesses is analyzed in relation to variables such as schooling, ethnicity, environmental attitude, and knowledge of the artisan. A model is empirically validated by means of the partial least squares approach to structural equation modelling (PLS-SEM) based on survey data from a spectrum of Mexican handicraft small businesses. The use of toxic substances was objectively measured through instantaneous lead detectors called "Lead Check Swabs". The results suggest that the use of toxic substances can be explained by the level of schooling and the environmental knowledge of the

artisans; however, the ethnic group and the environmental attitude do not influence the decision of the artisan to use toxic substances. The results of this study can help understand how to improve environmental protection in the artisanal sector and contribute to the reduction in use, or substitution of, toxic substances that harm the health of the artisan and the environment in general.

## Cost-Benefit Analysis of Reusable Takeaway Containers Considering Multi-Stakeholders: A Case on Campus in China

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**Abstract**
Takeaway food package has become one of the main sources of single-use plastics in China. Reusable takeaway food container is an effective way to reduce negative environmental impacts that caused by single-use plastic containers. However, how to promote it to be used widely is still a main challenge. This study is intended to figure out the barriers of this new business model deployment through evaluating the economic costs and benefits of reusable takeaway food containers from stakeholder's perspective. Based on the analysis of stakeholders' interests and activities in the pilot reusable takeaway food containers project at a university in Guangdong province, a detailed stakeholders' costs and benefits matrix was developed to evaluate main stakeholders' costs and benefits. Both market and non-market prices were used to evaluate the costs and benefits, and a sensitivity analysis was conducted to study the main influencing factors. The main stakeholders of the pilot project include the platform company, the university, restaurants, and consumers, whose interests are divergent. The cost-benefit analysis results show that the net benefits of the platform company, the university and the restaurants are negative, ranging from -3.4 to -81.3 thousand Chinese yuan per year in the pilot project under current operation situation, which may hinder the sustainable development of this new business model. The net benefit of consumers is positive, about 60.2 thousand Chinese yuan per year. The sensitivity analysis result shows that all the stakeholders could gain a positive net benefit through increasing the proportion of reusable takeaway food containers, the rental price, cleaning price and packaging price. Based on these results, we put forward several suggestions for the promotion of reusable takeaway food containers

## Does Environmental Tax Affect The Location Choice of Foreign-Invested Manufacturing Enterprises? --Evidence from China

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**Abstract**
Using 24,152 newly established foreign-invested manufacturing enterprises data combined with city socio-economic characteristic panel data in China from 2015 to 2019, this study empirically investigates the effect of environmental tax on the location choice of foreign-invested manufacturing enterprises. This study contributes to the literature which typically suffers from problematic aggregate data and controversial measurements of environmental regulation. Moreover, the study explores whether foreign-invested manufacturing enterprises with heterogeneous ownership property, industrial classification and investment scale respond differently to environmental tax. Our results suggest that environmental tax has a statistically significant and negative impact on the location choice of foreign-invested manufacturing enterprises, verified by a series of robustness checks. The heterogeneous effects of environmental tax manifest that the location choice would be remarkably more sensitive for the sole-venture enterprises, and for those in heavily polluting industries, and at small investment scales. The findings suggest that local governments should promote consistency in environmental tax rates between regions to promote overall environmental quality improvement and set reasonable environmental tax rates to balance economic growth and environmental protection.

## DAY 1 Session 12

### From Fenton Sludge Waste to Micropollutant-Free Fe(II) Product: New Potential for Wastewater-Driven Autotrophic Biocathode

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**Abstract**
Recycling of Fenton-derived ferric sludge is a major concern in homogeneous Fenton processes. Residual recalcitrant micropollutants in Fenton sludge mainly limited its disposal. This study investigated for the first time the effectiveness of simultaneously eliminating micropollutants in Fenton sludge and producing dissolved Fe(II) in an autotrophic biocathode. The sustainable biocathode was driven by the wastewater in the bioanode of a two-chamber microbial electrolysis cell. Granular sludge, which has good tolerance to toxic compounds, was used as the biocathode inoculum.

In the flow-through granular sludge biocathode, 175 mg/L of valuable dissolved Fe(II) was stably regenerated from the actual Fenton sludge waste at pH 6.3. Interestingly, all the 6 micropollutants in Fenton sludge were removed 80% to 100% during Fe(II) production. Moreover, 20 mg/L NO3--N in

the Fenton sludge was also completely removed. However, micropollutants and nitrate cannot be removed, using an abiotic cathode to regenerate Fe(II) at pH< 3.

Furthermore, Fe(II) production via the granular sludge biocathode was equally measured recycling actual and synthetic Fenton sludge. Mechanistic studies show that Clostridium sensu stricto was dominant in the granular sludge biocathode using actual Fenton sludge as an influent. The relative abundance of Methanobacteriaceae decreased obviously when the granular sludge was inoculated into the biocathode. The produced Fe(II) solution can be widely used in the environmental field (e. g., advanced oxidation and phosphate removal).

The granular sludge biocathode simultaneously enjoys the advantages of functional versatility, stable operation and negligible reagent input. These findings provide perspectives for developing a viable platform to convert Fenton sludge waste into valuable micropollutant-free Fe(II) product using wastewater.

## Valorization of Residual Wheat Straw in Chile for The Development of A Thermal Insulating Material Applied in Sustainable Buildings by Blowing Method

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**Abstract**
The construction industry demands energy, depletes materials and is directly associated with air pollution issues. In addition, housing in its operational stage requires efficient and low impact thermal insulating materials, that is why this work presents an evaluation, characterization and valorization of residual fibers from wheat crops located in the Araucanía Region, Temuco, Chile, in order to develop a prototype thermal insulating material. The results indicate that the fiber has a thermal conductivity of 0.034 [W/mK] comparable to expanded polystyrene, glass wool and several traditional materials in the Chilean market. In addition, the material can be blown into partition walls, improving on-site application times. Finally, it is indicated that the best alternative for locating a material processing plant is in the central sector of the region, between the localities of Victoria and Perquenco.

## Development of Iron-Coated Quartz Sand Composites for Efficient Phosphorus Adsorption in Aqueous Media: A Design of Experiments (DoE) Approach

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**Abstract**
Food production by modern agriculture requires the use of fertilizers containing nutrients such as Nitrogen, Potassium, and Phosphorus. Special attention is given to Phosphorus: the quality and quantity of its main remaining sources (phosphate rocks) are rapidly decreasing. On the other side, sewage is an alternative source of this resource. With appropriate technology, Phosphorus can be recovered from sewage in Sewage Treatment Plants (STPs), improving the quality of the effluent at the same time that sewage can be used as an alternative source of this nutrient. In this context, this work demonstrates the use of Design of Experiments (DoE) techniques in the development of iron-coated quartz sand composites focusing on optimizing its characteristics for Phosphorus adsorption in aqueous media. Nine different synthesis parameters were investigated in this process and important correlations between the physicochemical properties of the adsorbents and their synthesis parameters were elucidated. It was found that several iron oxides phases (with different degrees of crystallinity), such as goethite and magnetite, were obtained depending on the conditions employed during the synthesis by coprecipitation. The characteristics of the iron phases strongly affected the Phosphorus adsorption capacity of the composites. The best adsorbent predicted by statistical models fitted to a multivariate database built with DoE was successfully synthesized in laboratory, and it exhibited a Phosphorus adsorption capacity as high as 8,9 mg P/g (C0 = 10 mg P/L, pH 6,0, 2h). Finally, some investigations were carried out to simplify the production method, resulting in an optimized adsorbent that can be produced using an iron (III) chloride solution (obtained from acid dissolution of scrap-iron), a sodium hydroxide aqueous solution, quartz sand, and tap water as starting raw materials. The optimized adsorbent has potential to be used as a low-cost technology to capture residual Phosphorus in STPs, improving this resource conservation and recycling.

## Hydrochar from Hydrothermal Liquefaction of Municipal Sludge: A Critical Characterization for Its Valorization

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**Abstract**
Proper management of municipal sludge is always challenging due to the significant amount and hazardous contents (e.g., pathogens, organic contaminants, heavy metals, and micropollutants). The primary objective of sludge handling is moving towards minimal pollution and resource recycling. Hydrothermal liquefaction (HTL) is the latest waste-to-energy technology that can efficiently convert sludge biomass into a biofuel source – biocrude. The remaining solids (called hydrochar) are significantly reduced to minimize the management cost and environmental impacts. Although in small amounts, the recycling of hydrochar could improve the sustainability of HTL sludge treatment systems and achieve zero waste in the circular economy. This study comprehensively and critically assessed the characteristics and potential applications of hydrochar generated from HTL of mixed sludge at various reaction temperatures (290–360°C) and residence time (0–30 min). The fuel ratio of hydrochar significantly increased with HTL reaction severities, with H/C and O/C atomic ratios close to coal, while the higher heating values decreased compared to mixed sludge. Compared to sludge, hydrochar can perform more stable combustion, but the high ash contents (up to 69% by weight) may cause slagging issues. Hydrochar can be used for carbon sequestration due to reduced O/C ratio (<0.2) and enhanced thermal stability. Benefiting from the inherent catalytic metals (e.g., Ca and Fe), hydrochar could be potentially upgraded to graphite at a moderate temperature (1200°C). Although hydrochar could be restricted from land application as a soil amendment due to the accumulation of heavy metals (e.g., Mo and Zn), it is a promising source for metal and nutrient recovery. Considering the high phosphorus (P) contents (up to 8.5% by weight), recovering P from hydrochar is critical for the mitigation of environmental challenges and global P shortage. Overall, this study contributed to the state-of-the-art in the field of waste valorization for resource sustainability.

## Material Recycling of Acrylonitrile Butadiene Styrene (ABS) from Toy Waste Using Safer Solvents

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Organization(s): University of Massachusetts Lowell, United States of America

**Abstract**
Toy waste is an issue for municipal plastic recycling program. Although the toy takeback program allows toy waste to be collected and recycled, toy waste typically is composed of different types of plastics and some metals. Separation of different parts of toy waste would be necessary before mechanical recycling processes. In this study, a dissolution-precipitation process, coupled with density separation, was developed to extract acrylonitrile butadiene styrene (ABS) from toy waste using safer solvents and anti-solvents. The polymer solubility of ABS was measured using Hansen solubility parameters, which were then used to down-select proper safer solvents and anti-solvents. The acetone-water with a volumetric ratio of 3:1 was determined to be the most effective safer solvents and anti-solvents for extracting 81 wt.% of ABS at room temperature. The recovered ABS has comparable mechanical behavior to the feedstock material with a similar glass transition

temperature and molecular weight distribution. However, some degree of oxidative degradation of ABS were found, possibly due to the fact that additives such as antioxidants and/or stabilizers were removed from ABS during dissolution-precipitation processes. Compared to producing virgin ABS material, the dissolution-precipitation process could potentially reduce 58% embodied energy. Results from this study provide guidance to ABS material recovery and re-processing, which could be expanded to other post-consumer ABS waste.

## Implementation Considerations for Material Salvage and Reuse of Structural Steel Components Sourced from Building Demolition and Deconstruction Operations

Michael Jude Emmer
Organization(s): Roger Williams University, United States of America

**Abstract**
When structures within the built environment are slated for demolition there is a significant opportunity to deconstruct the building in such a way to allow maximum reuse of the existing materials. Many times, stakeholders overlook the potential to capture and preserve the invested embodied energy of the existing materials through their reuse. At best, the designers and constructors make cursory attempts to reuse a very narrow range of materials such as concrete, wood, and masonry. This approach of selecting the “low hanging fruit” ignores the true tenets of sustainability and avoids doing the challenging work of figuring out ways to reuse a greater portion of the materials for some future project. Construction and demolition (C&D) waste can make up a vast portion of the materials handled on a typical construction project and introducing the concept of steel reuse would reduce waste in the material supply stream. This research investigated the level of awareness of steel reuse on the design side of the built environment equation and developed a process by which structural steel can be extracted and re-purposed by reusing the sections. The results indicated that designers (architects and engineers) are for the most part unaware of the potential of structural steel reuse. The process that was developed from the research could be implemented into the architectural, engineering, and construction (AEC) industry. If these removed materials are not reintroduced back into the material supply chain their embodied energy is lost and must be made up somewhere along the line thru further depletion of our non-renewable resources.

# DAY 2 Session 13

## Evaluation of Copper Availability in China through Factor Analogy Method

Yongguang Zhu, Zhiyi Zhou, Yuna Gong, Deyi Xu
Organization(s): China University of Geosciences, China, People's Republic of

**Abstract**
Copper plays an important role in the process of the energy transition as a kind of critical minerals. As it is difficult to obtain data, it is an important problem to evaluate the availability of copper. In this paper, we propose a factor analogy method to estimate mineral resource availability through a few sample data. Through the four dimensions of geology, technology, economy, and environment, the heterogeneity between known samples and predicted samples is compared. Based on the results of known mine availability, the availability of unknown mines is calculated by the analogy factor. We selected 699 copper mines in China for a case study. Finally, we drew the cumulative availability curve of copper in China.

## Study on The Ecological Risk of Heavy Metals in Biochar Derived from Fast Co-Pyrolysis of Municipal Sludge with Polyvinyl Chloride Plastic

Zhiyuan Li, Yaji Huang
Organization(s): Southeast University, China, People's Republic of

**Abstract**
To investigate the issue of increased ecological risk of heavy metals in resultant biochar that may be caused by the addition of chlorinating agents to remove heavy metals from sludge during pyrolysis treatment, fast co-pyrolysis experiments of municipal sludge with polyvinyl chloride plastic (PVC) were conducted in a horizontal fixed-bed reactor to explore the effects of temperature (500-900°C) and PVC mixing ratios (0, 5 and 15%) on the migration and transformation behaviors of heavy metals As, Cr, Cu, Mn, Ni, Pb and Zn. It was found that increasing the pyrolysis temperature and adding PVC to feedstocks were beneficial to reduce the residual rate of As, Pb and Zn in biochar, but had almost no effect on the removal of Cr, Cu, Mn and Ni. Furthermore, the speciation analysis of heavy metals showed that the heavy metals (except As) in biochar generally transformed into more stable forms with increasing pyrolysis temperature. However, according to the ecological risk assessment of heavy metals, the presence of PVC in pyrolysis system increased the ecological risk of heavy metals in the obtained biochar when the pyrolysis temperature was 500 and 600 °C, but when the pyrolysis temperature exceeds 600°C, the addition of PVC in feedstocks can indeed lower the ecological risk of heavy metals in the resultant biochar, while decreasing the content of heavy metals. Therefore, corresponding attention should be paid to prevent the problem of increased ecological risk of heavy metals caused by PVC in feedstocks during the process of industrial pyrolysis for sludge disposal.

Keywords: municipal sludge, polyvinyl chloride plastic (PVC), co-pyrolysis, heavy metals behaviors, risk assessment

## Voluntary Sustainability Initiatives and Environmental Flows: Analysing The Lithium-Ion Battery Value Chain

Bernardo Mendonca, Damien Giurco, Northey Stephen
Organization(s): University of Technology Sydney, Australia

**Abstract**
With the decarbonization of the transportation sector, batteries' value chains are more convoluted and having their transparency challenged. To achieve the massive shift towards clean energy storage in the electric vehicles (EV) industry, mineral requirements will become more complex and intertwined - Involving rapidly growing logistic operations for lithium, Cobalt, Nickel, and rare metals. Most of these specialty metals have only previously been mined in small amounts, greatly increasing their forecast demand, and therefore the opening of new mining operations.

With EV manufacturers being pressured by the civil society to have a more transparent value chain, Voluntary Sustainability Initiatives have emerged as a potential mechanism to ensure and communicate the procurement of responsibly sourced raw materials by EV manufacturers within the lithium-ion battery value chain. This paper examines to what extent VSIs influence the collection of environmental flows' data that can be further used to improve product life cycle impacts to increase transparency in the critical minerals value chain moving downstream to electric vehicle manufacturers. Data related to raw critical minerals extractions is still inconsistent, which might mitigate declarations such as the Environmental Product Declaration (EPD) and standards aimed to facilitate business-to-business communication of environmental impacts.

With several countries already planning to phase out or ban sales of petrol- and diesel-powered cars, substantial mitigation opportunities exist in this emerging market. Promoting knowledge generation in this area may generate clear environmental communication within the complex value-chain associated with critical minerals and lithium-ion batteries.

## Aluminum Demand and Recovery Potential in China Considering Vehicle Light-Weighting Trends and Electric Vehicle Diffusion

Wang Binze, Zhang Zhengyang, Matsubae Kazuyo
Organization(s): Tohoku University, Japan

**Abstract**
Trends in vehicle light-weighting and the diffusion of electric vehicles in China increase the use of wrought aluminum alloys in automobiles and its scrap generation. The wrought scrap is ultimately downgraded to cast aluminum alloys by current remelting processes, regardless of the decreasing demand for cast alloys due to its major application parts such as engines disappeared from electric vehicles. Quantifying the demand for aluminum and its recovery potential by alloy types provides a starting point for the discussion of upcycling aluminum scrap along with meeting the demand for high-grade aluminum while reducing the consumption of primary aluminum.

We identified the flows of vehicle-derived aluminum in China by alloy types considering the change of aluminum composition in vehicles due to the light-weighting and electric vehicle diffusion, by material flow analysis. We also estimated the recovery potential of aluminum scrap by alloy types and the associated reduction potential of primary aluminum use, under different scenarios of collection, dismantling, and sorting yield ratios of end-of-life vehicles. We found that the demand for automotive wrought alloys will increase from 870 kt in 2019 to a minimum of 3,630 kt in 2050, while that for cast alloys will decrease from 2,599 kt in 2019 to a minimum of 1,830 kt in 2050. By applying an effective combination of collection/dismantling/sorting rates of end-of-life vehicles, the amount of recyclable wrought alloys is estimated to increase from 87-183 kt in 2019 to 1,054-7,152 kt in 2050 under different scenarios of vehicle light-weighting and the diffusion of electric vehicles. The recycled aluminum has the potential to reduce the total requirement of primary aluminum ingot for automobiles by 10%-37% from 2019 to 2050.

## Tracking Three Decades of Global Neodymium Stocks and Flows with A Trade-Linked Multiregional Material Flow Analysis

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Organization(s): 1: University of Southern Denmark, Denmark; 2: Chinese Academy of Sciences; 3: Sakarya University; 4: Chinese Academy of Geological Sciences and China Geological Survey

**Abstract**
Neodymium (Nd), an essential type of rare earth element (REE) has attracted increasing attention in recent years due to its significant role in emerging technologies and its globally imbalanced demand and supply. Understanding the global and regional Nd stocks and flows would thus be important for understanding and mitigating potential supply risks. In this work, we applied a trade-linked multiregional material flow analysis (MFA) to map the global and regional neodymium cycles from 1990 to 2020. We reveal increasingly complex trade patterns of Nd containing products and a clearly dominant but slightly weakening role of China in the global Nd trade (for both raw materials and semi- and final products) along the life cycle in the last 30 years. A total of 880 kt Nd was mined accumulatively and flowed into the global socioeconomic system, mainly as NdFeB permanent magnets (79%) in semi-products and conventional vehicles and home appliances (together 48%) in final products. Approximately 64% (i.e., 563 kt Nd) of all the mined Nd globally were not recycled, indicating a largely untapped potential of recycling in securing Nd supply and an urgency to overcome the present technological and non-technical challenges. The global Nd cycle in the past three decades is characterized by different but complementary roles of different regions along the global Nd value chain: China dominates in raw materials and semi- and final products provision, Japan focuses on magnets and electronics manufacturing, and the U.S. and EU show advantages in the vehicle industry. Facing increasing demand of Nd in emerging energy and transport technologies in the future, more coordinated efforts among different regions and increased recycling are urgently

needed for ensuring both regional and global Nd supply and demand balance and a common green future.

## A Geographical Profile of Risks and Impacts Due to Coal Mining in East Kalimantan, Indonesia

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**Abstract**
East Kalimantan is expected to be the site of Indonesia's new national capital. However, coal mining in this province is also undergoing expansion and has been associated with environmental harm, community conflict, and loss of life. To investigate the cumulative risks of population growth and coal expansion in this province, we have combined satellite monitoring, interviews, extensive review of provincial literature and GIS to construct a detailed geographical profile of coal activity and impacts.

In this presentation, we outline our approach to documenting and explaining patterns of land clearing, water cover, safety risks, human settlements, governance and regulatory infractions. Our results have indicated that ineffective coal mining governance has led to improper permit granting, widespread overlaps with competing land uses, increased deforestation, dramatic changes to the hydrological landscape, limited reclamation and increasing safety risks for nearby residents. Such local-scale effects are a significant supply chain concern for the world's largest thermal coal exporter. The identification of underlying spatial patterns that produce risk, coupled with political economy analyses enabled us to formulate a series of policy recommendations to reduce the impacts of population growth and future coal developments in this province.

## DAY 2 Session 14

## Potential Renewable Energy Development from Palm Oil Wastes in Indonesia with Consideration of Circular Economy

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**Abstract**
Indonesia is the largest producer of palm oil in the world, supplying 57% of its demand. The waste generated by this industry is around 34 million tons per year, and most of them are underutilized. The industry generates wastes in the form of shells, fibers, empty fruit bunches, and palm oil mill effluents. The accumulation of waste is growing at an alarming rate causing a significant impact on greenhouse gas (GHG) emissions, air pollution, and water pollution which directly affects climate change. To address this issue, the application of circular economy (CE) is needed. CE aims to convert wastes into renewable energy to help mitigate the effects of climate change. The objective of the study is to investigate the potential wastes derived from the palm oil industry and how they can be transformed into value-added products. An economic feasibility analysis is carried out considering four waste treatment technologies, namely, composting, incineration, covered lagoon, and continuous stirred tank reactor for each type of palm oil mill. Through these technologies, the wastes can be converted into two products: organic fertilizer and electricity. Considering both economic and environmental factors, this study will identify the most viable technology to be used depending on the types of mill, namely, mini, small, medium, and large mills. In addition, this study will perform an optimization task to select the technology for each mill with the objective of maximizing profits while limiting GHG emissions. We believe that the result of this study can provide insights for decision-makers to identify the best waste treatment technologies for their renewable energy programs.

## Estimating The Decoupling between Net Carbon Emissions and Construction Land and Its Driving Factors: Evidence from Shandong Province

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**Abstract**
Human use and transformation of land is an important factor for the growth of carbon emissions. In recent years, China’s urban construction land has expanded the fastest; meanwhile, it has seen the

highest carbon emissions in the world. However, little is known about the relationship between the two factors. This paper estimates the carbon emissions and carbon sequestrations of various types of land based on the land cover data of 137 county-level administrative regions in Shandong Province, China, from 2000 to 2020; then, it estimates the carbon emissions from energy consumption using energy consumption data and night-time light images hence net carbon emissions. The Tapio decoupling coefficient is used to analyze the decoupling between net carbon emissions and construction land, decoupling effort model is constructed to explore the driving factors of decoupling. The results show that, Shandong Province's net carbon emissions continued to increase, the areas with high carbon emissions were concentrated, centering on municipal districts. The relationship between net carbon emissions and construction land evolved from expansive negative decoupling to strong negative decoupling. Spatially, most areas in province featured expansive negative decoupling, but the areas with strong negative decoupling have gradually increased. The intensive land use rate, technological innovation efficiency restrained carbon emissions, and they contributed to ideal decoupling. Although carbon emission intensity and population size re-strained carbon emissions, their efforts for decoupling faded. The degree of land use promoted carbon emissions, in recent years, it made efforts for the ideal decoupling. Economic scale, technological innovation intensity, industrial structure contributed to carbon emissions, and made no effort to decoupling. The method of net carbon emission estimation devised in this study can lend itself to other studies, and the conclusions herein provide a reference for China to balance urbanization and carbon emissions in the future.

## Drivers of Carbon Footprint Pressure in Urban Agglomeration of The Middle Reaches of The Yangtze River, China

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**Abstract**
Climate change mitigation is linked to the Sustainable Development Goals, and urban agglomeration (UA) is a pioneer. Previous studies, however, have ignored the effects of regional biological carrying capacity and urban clustering on CO2 emissions. First, we proposed a carbon footprint pressure (CFP) index based on CO2 emissions and vegetation carbon sequestration capacity to characterize the environmental impacts of human CO2 emissions. Then, the expanded multidimensional IPAT equation was constructed, and the Logarithmic Mean Divisia Index (LMDI) decomposition method was used to decompose the contribution of drivers to CFP change. Finally, using the improved

decoupling method, the temporal and spatial variation of decoupling between CFP and Gross Domestic Product (GDP) was investigated. These techniques were used in the urban agglomeration of the Yangtze River's middle reaches in China. The results showed that the CFP of UA and its inner cities increased from 2006 to 2015. Increasing affluence and population were negative drivers for CFP mitigation strategies, whereas increasing carbon efficiency, improving vegetation carbon sequestration capacity, and improving GDP clustering were positive drivers. Furthermore, population clustering in core cities promoted CFP mitigation in surrounding cities. During the study period, less than 20% of cities in UA had not completely decoupled CFP from GDP, which was distributed in Nanchang and its surroundings. These findings not only contribute to the existing literature, but they also merit special attention from policymakers and urban planners in urban agglomeration.

## Research on Carbon Circular Economy Theory and Coordinated Development of Carbon Circular Economy in The Beijing-Tianjin-Hebei Region

Tiening Cui, Yang Zhang
Organization(s): Beijing University of Technology, China, People's Republic of

**Abstract**
Abstract： The carbon circular economy is the product of the coordinated development of low-carbon cycles. It is a concept based on the perspective of carbon removal to achieve systematic carbon emission reduction. Developing the carbon circular economy is an important way for China to build a modern economic system of green, low-carbon and circular development and achieve double-carbon goal—Carbon Peak and Carbon Neutrality—as scheduled. The low-carbon and circular coordinated development in Beijing-Tianjin-Hebei region is crucial to regional ecological coordination and the realization of the double-carbon goal. This study intends to construct the theory of carbon circular economy, improve the theoretical connotation of carbon circular economy, and then establish an evaluation system for the development of carbon circular economy. Meanwhile, combined with the development status of low-carbon and circular economy in the Beijing-Tianjin-Hebei region, we use the entropy method and the carbon circular economy development evaluation model to quantitatively analyze the development status of the carbon circular economy in the Beijing-Tianjin-Hebei region. Then, based on the coupling synergy theory, we also conduct a scientific assessment of the synergy level of the development of the carbon circular economy in the Beijing-Tianjin-Hebei region and use the STIRIPAT equation to establish a carbon emission scenario prediction model to predict carbon emissions in the Beijing-Tianjin-Hebei region from different scenarios of the development of the carbon circular economy and effectively evaluate the effect of coordinated emission reduction of the Beijing-Tianjin-Hebei region under different scenarios, scientifically analyze the future development direction of the carbon circular economy in the Beijing-Tianjin-Hebei region and propose a mechanism path for the development of carbon circular economy to help regional carbon neutrality. This study aims to lay a theoretical foundation for the coordinated development of carbon circular economy in the Beijing-Tianjin-Hebei region to achieve Carbon Neutrality.

## Decoupling Analysis between Resource-Environment Pressure and Economic Development of Water-Land-Carbon Nexus Based on Footprint Perspective in China

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**Abstract**
In the context of global sustainable development, China's economic development is gradually changing from extensive development mode to green development mode that pursues environment quality and benefits. Decoupling of economic development from resources and environment is an important symbol of sustainable development. Based on the ecological footprint and Tapio decoupling theory, this study analyzed the relationship between resource-environmental pressure index (RPI) and economic development decoupling and its driving factors in China from 2004 to 2019. Here we show that the RPI in China showed an overall trend of rising first and then declining, and the RPI reached its maximum value during 2012-2015. In 2004-2019, the global Moran's I vary from 0.085-0.32, and RPI shows a significant positive correlation in space. The local Moran's I index indicates that North China, Central China, Southwest China and Northwest China have obvious agglomeration characteristics, and most of them are low-high aggregation. In 2004-2019, the decoupling trend of China's RPI and economy has improved. On the whole, the decoupling state of RPI and economic development in Southwest China is good, Chongqing and Sichuan's RPI and economic development reached the decoupling state (weak decoupling and strong decoupling) in 2004-2019. The result of LMDI decomposition shows that R&D expenditure per capita is the main driving factor of RPI and economic development. The effect of industrial structure on the decoupling of RPI and economic development gradually became obvious after 2012, but the effect of industrial structure on the decoupling state was different in different regions. From 2008 to 2012, energy consumption intensity was the main obstacle factor to the decoupling of RPI and economic development. Therefore, this study will enrich the research on decoupling at the provincial level in China and will provide scientific support to the achievement of the "double carbon" and green economic targets in Chinese provinces.

## Decarbonizing University Campuses: Business Model for Food Waste Management in ITU Ayazağa Campus Turkey

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**Abstract**
Cities must like all others move towards decarbonization. One important area for this is to develop alternative food waste recovery (FW) strategies to close the loop and replace waste management facilities such as landfills and incineration. These alternative strategies convert FW into value-added products like fertilisers and energy. Transitioning to sustainably managed FW will require changes across the value chain and development of new business models. Pilot studies are needed before the strategy is expanded and university campuses could be pioneering centres for sustainability projects. The aim of this study is to find a FW management model that provides a more circular and decarbonized economy, considering both climate impacts and a business model. A LCA study was conducted by using the EASETECH model, for which a functional unit is taken as the annual source separated FW (577 ton/year) in Ayazağa campus. Four scenarios were created and according to results; incineration has most savings (-117 ton CO2-eq/FU) followed by anaerobic digestion (AD) (-80 ton CO2-eq/FU), composting (69 ton CO2-eq/FU) and landfill (428 ton CO2-eq/FU). In addition, circularity was calculated by considering substituting raw materials and leading nutrients back to fields. The circularity of AD is highest (86%), followed by composting (37%), while for landfill and incineration circularity is zero. While incineration has the greatest carbon savings, there is neither decoupling nor circularity for natural resources. AD was thus selected for further elaboration. Revenue streams considers sale of fertilizer and electricity while waste management agreements with the district municipality is another potential revenue. Operating costs cover salaries, transportation and other costs. Collaboration between internal and external stakeholders is a major social outcome. The new economic model will be in line with circular economy strategies. It will recover nutrients and avoids landfill emissions.

## DAY 2 Session 15

### Pollutants Generation and Discharge Performance, Accounting Model and Parameters Quantification Method Targeting Industrial Sector of China

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**Abstract**
An accounting method that uses emission factors is one of the most important methods for quantifying pollutant discharge amounts of individual enterprises. However, the applicability and accuracy of this type of method is greatly affected by industrial production activities, which are constantly changing and evolving. To further improve this type of accounting method, the Pollutant

Generation and Discharge Modular Accounting Model (PGDMA Model) was developed, based on the industrial metabolism characteristics of the industrial sector in China. This research focuses on modeling and parameter quantification methods. The pollutant-generation sections of long production processes were summarized as accounting units, because of the increasing trend of regional division of labor and specialized production, and in order to increase the flexibility of the model. The application results for China's industrial sector are that 41 industries were classified into process-oriented or discrete-oriented production industries, with a total of 940 accounting units, 1,291 main products, 1,575 raw materials and 1,521 technologies, and accounting parameters for 31,219 wastewater and atmospheric pollutant generation factors were developed. Compared with the former version of the Pollutant Generation and Discharge Coefficients of China, the 2017 version put forward in this research provides more accounting support. It could be applied to the Localized Life Cycle Inventory Database for China, the development of an atmospheric source inventory, carbon emission factors, etc. Notably, the PGEMA model and its parameters have a strong connection with industrial production and treatment activity, and are sensitive to changes in time, region, technological innovations, etc. The accounting parameters should be evaluated and revised in a timely manner based on the latest technological changes

## Ozone Pollution and Its Control-Type Identification in China

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**Abstract**
In recent years, China's ozone concentration has risen instead of falling, which has become an important factor restricting China's air quality. The generation of ozone is mainly affected by the synergistic effect of its precursors VOCs and NOx emissions, but different regions are sensitive to different ozone precursors, so it is necessary to carry out different prevention and control measures for ozone pollution in different areas. Nowadays, China has carried out ozone pollution-related sensitivity analysis and research on coordinated control of precursors in Beijing-Tianjin-Hebei, Yangtze River Delta, Pearl River Delta and other areas, which has achieved remarkable results. However, at the national level, there is still a lack of macro-judgments on classification of ozone pollution control areas and corresponding measures regarding different classified zones. This study is based on the satellite remote sensing indicator method, using 2019 as the base year, by comparing ozone on-site monitoring data, VOCs and nitrogen oxide emission intensity data, and satellite remote sensing data, on the basis of PM2.5 key regulatory areas, reclassifying ozone control areas, which means classifying areas where the annual average concentration of ozone exceeds the standard (above 160μg/m3) into different key zones; Identify the sensitive types of ozone precursors in each key zone, namely VOCs control zone, NOx control zone, and VOCs and NOx coordinated control

zone; For each type it is further confirmed into local pollution control zones and joint prevention and control zones. This type of ozone classification method that combines ground monitoring data, statistical data and remote sensing observation data can provide a new idea for the macro-zone classification control of air pollution and provide decision-making reference for the national level of ozone pollution prevention and control and PM2.5 and O3 coordinated control related policies.

## A Regional-Scale Human Health Risk Assessment for Soil Heavy Metals Pollution Based on Empirical Bayesian Kriging: A Case Study in The South Bank of The Yangtze River in Tongling

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**Abstract**
Soil heavy metals (SHMs) contamination caused by rapid urbanization and industrialization is seriously affecting human health and thus hindering the global sustainable development goals (SDGs) agenda. Currently, there is a lack of comprehensive human health risk assessment (HHRA) studies for multiple land use types at regional-scale, for which we propose a practical risk assessment framework. It integrates Empirical Bayesian Kriging (EBK), pollution level analyses, and modified HHRA modeling. Taking the copper industry-related metals (Cu, Ni, Cd, As, and Hg) in the south bank of the Yangtze River in Tongling as an example, 332 SHMs concentrations were collected. The results showed that except for Ni, the average concentrations of other SHMs were higher than the background values. The distribution of SHMs pollution presented a trend of "high in the south-low in the north" and "high in the east-low in the west". Non-carcinogenic risks of SHMs were assessed as acceptable in whole areas. The hazard index followed the order As>Ni>Cd>Hg>Cu. Nevertheless, the carcinogenic risks of Ni, Cd, and As in 70%-80% of the administrative units (AUs) were between 10-6 to 10-4, at an unacceptable level. It was worth noting that AU2, AU4, AU5, and AU7 were considered to be the priority control units, as well as Ni and As were identified as the priority control SHMs. The case demonstrates the feasibility and scientific validity of the new framework "EBK-HHRAs", which verifies that EBK can effectively predict the SHMs spatial distribution patterns while modified HHRA models are conducive to the risk integration at regional-scale. The "EBK-HHRAs" is generic in nature and provides substantial support for risk source identification and risk management of SHMs contamination at regional-scale.

## Synergy and Imbalance of Industrial Pollution Reduction Across Different Regions in China: A Bottom-Up Analysis Approach

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**Abstract**
China has made significant decreasing of industrial pollutants emissions with great efforts on point sources control. However, for the different industrial sectors with various development stages, it is not so clear on whether there is tradeoff or synergistic mechanism among them, and how it changes with the environmental policies. Based on 1.28 million data of gross industrial output value (GIOV), wastewater emission (WWE), wastewater treatment capacity (WWT), ammonia nitrogen emission (NH) and COD emission of enterprises, the generalized linear model with break-points and clustering was used to analyze the pattern of spatial evolution and pollutant emission changes for the five indicators mentioned above. The results showed that the pollutant emission per unit output value shows a power function decreasing trend. The WWE and COD emission in 2005 reached the inflection point earlier than WWT (2007) and NH emission (2007). The load reduction at different stages had synergic effects, and coastal cities reached the inflection point earlier. Besides, the pollutant reduction of different sectors responded differently to environmental policies. Chemical sector was the most sensitive one, while food processing sector was the least sensitive. There is a completely opposite pattern between pollutant emission and GIOV in spatial evolution, mainly due to the chemical and metal sectors with high pollutant emission and low GIOV migrated to western China. The evolution of spatial pattern of GIOV, WWE and WWT, NH emission, and COD emission is mainly dominated by metal sector, chemical sector, chemical and mining sectors, and food processing and textile sectors, respectively. This study reveals synergies and imbalances of pollutant reduction, and highlights the different responses of sectors to industrial pollution control polices. It is thereby necessary to pay more attention to the emission of the food processing sector and the transfer of the chemical and metal sectors to western China.

## Changes of production and consumption structures in coastal regions lead mercury emission control in China

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Organization(s): Key Laboratory for City Cluster Environmental Safety and Green Development of the Ministry of Education, School of Ecology, Environment and Resources, Guangdong University of Technology, Guangzhou, China

**Abstract**
China is important in global mercury (Hg) cycle and is experiencing substantial economic structure transitions. There are pronounced differences in economic development, industrial structure, and consumption patterns across regions in China. However, the impacts of regional economic structure transitions (i.e., production and final demand structures) on Hg emissions in China remain unknown. Here we reveal the transboundary impacts of changes in regional economic structures on provincial Hg emissions in China. We found that the transitions of production and final demand structures in coastal regions led to Hg emission reductions in China during 2007-2017. In particular, production structure changes in East Coast contributed to 36 tons of national Hg emission reduction, where 28 tons occurred in other regions (especially Hebei). Its final demand structure transition contributed to 19 tons of national emission reduction, where 15 tons occurred in other regions (especially Henan). Unfortunately, production structure changes in Northwest and final demand structure changes in Southwest contributed to Hg emission increments in China during 2007-2017. For instance, changes in the final demand structure of Southwest caused 34 tons of emission increments, mainly from provinces within the region. Thus, spatially explicit measures for China's Hg emission control can focus on the optimizations of production structure in Northwest and final demand structure in Southwest, as well as the promotion of interregional joint actions between East Coast and North China (especially Hebei and Henan). The findings of this study can inform region-specific policy decisions and interregional joint efforts to control Hg emissions around the world.

## Assessment, Source Identification and Zoning Control of Heavy Metal Pollution in Water and Soil Resources of Core Water Source Areas

Zhanqi Wang, Sheng Ye
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**Abstract**
The water source area is an important source of drinking water for a country, and the quality of its ecological environment is directly related to people's health. In recent years, with the accelerated pace of industrialization and urbanization in China, the ecological environment of water source areas has been damaged to different degrees, especially the content of heavy metals in water and soils has become increasingly worrying. In this context, this study was carried out in Danjiangkou Reservoir, one of the ten core water source areas in China. 85 water samples and 7735 surface soil samples were collected and tested for Cd, Cr, Cu, Pb, Zn and Hg. Nemerow Pollution Index (NPI), Potential Ecological Risk Index (PERI) and Pollution Load Index (PLI) were used to evaluate the heavy metal pollution of water and soil. Then the main sources of heavy metal pollution were analyzed using Principal Component Analysis (PCA), Multiple Linear Regression Analysis (MLRA), and geographic detector model. Finally, a zoning study was conducted combining the results of evaluation and traceability. The results show that there is no potential ecological risk of heavy metals in water of Danjiangkou reservoir, and the soil is at a low potential ecological risk level of heavy

metals. The soil is contaminated with Cd and Hg, whose sources are mainly anthropogenic, such as the discharge of industrial wastewater and the application of N and P fertilizers. This study provides a reference for the management of heavy metal pollution of soil and water resources in similar areas.

## DAY 2 Session 16

### The Role of Recycling and Novel Technologies in Mitigating The Environmental Impact of Non-Ferrous Metals: A Case Study from Germany

Jan Krusenbaum, Katharina Rothhöft, Rainer Radloff, Ali Abdelshafy, Grit Walther
Organization(s): RWTH Aachen University, Chair of Operations Management, Aachen, Germany

**Abstract**
The production of metals is associated with significant amounts of emissions. Therefore, their existing production routes and processes are going to change in order to generate climate-neutral products in the coming years. However, there is a knowledge gap in terms of the production and recycling processes of non-ferrous metals, and how the sector can manufacture carbon-free products. Hence, this research presents a cohesive analysis on the current material and energy flows of NF metals' production and recycling in Germany. Herein, four metals have been selected to be investigated owing to having the highest production and emissions volumes (i.e. aluminum, copper, lead and zink). Based on the roadmaps and interviews with industrial experts, the study envisages the changes in the material and energy flows in the coming years and the role of recycling and novel technologies in mitigating the environmental impact.

The results show that the use of hydrogen, as for steel, is a viable measure to further reduce emissions in the copper and zinc production processes. Other measures taken by the German copper and zinc industries include a gradual shift towards renewable-electricity sourcing, further optimization of energy consumption and implementing offset projects. The latter are particularly important for offsetting process-related emissions that cannot be reduced. Similarly, the lead industry aims at replacing coke as a reductant and improving the recycling process to be more efficient. In the aluminum industry, two innovative technologies are in focus: inert anodes and flexible electrolysis. The use of inert anodes offers the possibility of eliminating direct CO2 emissions. Also, the electrolysis is becoming more flexible through adaptations, which offers the possibility to adapt to the fluctuating electricity grid.

### Time Is Running Out for Natural Sand: A Critical Review

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**Abstract**
Sand has become an essential and utmost natural resource consumed widely after freshwater. The sand demand in the construction industry has increased globally due to increased living standards and urban expansion, and this demand is non-linear. The aim of this review article has addressed the issues of utilizing natural sand in concrete production. The review article also presents a state-of-the-art alternative to natural sand for the construction industry, which will help maintain the ecosystem. Today about 2/3 of the world's urban buildings are made of reinforced concrete, and the concrete itself is made up of 2/3 of sand. Between 2011 to 2013, China consumed about 6.6 giga tonnes of concrete, which the USA utilized in the whole 20th century. In the past, sand came from regional quarries, but now these sources are nearly depleted, and sand used in construction comes from rivers and the sea bed. Though our planet is covered with desert sand, the desert sand is the wrong type of sand as the sand grains are fine and round shape does not fulfill the criterion of use in concrete production. Therefore, Saudi Arabia imports sand from Scotland and UAE from Australia, and Egypt from India. Sands from rivers, banks, beds, floodplains, lakes, seashores, and deep-sea have rough edges, making them perfect for concrete production. China, India, Bangladesh, and countries like Singapore, Malaysia, Thailand, and maritime worldwide are extracting sand at an alarming rate, harming local hydrology, ecosystem, and wildlife. River sand mining significantly impacts the environment and the population thriving on river floodplains. An ever-increasing demand for sand for construction purposes cannot be met by using the river sand alone. Therefore, there is an intense need to find alternate sources of sand without harming the environment and ecology.

## Triboelectric Separation Technology for Removing Quartz from Low-Quality Magnesite

Zhenxing Zhang, Yongqiang Xu, Xinyu Wei, Jilan Shi, Jiahui Niu, Zihui Zhang, Haifeng Wang
Organization(s): China University of Mining and Technology, China, People's Republic of

**Abstract**
Magnesite is an important non-metallic mineral resource in China. In recent years, with the continuous reduction of high-grade magnesite resources, the sorting and quality improvement of low-grade magnesite has become a hot research topic. As a dry separation method, triboelectric separation technology is a simple and cost-effective process. Herein, the charge-to-mass ratio test and triboelectric separation system are used to study the triboelectric charge characteristics and electrostatic separation of magnesite. The results reveal that magnesite and quartz possess different charge polarities after friction with different materials and the difference in charge-to-mass ratio between magnesite and quartz becomes largest after friction with polyvinyl chloride (PVC). Also, the number of free electrons on the surface of magnesite increases with the increase in temperature. During the frictional collision of particles, the effect of triboelectric charging enhances. During magnesite separation process, the grade and recovery rate of magnesite initially increase with the increase in ambient temperature and, then, tends to be stable. Moreover, the grade and recovery of

magnesite initially increase with the increase in separation voltage, feeding rate and air flow rate, followed by a gradual decrease. The magnesite grade and recovery rate are mainly affected by the charge amount of particles in the friction charger and the movement time in the electric field of the sorting chamber. When the particle collision frequency is low, the charge amount and effect of the electric field force become small. Hence, the particles cannot be separated efficiently and the recovery rate of magnesite is low. With the increase in particle moving speed, the particle charge increases and the particle is strengthened by the electric field force, enhancing the charging effect and improving the recovery rate of magnesite. Therefore, operating parameters should be controlled to ensure the separation effect during the separation process of magnesite.

## A Novel Electrochemical Redox Method for The Recovery of Spent Lithium-Ion Battery Cathode Materials

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**Abstract**
The recovery of spent LIBs is of great significance for securing the supply of precious strategic metals and improving the ecological environment. However, the traditional electrochemical recovery method requires complicated pretreatment processes and operates at high cell potentials. Herein, a novel recycling method using electrochemical redox and a “sandwich-type” electrode is proposed, which can significantly lower the energy consumption. With sulfuric acid as the leaching agent, the spent cathode material is reduced to Co(II) under controlled potentials at the cathode, releasing Li(I) into the leaching solution. At the same time, the aluminum foil is separated from the cathode material under the effect of passivation and bubbles. At the anode, the copper plate is oxidized to Cu(II). The electrochemical behavior of spent LIBs cathode material in sulfuric acid solution was investigated utilizing cyclic voltammetry (CV), Tafel curve, and potentiostatic current-time transients (CTTs).

## A Brief Review on P Scarcity Characterization

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**Abstract**
Phosphorus scarcity characterization makes the way for phosphorus scarcity classification which is helpful to formulate effective and feasible countermeasures for sustainable phosphorus use. Based on

literature review and systematic analysis of phosphorus scarcity, systemic P scarcity is proposed due to its different nature and characteristics from other P scarcity categories. The concept is described from the three aspects of composition, structure and function of phosphorus flow system. When systemic scarcity occurs, the shortage happens in different industries/sections of the P flow system in a region during certain period simultaneously, with failure in expected socio-economic and ecological benefits of P-related industries. While, the essential properties of systemic P scarcity are analyzed from its spatiotemporal features, scale, externality, and wholeness of systemic P scarcity. These discussions over systemic P scarcity help clarify distinct scarcity reasons, judge/alarm and avoid the situation of systemic scarcity, and then find out a proper technical and economic countermeasures for alleviating systemic P scarcity.

## A Spiral Infinite-Life-Cycle Framework to Quantify The Environmental Performance of Critical Metal Circular Economy Systems

Jinliang Xie, Xi Tian
Organization(s): Nanchang University, China, People's Republic of

**Abstract**
Circular economy strategies are essential to ensure the supply security of critical metals and the smooth low-carbon transition. However, there is a lack of a feasible, clear, and consistent framework to assess the environmental performance of critical metal circular economy systems over a relatively long time horizon, causing evaluations to be incomparable. To address this issue, this paper develops a spiral infinite-life-cycle framework using the Archimedean spiral in a polar coordinate system as a skeleton, exhibiting circular, dissipative, infinite, and cascading features. Then, an evolutionary algorithm based on a dynamic parameter system and impact category satellite accounts is formulated. The energy intensity and carbon footprint of a lithium circulation system are employed as an example. The results show that: (1) the energy intensity of the system is at least 27.26% lower than that of the primary life cycle and 11.77% higher than that of recycled life cycles; (2) the carbon footprint assigned to the primary life cycle is at least 35.17% lower than that generating directly; (3) the decarbonization of electricity is identified as the most crucial factor affecting the evaluation results. This paper provides a polar coordinate-based paradigm for assessing the environmental performance of circular economy systems. With the expectation of increased recycling rates and reduced emission intensity, the improved framework can effectively reduce the total emissions of the system and spread the environmental burdens of critical metal mining over future life cycles. Therefore, we suggest that sustainable policies need focus on future waste collection rates. Meanwhile, efforts should be made to guide enterprises along the supply chain to reduce the emission intensity of unit processes with significant potential for improvement. Besides, carbon neutrality roadmaps should consider the synergies between material circulation and energy low-carbon transition through the critical metal pathway.

## DAY 2 Session 17

### Challenges Associated with Food Waste Digestate Composting: An Industrial Experience

M K Manu, Dongyi Li, Jonathan Wong
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**Abstract**
Anaerobic digestion (AD) is a sustainable biological process for converting food waste to bioenergy alongside with the production of digestate. In the past decade, limited focus has been devoted to digestate utilization despite of its increasing production. The physicochemical characteristics of dewatered food waste digestate (FWD) causes environmental and health hazards upon direct land application due to its high salt and ammonium N contents. Hence, further stabilization of FWD through aerobic composting is recommended. Irrespective of food waste type in different countries, high concentrations of NH4+-N (~6000-10000 mg/kg dry weight (dw)), high moisture content (~75-80%) and low C/N ratio (5-7) have been reported in several countries, which causes 60-70% of nitrogen loss as NH3 emission and phytotoxicity to plants. These innate characteristics significantly affect the composting process thereby reducing the compost quality, and emitting unwanted greenhouse gases, NH3 and N2O. Similar conditions have been observed in Hong Kong's first biological treatment facility (Organic Resource Recovery Centre 1 (ORRC1)). The lengthened composting process and low-quality compost production has significantly affected the plant operations. ORRC1 composting operations include mixing of digestate with mature compost, sawdust and structurants (woodchips) followed by tunnel composting. Due to the innate characteristics of FWD, several operational changes are required for effective composting. In this study, a comprehensive operational measure taken for effective composting at ORRC1 based on FWD characteristics will be discussed.

### How Can The Blockchain Be Integrated Into Renewable Energy? --A Bibliometric-Based Review?

Mingli Cui
Organization(s): China University of Geosciences, Beijing, China, People's Republic of

**Abstract**
With the growing popularity of blockchain technology and renewable energy around the world, the combination of the two topics have attracted attention. Although the research on "Renewable energy & Blockchain" has been intensified by experts, there are still limitations and gaps in the existing research. In this paper, 351 articles was selected for visual analysis using bibliometrics method and CiteSpace software from 2016-2022. The development status, influence contribution, research hotspots and research trends of this research field were analyzed. Based on the above analysis, we

summarized the relevant literature in the field of "Renewable energy & Blockchain" and analyzed the current hotspots in depth to get the future development direction. The research results show that: First, the related research in the field of "Renewable energy & Blockchain" is mainly focused on energy, technology and environment. Second, from the micro to the macro level, all subjects have certain scientific strength and influence contribution in the field of renewable energy and blockchain. Third, after summarizing the current status of "Renewable energy & Blockchain" research from different perspectives, we clarify the gaps in the research of blockchain-based renewable energy in terms of transaction, technology and policy, and further suggests potential trends in the field of energy internet, energy management, energy systems, green certificate trading and green power trading. This study provides a theoretical reference for researchers to gain a comprehensive understanding of current research efforts and future research directions in this field.

## Greenhouse Gas Reduction through Crop Residue-Based Bioenergy: A Meta-Analysis on The Efficiency and Abatement Costs of Using Various Products

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**Abstract**
Many countries have ambitious plan to use bioenergy as a way to make energy more environmentally sustainable. Crop residue-based bioenergy (CRB) is assumed to be a green replacement for fossil fuels as well as an effective way of disposing agricultural residues. Recent studies assess the greenhouse gas (GHG) reduction efficiency, abatement costs, and their influencing factors based on single plants or particular production technologies. However, previous research has not systematically analyzed the environmental and economic performance of CRB products, which depend on the dynamic feedstock supply, complexity of multiple products and diverse feedstock types. Using a database of 225 cases, composed of 71 carbon trading projects from voluntary offset programs and 154 projects from scientific publications, we conduct the first systematic analysis investigating the GHG mitigation effects and abatement costs of the principal CRB products. The results show that biomass briquette, bioelectricity and/or heat (bio-E&H) are highly efficient in reducing GHG emissions with comparably low abatement costs. Liquid biofuels are most inefficient in GHG reduction with the highest abatement costs. Based on a boosted regression tree (BRT) analysis, we identified some major factors that affect the GHG reduction efficiency of bio-E&H and liquid biofuel production, and highlighted the important roles of plant size and feedstock collecting distance. This research also provides recommendation on suitable plant size and feedstock type for CRB production. This study not only illustrates the results obtained from scientific literature and carbon trading projects, but also discusses the comparability of these two data sources. The datasets increase the completeness and improve the certainty of the results. These results provide scientific support to direct developing the CRB industry as a policy for reducing climate change. Thereby, the

study contributes to both environmental assessment methodology and the development of the CRB industry.

## Biogas Production from Sargassum Ilicifolium — Solution for The Golden Tides —

Luis Antonio Villalobos Robles, Kana Kuroda
Organization(s): Osaka Prefecture University, Japan

**Abstract**
Fossil fuels are the main resource of global energy nowadays. Emissions of greenhouse gases are produced because of the energy output from these sources. To lessen our reliance on fossil fuels, various biofuel and bioenergy forms have been suggested. Anaerobic digestion is one method for utilizing biomass by turning it into energy (AD). This biological conversion turns biomass into biogas, which contains methane and can be utilized to generate heat or electricity.

In recent years, Mexico has been suffering from the overaccumulation of macroalgae species known as Sargassum on the coastal shorelines of the Caribbean. Though there have been reports of the government using the plant as a compost, natural landfill, and other different approaches, most of this biomass is disposed of as garbage. The seaweed tends to get spoiled on the beaches, causing many problems such as odors and bad seeing, which causes economical losses in the peak of vacation seasons. The purpose of this study is to investigate the usage of Sargassum as feedstock for AD.

First, batch experiments were conducted to understand the methane yield of the Sargassum. The results showed that the seaweed has a low methane yield. According to other studies, food waste can show up to 410 NmL/g-VS while Sargassum shows 177 NmL/g-VS. Given Mexico's high production of agricultural products, co-digestion could reduce the stress caused by agricultural waste in addition to helping to boost the methane yield in the process. According to the findings, corn, sargassum, and co-digestion each produce methane yields of 268.7, 177.1, and 211.1 NmL/g-VS, respectively. This demonstrates that both biomasses can be used as feedstock for the AD process simultaneously. These results could help Mexico develop more sustainable waste management practices and gain a better knowledge of how Sargassum might be used as biomass for AD.

## Real-Time Monitoring of Decentralised Anaerobic Digestion Using Artificial Intelligence-Based Framework

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**Abstract**
Today, organic waste accounts for approximately 40% of the total municipal solid waste globally and it is currently a major source of concern in the world. This is due to its negative impacts on the environment, society, and economy. The anaerobic digestion (AD) as a sustainable technology and resource recovery attracted a lot of attention in the organic waste management due to its ability to convert organic waste into clean energy and digestate without emitting greenhouse gases into the environment and its potentials to provide green jobs in communities. However, the AD would suffer from limitations such as low removal efficiency of organic compounds and long retention time affecting the efficient biogas production. The integration of artificial intelligence (AI)-based models into the AD system has shown a great significance to improve biogas production. This paper presents an new AI-based framework for real-time monitoring and improving the operation of the AD system. This framework include two major components for infilling missing data by using an artificial neural network (ANN) model and predicting the biogas production by using various ANN models including feed-forward neural network, recurrent neural network, and weak learners machine learning. The input data of the ANN models are composition of food waste, water added, volatile solids and frequency of food waste feeding into the AD digester. The proposed methodology was demonstrated by its application to a real pilot study of decentralised AD plant in Camley-Central London. The results show biogas production can be accurately predicted in real-time operation and the best practice of food waste composition and feeding frequency can be adjusted to improve the system performance. Results also demonstrate acceptable predictions can be obtained for more lag times using the ANN models which play a significant role in improving the efficiency of the AD technology.

## Value Chain for Syngas Production by Cotton Stems Gasification in Burkina Faso

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**Abstract**
The increasing consumption of fossil fuels has enhanced the challenges of economic and energy security while contributing to global climate change. Gasification is one of the interesting energy alternatives to convert agricultural waste to energy and reduce the country's energy dependence. Cotton stalks are abundant residues in Burkina Faso, with an interesting energy content for energy production by gasification. This paper provides an in-depth analysis of the entire syngas production chain from the cotton fields to the gasification plant using a value chain analysis approach. Given the lack of an operational gasification energy production value chain in Burkina Faso, the analyses were carried out based on simulations and hypotheses using local knowledge, supplemented by individual interviews with transporters and traders of agricultural products, operators who have already used the technology, and reports from gasification projects. The data was analyzed through an assessment of the opportunity cost of biomass. The analysis shows that the key upstream activities of the production chain are the transport of biomass and pre-treatment, but mostly the buying of biomass. The latter requires a significant cost price, i.e. a proportion of over 70% of the global cost price. Future operators could then focus on biomass processing, and establish partnerships with structures that support the mobilization of cotton stalks in finding a way to interest producers.

Keywords: Value chain, syngas, cotton stalks, Burkina Faso.

**DAY 2 Session 18**

## A Carbon Metabolism and Regional Trade Analysis Based on China's Carbon Emission Trading System

Hongmei Zheng
Organization(s): Tangshan Normal University, People's Republic of China

**Abstract**
China’s carbon emission trading policy has been launched since 2011. The trading pilot regions included two provinces and five cities. As a vital tool for realizing carbon emission reduction target, it is required to conduct research on dynamic simulation analysis on carbon metabolism of the pilot regions, and optimize their metabolic processes. Meanwhile, China has been placing great emphasis on establishing a national emission trading market. Based on the theory of “carbon metabolism” and under the background of carbon emission trading policy, this research aims to trace carbon metabolic processes combining regional and sectoral scales. With the data of multi-regional input-output tables, the method of ecological network analysis is introduced to develop an indicator named embodied carbon emission intensity to describe the environmental and economic effects of regions or sectors. Spatial dynamic analysis is used to reflect the spatial distribution attributes of network models. Then, flow analysis and utility analysis are integrated to deduce both the structural and functional characteristics, and the core nodes and paths of carbon metabolic systems. And structural decomposition analysis is used to quantify the factors which influence carbon metabolic systems.

Finally, difference-in-difference method is useful in evaluating the effectiveness of carbon emission trading policy from an ex-post empirical perspective. Furthermore, different scenarios are set to detect the changes of the nodes and paths of systems through ex-ante scenario analysis, and support decision making for regional carbon emission reduction.

## How to Promote The Carbon Price Pass-Through to Electricity Price in China Based on "Electricity- Carbon" Markets Coupling ?

Hao-ran Wang, Tian-tian Feng, Cheng Zhong
Organization(s): China University of Geosciences (Beijing), China, People's Republic of

**Abstract**
To fight climate change risks, China pledge to have CO2 emissions peak before 2030 and achieve carbon neutrality before 2060. The national emissions trading system comes into operation to guide carbon emissions reduction with market mechanism. The power sector, as an energy-intensive and emission industry, is the focus regulated object of national carbon emission trading market. This paper analyzed the coupling relationship between carbon market and power market, and an econometric model of carbon cost pass-through to electricity price constructed using threshold regression approach. Further, a system dynamics model was built based on interaction between carbon market and electricity market. The results show that: First, the carbon market and power market operate independently, but are interrelated. The two markets have their own operation mechanism, but Chinese emission allowances and carbon price of carbon market are related with carbon emission and electricity price of power market. Second, because the electricity price formation mechanism is mainly regulated by China's government, the carbon price has a significant negative effect on the electricity price since the operation of national carbon emission trading system. There is no obvious linkage effect between the carbon price and electricity price. Third, under the current policy and market mechanism, the carbon price will experience the process of "remain low- rapid rise- remain high". The carbon price will drive the rise of on-grid price and sale price. Allowance auction mechanism and carbon cost pass-through rate are the drivers to promote the rise of carbon price and reflect carbon cost on electricity price. For long term, introducing auctioning in carbon market and reforming electricity price formation in power sector will tap the emission reduction potential of power sector and provide policy reference for establish a "electricity-carbon" markets linkage.

## Can Carbon Trading Policy and Local Public Expenditures Synergize to Promote Carbon Emission Reduction in The Power Industry?

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**Abstract**

The power industry is the largest carbon-emitting sector in China, accounting for about 40% of the country's total carbon emissions. Studying the carbon emission reduction effect from the perspective of the power industry has important theoretical and practical significance for formulating targeted carbon emission reduction policies. We study the carbon emission reduction effect of the power industry in 30 provinces in China from 2010 to 2019 under the carbon trading policy, local public expenditure and the coupling scenarios of the two. The study found that: (1) The carbon trading policy significantly promoted carbon emission reduction in the power industry, and the longer the carbon trading policy was implemented, the stronger the inhibitory effect. (2) In the overall period from 2010 to 2019, the carbon intensity of local public expenditures made the largest contribution to promoting carbon emission reduction in the power industry, with a value of -175.581%; The environmental protection output intensity of local public expenditures has the largest contribution rate to restraining carbon emission reduction in the power industry, with a value of 189.474%.(3) Under the synergy effect of carbon trading policy and local public expenditure, the output intensity of local public energy conservation and environmental protection expenditure can promote carbon emission reduction in the power industry. Paying attention to the timing, distribution, and complementarity of policies to promote the synergy effect of carbon trading policies and local public expenditures is a major feature of realizing carbon emission reduction in the power industry, green economic development, and improving China's unified carbon market.

## How Do The Electricity Market and The Carbon Market Interact and Achieve Integrated Development?--A Bibliometric-Based Review

Yan Li, Tian-tian Feng
Organization(s): China University of Geosciences, Beijing

**Abstract**

The global climate and environment are deteriorating. Green and low-carbon development has become the main theme of the world's energy economy. To achieve the goal of “carbon peak and carbon neutrality”, various countries have speeded up the development of carbon market and electricity market. Power is widely concerned as a key emission supervision. The interaction and integration research between these two markets helps to better reduce carbon emission. To understand the knowledge domains and evolutionary of carbon-electricity markets, we have downloaded 54739 related articles from web of science core collection between 1991 and 2022 based on themes of “electricity market” and “carbon market”. The citespace visual software is used to perform cooperative analysis, keyword co-occurrence analysis and co-cited analysis, which show the theoretical development state of electro-carbon coupling research, the author and national cooperation situation, and hotspots research. Based on the visual analysis results, we further conducts qualitative analysis of hot research directions, and concludes the development direction of

the coupling relationship. The study found that the electricity-carbon market has a mechanism correlation, price interaction, transaction information interaction and transaction behavior interaction, which have an impact on low-carbon investment decisions, power structure optimization and carbon emission reduction. Under the new situation, the research on electric-carbon market interaction will become a research hotspot, which has the characteristics of dynamic research objects, diversified research subjects and complicated research methods. In the future, the development of a low-carbon economy and the integration of renewable energy into the grid will lead to more frequent electricity-carbon market interactions.

## The Impact of Electricity-Carbon Market Coupling on System Marginal Clearing Price and Power Supply Cost

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**Abstract**
In this study, we assessed the impacts of the benchmark designs of emissions allowance allocation in China's national carbon emissions trading system with plant-level data and further estimated the marginal clearing price and power supply cost in Guangdong power market under electricity-carbon market coupling with unit commitment and economic dispatch model. We find that the existing allowances benchmark would result in a considerable surplus of allowances at about 222 Mt. But the benchmarking and exemplary levels on the heat rate of power supply would motivate thermal power units to reduce CO2 emissions. Under a tight balance of supply and demand in Guangdong, peaking thermal power plants will become the marginal clearing units and higher clearing prices will add to the revenue of lower cost inframarginal renewable energy power units. However, the combined impact of electricity-carbon market coupling would cause the marginal clearing price fluctuates obviously from 0 to 1159 CNY/MWh. Compared to the baseline scenario with free CO2 allowances allocation, the efficiency of thermal power utilization would decrease by 23%-59% and the net revenue per MWh power supply of coal-fired power units would decrease by 275%-325% under the stress scenario. Our study suggests that setting a more stringent allowances allocation benchmark for carbon price discovery is necessary. As electricity-carbon market coupling changes the role of coal-fired power plants to provide flexibility service and decrease their revenues, it calls for further market designs on proper reimbursement of flexible resources, under which the electricity market can effectively achieve the synergy among accommodating new energy, ensuring resource adequacy, and delivering cost efficiency.

## Green Patents and Green Codes: How Different Methodologies Lead to Different Results

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Organization(s): Area Science Park, Italy

**Abstract**
Green innovation (GI) refers to the innovation in technology aiming at minimizing wastage, global warming, and use of natural resources. Patent data in green technologies (GTs) is considered a good proxy for Green Innovation. Several international organizations such as EPO, WIPO and OECD studied the impact of patents in the development and dissemination of sustainable technologies. EPO developed the "Y02-Y04S tagging scheme" applicable only to patents classified with CPC codes. The WIPO and UNFCCC methodology, called IPC Green Inventory, covers the "Environmental Sound Technologies" (ESTs) and can be applied exclusively to patents with IPC codes. Since 2016, OECD developed the search strategy to identify environmental-related technologies (ENV-TECH) which can be applied to both IPC and CPC codes. The first goal of this study is the systematic organisation of IPC and CPC green codes of the three methodologies which was not available. We provide both the algorithms for periodic updates and the lists of green codes. The second goal is the application of these methodologies to classify patents filed at UIBM (Italian patent authority) identified only by IPC codes, and patents filed at EPO (European Patent Office) by the Italian applicants, identified by IPC and CPC codes. In literature, the combination of ENV-TECH methodology and IPC green inventory methodology is largely used to identify patents with IPC codes. This combined methodology is applied to identify green patents during the timeframe 2011-2020 filed at UIBM which are on average 7.5% of the total (with an increase over the last years), and at EPO which are 6.5% of the total. Furthermore, using the CPC codes, the "Y02-Y04S tagging scheme" methodology on its own identifies 7.8% green patents filed at EPO (1.3-point difference) during the same timeframe. These findings are a first important step towards further investigation. Coordinated methodologies could lead to harmonized results.

# DAY 2 Session 19

## The Influence Mechanism of User Comments on Public's Consumption Intention of Recycled Water from The Perspective of Consumers: Evidence from Eye Tracking Experiments

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**Abstract**
Recycled water is an effective way to address the scarcity of water resources; its widespread adoption and use have far-reaching implications for water scarcity and environmental protection. The price of recycled water and user comments are important factors influencing the public's purchase intention as a renewable resource product. Therefore, from the perspective of consumers, this study simulates the purchase scenario of recycled water, takes the Stimulus-organism-response (S-O-R) model as the theoretical framework, using 3 (experimental group: high price vs. medium price VS. Low price) *2 (Review category: quality review vs. environmental review) eye movement tracking experiment to explore the behavior mechanism of the public in the process of purchasing recycled water. (1) The willingness of the public to use recycled water is highest in the middle price group, followed by the low-price group, and lowest in the high price group, according to the findings. (2) During the decision-making process, whether it is the reclaimed water quality evaluation or the environmental evaluation, the public tends to focus on the negative comments. (3) During the consumption process, comments can influence the consumption mood and thus the willingness to use recycled water. (4) The influence paths of comments on the public's willingness to use recycled water differ significantly across price levels. This study can provide scientific reference for the further promotion of recycled water and optimal allocation of water resources.

## The Impacts of Environmental Regulations and Knowledge Spillovers on China’S Regional Economic Growth

Xiao Li Shi, Ying Chen
Organization(s): Jimei University, People's Republic of China

**Abstract**
After entering the period of new normal, reform, innovation, environmental protection, knowledge production and transformation of growth motivation have become the crucial choices for China’s economic development. We analyze the evolution of regional economic growth in China over 1997-2017. The impacts of environmental regulations and knowledge spillovers on the regional economic growth are investigated with spatial econometric models. Further more, those models also take FDI, human capital, physical capital stock, knowledge stock and economic growth of neighbouring regions into consideration. The results show that environmental regulations, knowledge spillovers, FDI, human capital, physical capital, knowledge stock and the economic growth of the neighbouring regions all have positive effects on the economic growth of the region with three different spatial weight matrices which call for a reconsideration of regional economic policies.

## Chinese Residents' Ethical Dilemmas of Pro-Environmental Behaviour from The Perspective of " Psychological Fence"： Evidence from Surveys of Residents in Six Urban Agglomerations

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**Abstract**
As the main method to conserve resources, protect ecology, and improve health, residents' voluntary pro-environmental behavior is an autonomous behavior that is not directly or explicitly rewarded. However, the inherent nature of pro-environmental behavior, which is “costly to the individual but beneficial for others”, makes it necessary for residents to face the ethical dilemmas of inconsistent beliefs or values. In this paper, we use the metaphor of " psychological fence" to view the ethical dilemma of pro-environmental behavior as a holistic process in which individuals interpret, evaluate, and judge a series of conflict points arising from multiple inconsistent ethical or behavioral norms. Two studies were conducted to clarify the structure of the "psychological fence" and to reveal Chinese residents' ethical dilemmas of pro-environmental behavior. In Study 1, drawing on the theory of the dual inheritance, we construct a four-dimensional structure of the ethical dilemma of pro-environmental behavior by grounded theory method, namely the "quality of life-relationship-spatial-role" dimension. In study 2, we reported findings on the status of the ethical dilemmas of pro-environmental behavior in six urban clusters (2081 people) in China. Through heat maps and other data visualizations, we systematically demonstrated the geographic and demographic heterogeneity of Chinese residents' ethical dilemmas of pro-environmental behavior. Our key takeaway is that through the metaphor of "psychological fence", we reveal the mechanism of proximal factors before pro-environmental behavior, and help the government and policymakers to clarify the key people and penetration mechanism of pro-environmental behavior intervention. We also provide theoretical and practical references for better promoting residents' voluntary pro-environmental behavior.

## Copper Demand and Recycling Strategy of New Energy Vehicle Development in China

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**Abstract**
The rapid development of new energy vehicles (NEVs) in China, especially electric vehicles, will require more copper resources, which may lead to new resource challenges and industrial chain risks. In order to strengthen the flexibility and sustainability of the NEVs industry chain, circular economy strategy is needed to reduce the demand for primary resources. Based on the development planning of NEVs in China, we construct the dynamic material flow model of copper resources-components-NEVs and analyzes the scenarios simulation of circular economy strategies to research the relationship between NEVs development and copper resources in China. The results show that the demand for copper in NEVs will increase by 13 times from 2020 to 2035, mainly used for traction motors and batteries components in electric vehicles. Driven by secondary copper resources, its consumption proportion increased by 22%, and the consumption of primary copper resources showed a decoupling trend from the total copper demand. A variety of policy scenarios were constructed to analyze the strategies impact on copper resource utilization, and the advantageous strategies such as extending product life, resource reduction, high recovery increase rate and high disassembly level were integrated to construct the policy combination scenarios. The results show that the combined scenario can reduce the demand for primary copper resources and increase the secondary copper recovery rate to 85%. Therefore, there is an urgent need for cooperation between the copper industry, new energy vehicle industry, scrap vehicle recycling and dismantling industry, and government to realize the secondary copper resources recycling and utilization, in order to successfully deal with the current and future copper resource challenges in the NEVs development.

## Influential Factors of Food Waste Prevention Behaviors at Supermarkets and Restaurants in China

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**Abstract:**
Food waste at consumption stage has received global concerns in recent years. Owing to its large population and the limited available supply resources, China has become one of the hot-spots of food waste issue in the world. Accordingly, in 2021, Chinese government began to take strong measures to reduce food waste at consumption stage, especially on food suppliers and food service sectors. To ensure effective policy implementation, theoretical foundation is required. However, current studies are mainly focusing on the food waste behaviors in household, lacking analysis on the supermarkets and restaurants. In addition, previous studies majorly targeted on the consumers' side, lacking analysis on the economic entities' side. Therefore, we built two comprehensive models to explore the effects of influencing factors on the food waste prevention behaviors between supermarkets and restaurants in China. Based on the two models, we designed corresponding questionnaires and conducted online surveys in Beijing, Shanghai, and Wuhan in China. A total of 312 managers

answered the questionnaires. The result shows that food was wasted more in smaller scales of supermarkets, as well as buffet restaurants and hotels. Besides, the average food waste amounts of restaurants at undeveloped districts were significantly higher than that at the developed districts. The model analysis results show that overordering the foods from food suppliers were the strongest driver to the food wastes for both supermarkets and restaurants. For supermarkets, the manager's intention to save food showed strong effect on the food waste behaviors. However, such relationship is insignificant for restaurants. For restaurants, provisions of doggy bags, and punishment based on consumers' leftover weights showed strong influences on reducing the food waste. Based on the results, policy implications were provided to reduce food waste at supermarkets and restaurants in China.

## Synergistic Utilization Mechanism of E-Waste in Regions with Different Development Levels: A Case Study of Guangdong Province

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**Abstract**
Affected by the regional economic development level and industrial division of labor, e-waste is concentrated in economically developed areas, but its dismantling and utilization are spontaneously gathered in less developed areas, which has formed a long-term reverse supply chain pattern based on cross-regional flow. Comprehensive management of multi-stakeholders in the supply chain (consumers, recyclers, dismantling and utilization enterprises, etc.) is a key way to guide regions with different development levels to form e-waste utilization synergy. This study starts with the e-waste circulation trends in regions with different levels of development, reveals the interaction mechanism of multi-stakeholder, constructs a regional e-waste synergistic utilization model, and selects Guangdong Province, the most typical urban-rural dual structure in China, as the case for analysis. The results show that, from 2020 to 2030, the cumulative amount of e-waste transferred from developed areas to less developed areas in Guangdong Province will reach 23.11 million units, of which the formal dismantling rate is only 52.6%, and the loss of environmental performance will be reduced by 18.8%. In order to solve the above problems, this paper further constructs three policy guidance scenarios for multi-stakeholder behavior: strengthen the extended responsibility, regional joint prevention and regional collaborative innovation. The synergy effect of the policy combination application was obvious, the official demolition rate is increased by 38.6%, and the loss of environmental performance is reduced by 18%. This study proposes a novel model of cross-regional collaborative utilization of e-waste, and promotes the establishment of producer and consumer responsibility extension system, reverse supply chain traceability system and regional green circular supply chain system.

## DAY 2 Session 20

### Imbalance of City-Level Crop Water Footprint Aggravated The Regional Inequality in China

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**Abstract**
Agricultural production is the main consumer of water resources. Regulating water use for agricultural production and water resources endowments to form a reasonable pattern of water resources allocation plays an important role in reducing the pressure on water resources in China. However, there is no study that can provide a spatially and temporally explicit city-level inventory of crop water footprint (CWF) and CWF inequality in China from a micro perspective. Here, we quantified the CWF of 356 cities in China from 2000 to 2020, measured the inequality between the city CWF and the amount of water resources and finally determined the specific factors causing the inequality. We found that CWF increased by 16614.8 (108m3) from 2000 to 2020 in China. Cities with large CWF are mostly concentrated in the Northeast Plain, North China Plain and the middle and lower reaches of the Yangtze River. Meanwhile, great inequality, with a Gini coefficient of 0.697, among cities in 2019 is observed. Compared with 2010 (0.631), the inequality is aggravated. Due to the differences in water resource endowment, industrial structure and economic development level of cities, 168 cities are always in inequality, and the distribution of cities with CWF inequality is roughly the same as that of cities with large CWF, except for cities in the northwest. The results remind us that the inequality of CWF in cities is increasing, and it is urgent to clarify the influencing factors of city inequality and reasonably regulate the allocation of water resources.

### Expressing The Contribution of Ecosystem Services in Urban Metabolism Assessments: Integrated Framework and Application to The City Of Lima, Peru

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**Abstract**
Urban Metabolism (UM) is a discipline tailored to undertake future urban sustainability challenges (i.e. global environmental impacts due to the allocation of resources and energy) since its overarching goal is to assess the activities underpinning resource demand and waste generation in cities. Moreover, Ecosystem Services (ES) analysis provides a vast reservoir of tools and strategies

to optimize cities' metabolism through improved resource cycling and emissions reduction. Despite significant improvements in ecosystem service knowledge and classification, this reservoir remains mostly unexplored in UM research. In response to this knowledge gap, we propose an integrated Urban Metabolism and Ecosystem Service framework to extend the Economy-Wide Material Flow Analysis (EW-MFA). The framework utilizes "Pressures", "Drivers" and "State" indicators to explain the relationships between anthropogenic and natural systems. In addition, we utilize System Dynamics (SD) as a modelling method to quantify the relationships between factors; this allows the elaboration of temporally dynamic assessments and predictive forecasting. Through the proposed framework, interdependencies and causal relationships between ecosystem service assessment and EW-MFA flow categories can be identified. The framework is applied and tested in a case study, the city of Lima, Peru. This case study will provide opportunities to analyze the contribution of six selected ES (carbon sequestration, pollution deposition, peri-urban agriculture, biomass as construction material, biowaste-to-energy and water) to the overall urban-scale dynamics of resources and emissions. Simulations will be considered to estimate spatial and temporal variation based on urban growth, climate simulations, and land-use data. Scenario analysis is used to jointly estimate the amounts of resource flows/emissions and the change in ES supply levels to 2050 (increased or decreased quantities for each service). The findings have the potential to promote awareness of the value of nature in anthropogenic-dominated environments, as well as the integration of UM and ES knowledge in urban planning and design.

## Coordination between Urban Waterlogging Resilience and Land Use Pattern

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**Abstract**
Land use pattern has been changing significantly along with rapid urbanization, which in turn weaken the city's capability to resist external risks. The coordination between land use pattern and waterlogging resilience is the key solution to mitigate urban waterlogging risks. By combining multi-source spatiotemporal data such as remote sensing, points of interest, and traffic road networks, this study constructed an urban land use-waterlogging coupling assessment framework, and conducted an empirical analysis of Beijing. First, the urban waterlogging resilience assessment framework was built considering public service resilience. The spatiotemporal differences in land use and waterlogging resilience were also revealed based on geographically and temporally weighted regression model. Then, the Coupled Coordination Degree Model (CCDM) was established to quantify the coordination between land use and waterlogging resilience in Beijing from 2000-2020. Finally, resilience-oriented urban land use mode was proposed based on multi-objective optimization model to provide optimal land allocation. The findings may help identify the waterlogged and sensitive areas to waterlogging and provide a useful tool for resilient city planning.

Keywords: resilient city, Coupled Coordination Degree Model, waterlogging, land use optimization.

## Offsetting Anthropogenic Carbon Emissions through Cement Industry-Centered Urban-Industrial Symbiosis

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**Abstract**
Cross-sectoral strategies for better meeting carbon peak and neutrality targets and commitments in countries around the world. In advancing cross-sectoral strategies, the cement industry will be called upon to leverage its unique advantage in utilizing diverse industrial and municipal wastes and play a vital role. However, the large-scale impact of such strategies has not been quantified. Quantifying environmental and economic performance of cement industry-centered industrial-urban symbiosis (CCIS) system at the national or global level remains hitherto unexplored. On this basis, we construct a symbiotic network optimization model centered on the cement industry that includes multiple types of constraints such as resources, capacity, technology, economics, policies, and standards to quantify the energy saving and emission reduction potential of the Chinese CCIS. Using enterprise-level data to solve the optimization model, we find that there are 36,312 potential symbiotic pathways in the Chinese CCIS, which lead to 10.84 million tce of energy saving and 91.7 million tons of CO2 reduction in the cement industry, as well as synergistically disposing of 36.4 million tons of steel slag, 47.02 million tons of fly ash, 38.83 million tons of sludge and 10.47 million tons of municipal waste. Further, we design various scenarios such as the policy incentive scenario, the technology improvement scenario, the scale production scenario, and the symbiotic subject development scenario to explore the optimal operation of Chinese CCIS. The results show that the symbiotic network is the most effective in terms of energy saving and emission reduction under the policy incentive scenario, achieving 32.5% of the "2025 Cement Industry Energy Saving Target" and 35.2% of the "2025 Cement Industry Carbon Emission Reduction Target", followed by the technology improvement scenario, the scale production scenario, and the symbiotic main development scenario.

## Evaluate The Effect of Urban Innovation Performance of Smart City Construction Policies in China

Guo, Qingbin; Zhong, Jinrong
Qingbin Guo, Jinrong Zhong
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**Abstract**

In the setting of Digital China, the smart city pilot strategy has become a fundamental part of the intelligent upgrading of the urban development model. Exploring its influence of smart city pilot policies on urban innovation performance is critical for achieving high-quality economic development and creating a country that is innovation-driven. The smart city pilot policy in China is viewed as a quasi-natural experiment in this article.This study identifies and assesses the improved influence of smart city development on urban innovation performance by constructing a multiple period difference-in-differences (DID) model, and then confirms it using a variety of robustness test methodologies. The results show that: the smart city building enhances the urban innovation performance of the pilot cities by about 6.97 percentage points per year on average, and the policy effect is sustainable; The level of economic development, the level of information infrastructure, and the financial innovation expenditure all have a beneficial effect in encouraging smart city construction innovation performance, while the degree of opening-up hinders the improvement of smart city urban innovation performance as a result of the crowding-out impact is bigger than the technological spillover effect. In terms of heterogeneity, the promotion effect of smart city building on urban innovation performance is significant in the eastern region, whereas the effect on the western region has not been statistically significan, additionally, heterogeneity of the effect of smart city policy is due to the different sizes of urban populations.

## Multi-Scenario Land Use and Land Cover Simulation Based on “Urban Development Land Use Suitability, Capital Farmland and Ecological Protection Red Line” under The Policy Impact of Territorial Spatial Planning

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**Abstract**
The land use and land cover (LULC) change model is an effective tool for predicting future land use. The existing models lack the ability to simulate the detailed patch evolution of multiple land use types and they cannot consider the multi-level policy impact which only consider the restrictive effect. Therefore, this study analyses the LULC change and sets forth the policy impact-patch generating land use simulation (PI-PLUS) model. With the policy impact of urban development land use suitability (UDLS), capital farmland (CF) and ecological protection red line (EPRL) in the context of territorial spatial planning, five scenarios (inertial development, S1; EPRL, S2; CF, S3; EPRL and CF, S4; UDLS, EPRL and CF, S5) is set. A rapid development city, Changchun, where the land type is mainly arable land and facing urban expansion, serves as the study area. The results show that from 2010 to 2020, the area of built-up land increased the most (1016.61 km2), which mainly came from the transfer of arable land. The patches were more scattered (CONTAG=75.58),

while landscape fragmentation of arable land (SPLIT=1.65) and build-up land (SPLIT=1307.05) was gradually decreasing. In addition, terrain elevation was the most important driving factor of LULC change. The PI-PLUS obtain high simulation accuracy (Kappa coefficient=0.9186). For the simulation results of 2030, the patches of S1 and S2 are smaller and more fragmented, while the connectivity between patches is better in the scenarios of S3, S4 and S5. This model can make the analysis of policy impact more valuable and flexible, and can help policymakers better understand how policy impact affect various types of land expansion in the future, which can be an effective tool to assist the research of territorial spatial planning.

## DAY 2 Session 21

### An Efficient Method for Production of Nano-Clinoptilolite and Its Utilization in Recovery of Nitrogen-Rich Water

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**Abstract**
In order to improve the effectiveness in utilizing the resources of eutrophic water bodies, nano clinoptilolite (NCP) was prepared using ultrasonic crusher under different parameters. Besides, analysis of material structure parameters was carried out to characterize NCP before and after loading ammonia nitrogen in N-rich water. According to the results, NCPs (<100nm) were produced in a simple and efficient way by using ultrasonic crushing method, with its maximum yield reaching 61%. The parameters of the manufacturing environment included a 500ml ultrasonic container, a 8:3 ratio of water to sample, and a 2000W working power. The adsorption of ammonium ion rate of NCP was found to be usually higher, reaching up to 85.83%, which was about 20% higher than that of natural CP. This was largely attributed to the specific surface area of NCP expanding by up to 17 times, the widespread involvement of Ca2+ in ion exchange process, and the change of the silicon hydroxyl groups further promoting the NH4+ adsorption of NCP. Additionally, the elements analysis was conducted to confirm that the content of N in N-loaded NCP increased from 0 to 1.06%, and that of H increased from 1.51% to 1.97% (might be loaded with -NH2). Pot experiment revealed that the nitrogen availability of nitrogen-rich NCP reached a higher level during 40 to 60 days after transplantation in the tillering stage of rice, which was conducive to crop growth. The adsorption efficiency and quantity of NCP both increased, which was beneficial to address the high energy consumption limit of large-size zeolite for the adsorption of ammonia nitrogen. In addition to reducing the pollution of eutrophic water, it also helped address the nitrogen deficiency in soil, which promotes eco-friendly and sustainable development in the irrigation area.

## Developing Nutrient Resources in Water

Yanqi Li, Qi Wu
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**Abstract**
With the aim of minimizing the negative impact of ammonium and phosphate pollution, a novel magnesium modification biochar adsorbent (MgBC) was prepared, characterized and used for removal and recovery of NH4+ and PO43- from aqueous solution with the agronomic reuse as a slow-release fertilizer. In this study, the effects of adsorbent dosage, solution pH, contact time and initial solution concentration on adsorption were investigated to optimize the adsorption conditions. Results indicated that the adsorption equilibrium was quickly reached within 30 min. Under the optimized conditions (dosage 0.6 g/L; initial NH4+ and PO43- concentration 120 and 60 mg/L), the maximum NH4+ and PO43- adsorption capacity of MgBC was 59.95 mg g-1 and 98.6 mg g-1 at initial pH 8.0. The adsorption kinetic was well described by pseudo-second-order kinetic model, whereas adsorption isotherm results elucidated that Langmuir model fitted the experimental data better than the Freundlich adsorption model. Adsorption kinetics, isotherms and characterizations using SEM–EDS and XRD suggested that MgO and Mg(OH)2 particles on the biochar surface were the main adsorption sites for struvite and adsorption was controlled by a precipitation mechanism. Moreover, the as-prepared magnesium modification biochar product not only had high removal efficiency for NH4+ and PO43-, but also was an excellent ammonium and phosphate carrier material. The NP-laden MgBC into the soil planted with rice significantly promoted tillers. These results suggested the MgBC is a promising adsorbent, which can be used to reclaim ammonium and phosphate from water, alleviate eutrophication and reduce ammonium and phosphate removal pressure in water. In addition, the NP-laden MgBC could be cycled back directly to soils as an effective slow-release NP-fertilizer to realize the recycling and utilization of ammonium and phosphate resources.

## Lithium/Magnesium Selectivity in Membrane Separation: Definition, Measurement, and Process Scale Evaluation

Ruoyu Wang, Shihong Lin
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**Abstract**
To investigate the issue of increased ecological risk of heavy metals in resultant biochar that may be caused by the addition of chlorinating agents to remove heavy metals from sludge during pyrolysis treatment, fast co-pyrolysis experiments of municipal sludge with polyvinyl chloride plastic (PVC) were conducted in a horizontal fixed-bed reactor to explore the effects of temperature (500-900°C) and PVC mixing ratios (0, 5 and 15%) on the migration and transformation behaviors of heavy

metals As, Cr, Cu, Mn, Ni, Pb and Zn. It was found that increasing the pyrolysis temperature and adding PVC to feedstocks were beneficial to reduce the residual rate of As, Pb and Zn in biochar, but had almost no effect on the removal of Cr, Cu, Mn and Ni. Furthermore, the speciation analysis of heavy metals showed that the heavy metals (except As) in biochar generally transformed into more stable forms with increasing pyrolysis temperature. However, according to the ecological risk assessment of heavy metals, the presence of PVC in pyrolysis system increased the ecological risk of heavy metals in the obtained biochar when the pyrolysis temperature was 500 and 600 °C, but when the pyrolysis temperature exceeds 600°C, the addition of PVC in feedstocks can indeed lower the ecological risk of heavy metals in the resultant biochar, while decreasing the content of heavy metals. Therefore, corresponding attention should be paid to prevent the problem of increased ecological risk of heavy metals caused by PVC in feedstocks during the process of industrial pyrolysis for sludge disposal.

Keywords: municipal sludge, polyvinyl chloride plastic (PVC), co-pyrolysis, heavy metals behaviors, risk assessment.

## Incorporation of Nanoclay-Based Adsorbent into Ultrafiltration Membranes for Enhanced Phosphorus Capture in Aqueous Solution

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**Abstract**
Phosphorus (P) is a critical element related to life, an irreplaceable and non-renewable resource and is considered a pillar of global food security. The mineral extraction of this element is used primarily for fertilizer production. However, many researchers claim that phosphate rocks can be depleted in 50 to 100 years. In light of this, the removal of P from wastewater has recently gained attention as a sustainable method for this element removal from effluents. One of the most recent methods in the literature is the adsorption of P by nanocomposite membranes, materials that combine the advantages of adsorbents and membranes. In this work, a chemically modified clay adsorbent was added to a polyvinylidene fluoride (PVDF) solution, and then the membrane was synthesized through the phase inversion method. With the addition of the nanoclay adsorbent to the PVDF matrix, the porosity and thermal stability of the nanocomposite membrane were enhanced. The modified membrane had a 101 µm thickness and tensile strength appropriate for ultrafiltration processes. The cross-section morphology observed using the Scanning Electron Microscopy (SEM) showed that all membranes possess an asymmetric structure, with larger and longer finger-like pores on the nanocomposite membrane. Furthermore, the P uptake equilibrium was established in 8 h of contact leading to 50% of the removal. The present membrane has great potential in P uptake from effluents and promising technology for wastewater treatment.

## Evaporation of DTRO Concentrate Derived from Leachate Produced in MSW Incineration Plant

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**Abstract**
The thermal evaporation technology was used to treat the leachate membrane concentrate of the waste incineration plant, the effect of evaporation rate and pH of the initial concentrate on the water quality of the evaporation product condensate, and the precipitation law of solid phase substances during the evaporation process of the concentrate were explored. The result indicated that in the earlier stage and late stage of evaporation, the COD in the distillate was high, while in the middle stage of evaporation, only a small amount of organic matter entered the distillate. At the initial stage of evaporation, a large amount of ammonia nitrogen entered the distillate. With the increase of the evaporation rate, the concentration of ammonia nitrogen in the distillate decreased gradually, and the rate of change slowed down. On neutral or alkaline condition, the COD of the distillate was lower and the NH3-N concentration was higher. With the increased of the evaporation rate, the change of the conductivity of the distillate has a strong correlation with the concentration of ammonium ions and chloride ions. The main components of the solid insoluble precipitate during the evaporation of the concentrate were K2SO4, CaSO4, NaNO3 and NaCl. Among them, sulfate and nitrate were precipitated first.

## Metal-Organic Framework-Derived Nanomaterials Boosting Wastewater Energy Recovery Via Biotic and Abiotic Process Intensification In Bioelectrochemical Systems

Mengxi Yin, Xiaoyuan Zhang
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**Abstract**
Bioelectrochemical systems (BESs), which can realize self-sustaining energy recovery of wastewater, hold promise for future wastewater treatment towards carbon neutrality. Typical BES is an integrated system that incorporates biotic and abiotic processes. The boom of sophisticatedly engineered nanomaterials has brought more prospects for this integrated system, where the interaction between the nanomaterials and the integrated system trigged people’s interest. Among these, metal-organic frameworks (MOFs) possessing merits of high stability, ordered open cavity and facile synthesis, have caught our sight. MOFs have unsaturable metal-ion sites and metal active components could be easily incorporated. Bimetallic MOF-derived cobalt embedded porous carbon

skeleton was optimized based on a dual regulation strategy including particle size tuning and zinc fencing, and was applied to accelerate the oxygen reduction reaction kinetics on BES cathodic interfaces, along with which the organics in wastewater were eliminated. The power density achieved was 39.7% and 54.4% higher than Pt/C BES and AC BES. Efficient wastewater treatment with an organic removal rate of 1.94 ± 0.24 kg m−3 h−1 was achieved. As for the anode, porphyrin iron constitutes the structure center of outer-membrane c-type cytochromes, which plays an important role in extracelluar electron transfer. Considering the similar structure of FeNx site and porphyrin iron, a MOF-incorporated necklace-like carbon fiber membrane was designed on the nanocage confinement−electrospinning route. The membrane electrode with atomically dispersed FeNx moieties was first applied as BES anode. This membrane anode with high electrochemical activity, high specific surface area and low charge transfer resistance, was found to be conducive to the adhesion of exoelectrogenic bacteria and the electron transfer process at the microbe-electrode interface. The power output was 170.7% that of the pristine carbon fiber membrane. Hence MOFs-based nanomaterials facilitate both biotic and abiotic processes in BESs, accelerating the wastewater energy recovery and treatment in this integrated system.

## DAY 2 Session 22

### Techno-Economic-Environmental Impacts of A Circular Bioeconomy for Forest Resource Utilization

Yuan Yao
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**Abstract**
Climate change and increased forest fires present the urgent need to remove excessive biomass from forests. In 2018, the damages of forest wildfires in California were estimated to be as high as $126–193 billion [1]. Current practices such as prescribed burning or mechanical thinning lead to the direct release of carbon to the atmosphere through combustion or decay of low-value forest residues from thinning [2]. Converting forest residues to valuable bio-products presents a promising solution to climate change and forest fire and supports the development of a circular bioeconomy. Life cycle assessment (LCA) and techno-economic analysis (TEA) have been applied to understand the environmental and economic feasibility of different forest residue conversion technologies (e.g., pyrolysis or gasification). However, previous studies have rarely considered the significant variations in spatial and temporal factors related to forest growth and management, residue composition and quality, and different process, product portfolio, and supply-chain design strategies. It is critical to understand the impacts of these factors on the environmental and economic performance of forest residue utilization systems to design systems-wide optimization for sustainability. This talk will present a modeling framework that integrates process simulations, TEA, and LCA. The framework is applied to several case studies utilizing forest residues in the different U.S. regions with distinct applications, e.g., biofuels, biochar, and bio-chemicals. The results highlight the trade-offs and co-

benefits of converting forest residues to different products. The talk will demonstrate how the integrated framework can support the optimization and design of a climate-beneficial, economically competitive, and sustainable circular bioeconomy for forest residue utilization.

References:

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## A Perspective on Applying Life Cycle Analysis to Injection Molding

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**Abstract**

Life cycle analysis (LCA) offers a methodology that analyzes the energy consumption and environmental impact of a product's life cycle. Initial research aimed to apply LCA towards the recycling of acrylonitrile-butadiene-styrene plastic products while accounting for the injection molding process. While attempting to perform the LCA, a problem was discovered in the methodology of the research. It was found that current LCA research relies on average data such that any variations in a system can be simplified into one representative value. This causes major issues due to the nature of variations within the injection molding process. For example, the temperature that is used to plasticate the plastic significantly affects the energy used during the plastication process. Thus, the processing parameters in injection molding can cause the energy consumption of processing conditions to significantly deviate from the average energy consumption. There are also variations regarding some individual components of the injection molding system which should not be lumped together as an "average value". Cold runner molds, where the runners solidify, require more polymer (melt) and create more scrap, but use less energy than hot runner systems which keep a portion of plastic molten. Furthermore, hydraulic injection molding machines use significantly more energy than all-electric injection molding machines; they also require an additional material input. These differences in the injection molding process cause fundamentally unique material and energy outputs, which invalidates the use of averaged data. To solve this problem, LCA should be performed such that a statistical analysis can be done to access processes that have many complex factors that affect their energy consumption and environmental impact.

## Medical Oxygen: Life Cycle Assessment of An Atmospheric Resource

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**Abstract**
Medical oxygen is a vital healthcare resource provided to a patient to achieve the minimum required oxygen blood saturation. There is a growing interest in medical oxygen as a result of supply shortages experienced during COVID-19. The World Health Organisation has emphasized the need for environmental sustainability efforts and the resilience of health systems. There is limited sustainability research on medical resources, their production and consumption, and environmental footprint.

This project considered a life cycle assessment (LCA) of medical oxygen. Medical oxygen, which accounts for a small fraction of total refined oxygen production, is produced using two technologies: (1) cryogenic distillation, where liquid oxygen is produced via liquefaction of air and then is transported to site, (2) and pressure swing adsorption (PSA), where gaseous oxygen is produced, typically on-site, by passing ambient air through a molecular sieve. Our baseline system considered a common Western scenario: production via cryogenic distillation and transportation of liquid oxygen to a hospital, where it is gasified for distribution. We considered data from ecoinvent and industry expert sources relevant to 2021 in Toronto, Canada. We used OpenLCA and TRACI impact method. LCA results for the baseline showed a global warming potential indicator of 0.4 kg CO2e per cubic meter of gaseous oxygen provided to a hospital bed per day, with transportation and electricity as key drivers. In comparison, PSA production yielded 0.09 kg CO2e. In a different product system, we considered delivery in aluminum cylinders, whose transportation added considerably to environmental burdens in the supply chain.
Overall, medical oxygen, when delivered efficiently, to a hospital has a relatively small environmental burden. However, the use of this important resource is often wasteful. Our results highlight aspects of the medical supply chain where there is risk of disruption and where attention to health system resilience is needed.

## Integrating Risk Likelihood and Impact Analyses for Sustainable Product Design Decision-Making

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**Abstract**
Decision making during sustainable product design involves considerable number of risks which need to be identified, assessed, and mitigated through appropriate strategies. Optimization and other decision-making methods allow identifying designs that satisfy desired performance objectives. After a product is launched following any such design, many uncertainties affect the performance over its total lifecycle, giving rise to risks that can influence the performance objectives. The level of these risks is a measure of their likelihood – probability of occurrence, and impact – consequence

when occurred. Risk assessment literature is limited to developing methods to analyze the likelihood of risks during product design decision making without emphasis on methods for impact analysis, should the risks occur. Hence, most risk-informed decision making is skewed; combination of quantified likelihood and impact of risks are not used for accurate representation of risk. This presentation will discuss an approach using a quantitative Risk Level Quadrant (RLQ) diagram, that combines information from both risk likelihood and impact, to select the best sustainable product design. Two new metrics – operational risk index for likelihood (ORI_L) and impact (ORI_I) which are consolidated measures of the likelihoods and impacts of each product design are defined as the coordinates of RLQ. Following ISO 31000 Risk Management Guidelines, the risks affecting different designs were identified from a predefined taxonomy with inputs from experts. The likelihood of risk affecting each design is assessed using an existing Bayesian Belief Network-based approach that captures the interdependencies among risks. A novel approach for quantifying the impacts of new product design risks developed by adapting the ISO 14040 Lifecycle Assessment (LCA) methodology is used to hypothetically estimate the impacts of the risks on performance objectives. The result shows that the RLQ simplifies understanding the risk levels of alternate product design and helps to make better design choices.

## Environmental Evaluation of Enhanced Microalgae-Based Eicosapentaenoic Acid (EPA) Production

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**Abstract**
Microalgae attract attention from various fields due to their potential ability to accumulate diverse value-added products such as polyunsaturated fatty acids. Many approaches have been applied to boost productivity, only focusing on economic competitiveness. However, it is imperative to quantify and optimize the associated environmental impacts simultaneously in an early stage to guide a sustainable scale-up. In this study, a Life Cycle Assessment (LCA) of the lab-scale eicosapentaenoic acid (EPA) production from Phaeodactylum tricornutum was conducted. Results indicated that the scenario coupled with metabolic engineering and medium optimization achieved a significant reduction (93.48%) of global warming potential (100-year horizon, fossil based) compared with wild-type scenario due to the enhanced microalgal growth and EPA yield. Electricity consumption remained the dominant contributor to the impacts, attributed to energy-intensive processes in cultivation and harvesting stages. Additionally, extraction solvents played another important role regarding life cycle aspects, along with nutrients needed for microalgae growth.

## Impact of Allocation Methods in Open Loop Recycling Systems: The Carbon Footprint of Injection Moulded Products Based on ABS, PA66GF30, PC and POM

Jan Tinz, Tim de Ancos, Holger Rohn
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**Abstract**
The consumption of recyclates in open loop recycling systems raises in Life Cycle Assessments (LCA) the question of how the environmental impacts caused by the recycling process can be allocated to the corresponding products. Along the production chain, the flow of materials in a cascade of product systems fulfils several functions, like the waste management in the prior system and the demand for raw materials in the subsequent system. In order to solve this multifunctional issue in an open loop, this study applies three allocation models across two successive product life cycles that are interconnected via one recycling process, including the cut-off (recycled contend) approach, the 50:50 method and the end-of-life (avoided burden) approach. The analysis is based on the injection moulding of tension rods according to ISO 527-2 Type 1A made of virgin and secondary materials using the plastics ABS, PA66GF30, PC and POM from post-industrial waste. For the calculation of the carbon footprint, the LCA software Umberto version 10 was used with the databases ecoinvent 3.8 and GaBi SP40 2020 as background system. Further measurements of the electricity consumption during the injection moulding and a followed tensile test as a use phase allow a presentation of the CO2 equivalents for each individual life cycle phase of the products made of virgin and recycled material. The results of the three allocation models show that the carbon footprint can range up to 15% compared to the equal values of the 50:50 Method, even though the recycling process itself is only responsible for about 1% of the total product carbon footprint. That illustrates the effects of credits and burdens on the raw material production, material recycling and energy recovery according to the material flow.

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# DAY 2 Session 23

## Assessment of The Criticality and Recovery Potential of Major Metals in Lithium-Ion Battery Systems in China

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**Abstract**
Lithium-ion batteries (LIBs) have penetrated into different application fields due to their high energy density and long cycle life. China has now become the world's largest LIB producer and consumer country. The rapid growth of LIB production poses a great challenge to resource supply. The potential risk of mineral supply disruption threatens the stability and economic security of the LIB industry and even the country. Based on a two-dimensional criticality matrix, the supply risks and economic importance of seven major metals in LIBs are assessed from 2010 to 2020. Metal recycling from spent LIBs may be a viable way to relieve metal supply pressures. Based on a stock-driven model and a comprehensive bottom-up estimation of LIBs and metals in four types of LIB end-users from 13 sectors, the amount of stock, demand, and recycling was predicted for seven main metals used in LIBs in China from 2021 to 2050. Lithium and cobalt are identified as the most critical metals, and the criticality of nickel is decreasing year by year. Cobalt has the highest supply risk, and lithium has the greatest economic importance. By 2050, the demand for lithium, cobalt, nickel, manganese, copper, aluminum, and iron will reach approximately 640, 520, 3000, 3000, 3200, 4000, and 700 kt, respectively. Spent LIB recycling provides approximately 35%, 66%, 66%, 66%, 59%, 58%, and 34% of the lithium, cobalt, nickel, manganese, copper, aluminum, and iron required for manufacturing new LIBs, respectively. If battery technology develops toward using less cobalt and more nickel, the demand for cobalt will decrease by 18%. Although future materials demand will not be completely met through LIB recycling, such recycling will still be significant to minimize material shortages.

## Ecological Restoration Potential Is Overestimated by Half If Topography Limits Are Not Considered

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**Abstract**
Ecological restoration remains among the most effective strategies for climate change mitigation and ecological conservation. However, the magnitude, intensity, effect and potential of revegetation are limited by adverse environments, especially water resource and topography. In this study, we propose an assessment framework of ecological restoration potential under the dual limits of water resource and slope, and evaluate the future revegetation space for China’s terrestrial ecosystem. The results suggest that 20%, 0.19% and 32% of the area of China’s 31 provinces have their vegetation planting above, equal and below local vegetation carrying capacity permitted by local water resource, suggesting around an additional 0.299 billion ha of revegetation space. The ecological

restoration potential under the dual limits of water resource and slope is 0.4 Pg C, less than half (47%) of the potential under water resource limit. Yet, this potential plus China's current terrestrial ecosystem carbon sink is estimated that can just offsets around 5.24%-7.55% of its contemporary fossil fuel CO2 emissions. And ecological restoration in regions with slope higher than 5°requires additional economic investment brought by Soil and Water Conservation programs, around 10.04%-4.18 times of China's GDP in 2020. Future sustainable ecological restoration needs the integration of process-based assessment, field investigate, landscape design, etc. This study can provide technical support for quantitatively assessing ecological restoration potential under the dual limits of water resources and slope, and guidance for ecological restoration programs implementing in a more sustainable way.

## Dynamic Nonlinear Impacts of Energy Consumption and Globalization on Ecological Footprint：Empirical Research from Brics Countries

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**Abstract**
Environmental degradation has caused an irreversible effect on human and ecosystem, and sustainable development is considered as the best way to solve these problems. In the recent studies of sustainable development, ecological footprint is regarded as an indicator of sustainable development of a country and a region, because it combines the whole range of environmental data into a single indicator, which can not only measure human demand for environmental resources, but also fully reflect biocapacity of a region. Exploring a region's ecological footprint level will provide policy suggestions for countries to achieve sustainable development goals.
Energy consumption and globalization will affect the ecological footprint through production and consumption. Specifically, in order to achieve economic growth, countries will affect their ecological footprint by increasing commodity supply, trade and foreign direct investment. However, because of the complex and nonlinear relationship among energy consumption, globalization and ecological footprint, the existing empirical research results were mixed. The quantile-on-quantile regression (QQ) approach proposed by Sim and Zhou(2015) can provide a comprehensive and clear image to explore this complex relationship. Therefore, taking BRICS countries as samples, this paper explores the relationship between globalization and energy consumption on ecological footprint by quantile-on-quantile regression approach. The results show that energy consumption will have a negative effect on the ecological footprint of China and India, whereas at low ecological footprint quantiles, while in South Africa, a negative feedback interconnection exists between energy consumption and ecological footprint at most quantiles. Globalization will have a negative linkage at low quantiles ecological footprints of China, South Africa and Russia, while Brazil and India have a negative

feedback at high quantiles ecological footprints. The results can provide reference for BRICS countries to reduce ecological deficit, adjust energy structure and formulate globalization policies.

## Carbon Emissions on Energy Infrastructure Concealed in Inter-Regional Sectoral Dynamics in China

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**Abstract**
Abstract: The energy infrastructure is vital for energy conservation and low carbon transition. Though environmental accounting has undergone a wide range of studies under structural decomposition analysis (SDA), it pays little attention to comparative advantages between regions. The multi-dynamic interregional input-output shift-share model (MDIOSS) is adopted in this study to ascertain the dynamic intersectoral relationships between the spatial units. Based on MDIOSS, the carbon emissions generated from production and consumption perspectives are analyzed for three sectors in the input-output table related to energy infrastructure in 2012, 2015, and 2017. The findings reveal that the most growth-enhancing linkages from 2012 to 2015 are those between a province and the others outside the region. However, from 2015 to 2017, the most growth-enhancing linkages are those intra-provincial. The changes in carbon emissions experienced by most provinces are affected significantly by a change in economic structure rather than the difference in carbon emission growth rates. The relative significance of carbon emission variation factors in each province is examined quantitatively to disclose regional differences in the influencing factors. The results indicate that the main factors facilitating the growth of carbon emissions are the same in all provinces within the region, yet heterogeneity is manifested amongst regions.

Keywords: MDIOSS, energy infrastructure, carbon emissions, China

## Does Industrial Upgrading Promote Green Land Use Efficiency? New Evidence from 115 Resource-Based Cities in China

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**Abstract**
The rational use of land is an important guarantee for the sustainable development of resource-based cities. First, this paper uses the panel data of 115 resource-based cities in China from 2004 to 2018 to measure green land use efficiency (GLUE) by SBM model and Metafrontier-Malmquist productivity

index model. Secondly, it analyzes the industrial upgrading from the perspectives of the optimization of industrial structure (OIS) and the rationalization of industrial structure (RIS) to explore the impact mechanism of industrial upgrading on green land use efficiency. Further, the heterogeneity analysis is carried out from the following two perspectives: exploring the impact of industrial upgrading on green land use efficiency under different types of urban samples; using the quantile model to analyze the impact of industrial upgrading under different green land use efficiency quantiles. The main conclusions of this study are as follows: (1) Both the optimization of industrial structure and the rationalization of industrial structure have significantly promoted the improvement of green land use efficiency, and the robustness test and instrumental variable method support this conclusion. (2) For different types of resource-based cities, the rationalization and optimization of industrial structure have positive coefficients in regeneration cities, growing cities, and declining cities, but have a negative effect on mature cities. (3) In all quantiles, the effects of industrial structure optimization and industrial structure rationalization are positive. However, with the increase of quantiles, the role of industrial structure optimization gradually decreases, and the role of industrial structure rationalization gradually increases. This paper provides a theoretical reference for the transformation and development of resource-based cities.

## DAY 2 Session 24

### Statistical Parametric- and Non-Parametric Control Charts for Monitoring Water Consumption in A Building Environment

Allyson Belli Bogo, Elisa Henning, Andreza Kalbusch
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**Abstract**
The main objective of this paper is to conduct a comparative study of the application of parametric and non-parametric control charts for the monitoring of daily water consumption time series in the city of Joinville, Southern Brazil. The methodological procedures include the use of the Shewhart and EWMA control charts in addition to the non-parametric alternative, the EWMA-SN control chart. Daily water consumption in the city ($m^3$/day) was investigated, categorized and analyzed as residential, commercial, industrial or public. The water consumption of two housing projects was also investigated to assess the effectiveness of the control charts in detecting leaks at a residential scale. The data sets represent a period of 243 days and were obtained through a telemetry measurement system from the city's water utility. All analyses and applications were performed using the R software. The results show that control charts are a powerful tool in identifying changes in water consumption patterns, both at municipal or residential scales, including the prespecified categories. The Shewhart control chart obtained better results in identifying sudden and large changes in water consumption, such as the occurrence of leaks. The EWMA chart proved to be more efficient in identifying small and consistent changes in the water consumption pattern, due to its characteristic of accumulating the weight of more recent observations. The non-parametric EWMA-

SN chart behaved similarly to the EWMA plot, being a relevant alternative to be considered when the dataset does not meet the assumption of a normal distribution.

## O2 and H2O Molecules Served As The Resources for Sustainable Synthesis of Hydrogen Peroxide

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**Abstract**
Hydrogen peroxide (H2O2), one of the most important fundamental chemical resources in the world, has a global demand approached about 4 million tons per year. However, the synthesis of H2O2 is currently restricted by the energy-demanding and waste-intensive anthraquinone process, as well as other photocatalytic and electrocatalytic routes. Herein, we report a green approach via a ternary catalyst MnFeTiOx auto-catalyzing H2O and O2 molecules to produce H2O2 without extra energy input (e.g., light, electricity). More than 0.7 μmol/L, 1.7 μmol/L, 4.3 μmol/L, 13.0 μmol/L and 27.3 μmol/L of of H2O2 could be generated in MnFeTiOx/H2O/O2 systems at pH = 11.0, pH = 9.0, pH = 7.0, pH = 5.5 and pH = 4.0, respectively. The MnFeTiOx catalyst possessed a robust magnetic property with the saturated magnetization value of 16.0 emu/g, greatly facilitated the collection for reuse, achieving the sustainable synthesis of H2O2. This finding provides a useful strategy for H2O2 generation using the earth’s most abundant O2 and H2O molecules as the sources, dealing with the challenge of the global resource depletion.

## A Systematic Review of MCDM Methods in Environmental Sustainable Design

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**Abstract**
The scope and complexity of the transformations required for achieving the Sustainable Development are unprecedented. Design process has been identified to greatly influence the environmental sustainability. Considering the various technical trade-offs at the early stage of design process, researchers involve multi decision-making methods to weighing and integrate sustainable factors in product design, which also refer to product features such as pollutant emissions, eco-balance, energy efficiency, human health and safety risks. Decision-making methods were applied to achieve sustainable design in areas such as product structural and functional, reverse logistics, material selection and waste management. However, decision-making methods have their own relative merits and adaptability. Scholars used various methods to support the decision-making in design process to achieve sustainability whilst there is no clear framework to select appropriate decision-making methods.

Therefore, this research has a comprehensive review on the studies of sustainable design, and set up a new framework to select appropriate decision-making methods for sustainable design studies in different areas. The framework presents a five-step investigate of the related research: criteria weight, subject area, output style, sample size and criteria characteristic.

A systematic literature review (SLR) was employed in this study which crossed over past four decades. The frequently-used decision-making methods have been identified and discussed. The following themes were investigated in the analysis: the stated reasons for choosing to apply decision-making methods, the frequently-used decision-making methods, the relative merits and of the methods, the preference of decision-making methods in different areas and how the methods were chosen. The themes were investigated to guide the analysis of the review and a decision-making framework has been developed to aid the researchers to select appropriate multi-criteria decision-making methods in sustainable design, which will help improve the stability and feasibility in sustainable design, and finally help achieve green eco-design and reduce the environmental pressure.

## What Circular Economy Indicators Really Measure? An Overview of Circular Economy Principles and Sustainable Development Goals

Oliveira, Giovanna Groff Andrade; De Oliveira, Carla Tognato"
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**Abstract**
The population growth has resulted in the need for new alternatives that guarantee resources for producing goods and a reduction in the generation of by-products and waste. Among the alternatives are the circular economy (EC) and sustainability. This paper aims to analyze the indicators that intend to measure circularity at the nano and micro levels and also sustainability in order to ensure that they fulfill their purpose. In order to achieve this goal, eight circular indicators were selected from de Oliveira et al. (2020) that address sustainability. We propose a three-step method. First, the indicators were characterized by Sources, Type, Cycles, CE Practice, Business Strategy, and Methodology. Second, the indicators were analyzed based on the three EMF's principles of circular economy, and thirdly, they were analyzed by sustainability and EC practices that contribute directly to the SDGs. The main results establish that only one indicator considers the option of measuring the biological cycle. Among the three principles of the circular economy, "Keep products and materials in use" is the main one considered, and recycling is the most common strategy used for that. Additionally, only two indicators approached water management (SDG 6). Therefore, the result shows that even if an indicator is considered circular, it does not always bring the full potential of measuring the sustainability of resources. Finally, this issue could be explored in industries and

companies that require their managers to adopt the indicator to better attend to specific parts of their production process to promote the circular economy. Moreover, academic researchers can help decision-makers review indicators to measure all the CE principles and not just focus on recycling. Thus, improving CE practices in companies and generating more accurate information for society's understanding of what companies are doing in favor of CE.

## Helium Resource Supply and Supply Risk

Ankesh Siddhantakar1, Jair Santillán-Saldivar2, Thomas Kippes4, Guido Sonnemann3, Armin Reller4, Steven B Young1
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**Abstract**
Global supply and geopolitical supply risk of helium resource are assessed for top importing countries using the GeoPolRisk indicator. Helium is a non-renewable resource identified as a critical raw material by the USA, EU, and other nations. There is little extant research on the helium life cycle, its resource criticality, its environmental footprint, or on quantifying material resource losses (which, given that helium is both inert and light, exit the Earth's atmosphere). Roughly 30% of production is used as cryogenic coolant in magnetic resonance imaging (MRI) machines, supporting healthcare. Other uses include laboratory research and advanced manufacturing. Obtained from refining hydrocarbon natural gas, global helium production was approximately 160 million cubic meters in 2019 and is concentrated in three countries (USA, Qatar and Algeria). Helium is stored and transported as a cryogenic liquid, then distributed as a liquid or compressed gas, making logistics challenging and time-constrained, given its tendency to leak. We quantified the supply risk for ten helium-importing countries (China, Japan, South Korea, Taiwan, Germany, France, the United Kingdom, Mexico, Canada, and Brazil) from 2015 to 2019. An original database on helium processes and supply chain supported the calculation of the GeoPolRisk indicator. As a noble gas, helium does not change its form or mix over its life cycle, thus providing ease of tracking through multinational trade. Results show three global regions, each with a different pattern of supply and variations in GeoPolRisk. Given growing use in East Asia, where there is no current regional production, future challenges in supply and supply risk are emerging.

## Sustainable Operational Practices and Operational Performance: A Quest and Understanding of The Current Research

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**Abstract**
There has been an increasing concern for the preservation of the biosphere and the rational use of resources, which has led to a more responsible orientation of organisations. Stakeholders are more interested in the environmental integrity of business operations, even showing willingness to pay premium-prices for environmentally-sound products and services. This drives organisations to implement sustainable practices in the operations realm, given its crucial role for overall performance and its involvement in the different stages of an environmentally-friendly product life-cycle: design, supply chain (planning and procurement), transformation (cleaner production), and reverse logistics.
The purpose of this study is to document the scientific contributions on the relationship between the implementation of sustainable operational practices (SOP) and operational performance in organisations. Through the several stages of the systematic review of scientific articles from the past five years a final sample of articles is achieved and analysed.
Preliminary findings of the review include the different portfolios of SOP and the varied forms of approaching and understanding operational performance. It is found that there is a predominantly positive association between SOP and operational performance, which comprises aspects related to quality, costs, safety, delivery speed and flexibility. Interestingly, literature report specific SOP related to green purchasing and engagement with customers as drivers of a boosted operational performance. Nevertheless, such form of performance is not affected by SOP such as eco-design, packaging and reverse logistics.
The contributions of this study include a better understanding of the organisational efforts through the implementation of SOP to respond to societal demands for a better utilization of resources such as water and energy, and the reduction of pollution throughout the entire lifecycle of products and services. Findings of the review also help managers and practitioners to identify relevant SOP that contribute to both corporate environmental and operational performance.

## DAY 3 Session 25

### China's Consumption-Based Tungsten Export from 1990 to 2016

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**Abstract:**
Tungsten is a crucial strategic metal due to its irreplaceable application in the military and other industries. Besides direct tungsten export in terms of mining and intermediate products, China, as the

largest global exporter and tungsten producer, has also exported consumption-based tungsten through supply chains to meet final demand of other countries. This paper analyzes China's consumption-based tungsten export based on the multi-regional input-output analysis from 1990 to 2016. China's consumption-based tungsten export was at a low level in 1990s (accounting for about 10% of the total export), but grew very fast after 2000 (increasing by 2.24 times during 2000 to 2016; accounting for about 24% of the total export). China's tungsten exports are concentrated in the top 5 countries (Japan, the United States, the Netherlands, North Korea and Germany), accounting for more than 70% of the total export. The United States was the largest importer of China's consumption-based tungsten, sharing 27% of China's total consumption-based tungsten export during the study period. Japan and the Netherlands mainly rely on the direct import of tungsten intermediate products to meet their technology-intensive high-end products. Demand for China's tungsten in some regions (such as South Korea and the UK) rapidly shifted from direct to indirect import. The demand in machinery & equipment, tools and consumer durables as the major end-user for tungsten were far exceeded other applications. The demand in machinery & equipment gradually has overtaken tools and consumer durables as the largest application of China's consumption-based tungsten export after 2000. The decomposition analysis showed that almost all factors (such as production structure and final demand structure) were drivers for the growth in China's consumption-based tungsten export, except for technology change.

## Assessment of the Lead Secondary Reserves of Nations

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**Abstract:**
Lead is a blue gray metal with good corrosion resistance and plasticity properties which has been used by human societies for 5000 years. Lead poisoning provokes mental retardation and is a serious health problem. As a result, nations have adopted lead phase-out policies to eliminate lead from the human environment. On the opposite, the use of lead in batteries has spread in recent years raising questions about their recyclability and the lead availability for its increasing demand. In the present research, we examine the secondary reserve, i.e., the part of lead in in-use stock potentially recoverable, in major lead consuming nations: France, United Kingdom, Italy, Spain, Germany, United States, Russia, China, India, South Korea and Japan. Results shows the total input to stock has increased 40-fold between 1950 and 2018, the biggest increase being observed for the battery use in the transportation sector (85-fold increase). Secondary reserve ratio ranged from 40% (China) to 80% (Spain) in 2018.The capacity of secondary reserve to fulfill the demand defined as the ratio of the secondary reserve released in the year over the input to stock varied in 2018 from 33% for China to 70 % for Spain.

## Mineral-Energy-Water Nexus in Four Municipalities of China

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**Abstract:**
In recent years, the interdependencies among different resources have been an increasing focus in the research communities. As the basic natural resources to sustain the development of human society, minerals, energy, and water resources are very closely related to each other. In this paper, a systems framework based on the input-output analysis is contributed to analyzing the mineral-energy-water (MEW) nexus of a city. The direct/complete MEW nexus is defined as the direct/complete M/E/W resources that are required to produce one unit final product of the M/E/W sector. To distinguish among them, the nexus is grouped into four categories by the city boundary: Scope0 (Direct nexus within the boundary), Scope1 (Complete nexus within the boundary), Scope2 (Direct nexus across the boundary), and Scope2+3 (Complete nexus across the boundary). The framework is then applied to four municipalities in China. The results show that the direct mineral use of water in Beijing is the highest, while the direct energy use of mineral and the direct water use of energy in Chongqing are the highest. The embodied mineral and water triggered by the unit final product of the energy sector is the highest in Shanghai. The embodied energy and water triggered by the unit final product of the mineral sector is the highest in Tianjin. The embodied energy and mineral triggered by the unit final product of the water sector in Chongqing is the highest.

## Estimating the Energy Saving Potential of Residential Consumption in China Based on Decent Living Standards

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**Abstract:**
With the improvement of residents' living standards, the transformation to an energy-saving lifestyle in China is becoming increasingly important in ensuring energy security and achieving the “dual-carbon” goal proposed by the Chinese government. However, the basic well-being of residents should be fully considered when making residential energy-saving policies. For this study, first, decent living standards for China were proposed. Then, based on this information, the provincial energy consumption and energy saving potential of Chinese residents were estimated from a lifetime perspective using environmental extended input–output analysis. The results show that, in 2017, the energy saving potential of Chinese residents was 9865.90 trillion kJ; the consumption categories of

transportation, housing and cooking had the greatest energy saving potential of 1668.40, 3540.83 and 3229.75 trillion kJ, respectively. Among these three consumption categories, the energy saving potential from direct consumption accounted for more than 85%. For food, clothing, water, health care and education, there was substantial energy saving potential from indirect consumption. However, the primary energy saving potential varied at the provincial level, coming from different consumption categories, verifying the importance of differentiated and targeted energy saving policies for residential consumption in different provinces.

## High Spatial Resolution Environmental Dataset and Application

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**Abstract:**
The construction and application of high-spatial-resolution environmental databases is critical to addressing increasingly prominent environmental issues. High-spatial resolution data reflect the specific distribution and characteristics of research subjects at a fine scale, which can identify hotspots of environmental pollution and help formulate environmental control policies tailored to local conditions. Scholars at home and abroad have built a large number of high-spatial-resolution environmental databases and applied them to solve different environmental problems. However, there is no systematic review summarizing the types and applications of high-spatial-resolution environmental databases. Therefore, this paper summarizes the common high-spatial-resolution environmental databases from the aspects of scale and substance type. Moreover, the application of high-spatial-resolution environmental databases has been summarized in three different aspects, including emission source analysis, environmental impact assessment, and economic influencing factors. This article proposes several recommendations to improve the existing high-spatial-resolution environmental databases, including further improving the resolution to ensure the data accuracy, improving data quality, and broadening the scope of applied research.

## Resource Exergy Analysis of a Developing Society: China 2017

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**Abstract:**

Resource exergy analysis clarifies the biophysical foundation of social development. This paper aims to explore the resource utilization pattern of the Chinese society by employing the exergy-based unified accounting. In 2017, China's total resource input was 160 EJ with the resource self-sufficiency rate of 79%. The national total consumption of non-biological resources reached 137 EJ. China's medium-high economic growth rate was not accompanied by the rapid growth of resource exergy consumption. The slight increase of resource consumption along with improved exergy conversion efficiencies of most social sectors from 2012 to 2017 were revealed. The per capita resource consumption dropped from 112 GJ to 110 GJ. Resource exergy utilization structures and conversion efficiencies of main social sectors had significantly changed. To be specific, the proportion of resource exergy consumption in the tertiary sector was up-regulated from 10% in 2012 to 17% in 2017. The exergy conversion efficiency of the agriculture sector increased by 22%, and the efficiency of the domestic sector rose from 1% to 20%. The accounting results from a biophysical perspective confirm that China's efforts to increase the resource use efficiencies and avoid overdrawing the vital production factors have had a significant effect. Exergy-based unified assessment provides empirical evidences for policymakers to understand the scarcity and degradability of resource exergy in the non-monetary sphere and improve resource utilization structure and efficiency at different scales towards a sustainable economy.

## DAY 3 Session 26

### Circular Economy and Standardization: A State-of-The-Art Review

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**Abstract:**
Our research aims to monitor and capture developments in the area of standardization of the "Circular Economy" (CE) and, specifically, the most applied part of the latter, i.e. the standardization of the companies/bodies whose “work” is part of the CE.
Undoubtedly, the research area of CE has become popular lately, both in the field of scientific research as well as in the social and everyday life of people. This seems perfectly normal, considering that the actions related to CE can contribute to i) dealing with the challenge of climate change, i) the goals of sustainable development, iii) the optimal management of ever-decreasing natural resources, and, at the same time, iv) in the protection of the environment.
Another area of intensive research relates to the quality of products/services, which is ensured through the development of standards and the implementation of Quality Management Systems. The scientific impact of the particular research area has been undeniable for many decades: thousands of relevant publications and international scientific journals can be found.
The most important stage of this research up to now was the literature review. At the time of writing the abstract, we found out that there is no international standard (e.g. of ISO or other standardization

body) on the basis of which a quality system can be developed by the aforementioned companies/organizations. However, several preliminary efforts have been made.
Additionally, in this research, we identify the problems (strategic, regular, operational, etc.) faced by companies/organizations involved in CE and its principles (such as the sustainability of natural resources, the protection of the environment, etc.). This reveals the needs that make it necessary to develop relevant standards.

## Synergistic Emissions Reduction of Energy Transition in Guangdong-Hong Kong-Macao Greater Bay Area over 2020-2050: A CGE-GAINS Integrated Model

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**Abstract:**
The pace of energy transition holds the key for synergistically reducing air pollution and CO2 emissions. The energy development pathway for co-reduction of air pollutants and carbon emission needs to be identified as China reaches a critical point of decarbonization in the next decades. In this study, using a CGE-GAINS integrated coupled health model, we simulated the synergistic reduction effects of CO2 and the four most major air pollutants (SO2, NOX, PM2.5, PM10), subsequent socioeconomic impacts and health benefits in Guangdong-Hong Kong-Macao Greater Bay Area (GBA) over 2020-2050 considering 4 scenarios of policies increasingly strict (BAU: Business-As-Usual scenario, ESS: energy safety scenario, CES: clean energy scenario, FDS: fast decarbonization scenario). The results show that with the transition policy strengthening, the primary energy consumption would achieve peak 5,9 and 12 years earlier and the peak value would 6.9%, 10.3% and 37.9% lower than the BAU scenario. The carbon emissions under the BAU scenario would be 430 Mt, while the policy scenarios would be reduced by 4.0%, 4.2% and 7.0%, respectively. In addition, the additional health spending and premature deaths population would also significantly reduce, accounting 15.4%-54.4% and 23.3%-68.5%. However, the loss of regional GDP is also higher in the stricter policy scenarios, with a 14% additional reduction under FDS compared to the BAU scenario. We suggest that policymakers not expect that higher shares of clean energy or stricter environmental policies would lead to higher synergistic emission reduction benefits, though it would certainly help achieve exciting peak attainment targets.

## Urban Sustainable Development Evaluation and Transformation Research Based on the Super-EBM Model

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**Abstract:**
Based on the theory of social-economic-natural composite ecosystem, we construct an evaluation framework of ecological-economic-social coordinated development of urban sustainable development, apply the two-stage network Super-EBM model and Malmquist index model to measure ecological-economic sustainable development level, economic-social sustainable development level and ecological-economic-social sustainable development level of 285 cities in China from 2002 to 2019, and explore the spatial-temporal evolution characteristics and transformation paths of sustainable development of Chinese cities.
The results show that: (1) China's urban sustainable development level increased from 0.9005 to 1.0855 from 2002 to 2019, with an average level of 0.9642, showing a slowly fluctuating upward trend, with increased inputs, economic development, improved welfare and improved technical efficiency as the main reasons. (2) The unbalanced level of urban economic-social sustainable development leads to regional differences in the average level of urban ecological-economic-social sustainable development in China, with the distribution being highest in the east (0.9978), followed by the northeast (0.9757), followed by the west (0.9508), and lowest in the center (0.9359). (3) According to the ecological-economic-social sustainable development framework, Chinese cities can be classified into four types: ecologically-economically-socially coordinated, economically-socially efficient, ecologically-economically efficient and ecologically-economically-socially dysfunctional, with the number of cities accounting for 16.49%, 2.46%, 61.4% and 19.65% respectively. (4) Ecologically-economically-socially coordinated cities are mostly provincial capitals with clusters in the Yangtze River Delta and Pearl River Delta, economically-socially efficient cities exist sporadically, ecologically-economically efficient cities are distributed contiguously over a large area of China, and ecologically-economically-socially dysfunctional cities are concentrated in Henan, Hubei, Jiangxi, Guangxi and the northeast region. The study concludes that clarifying the functional positioning of cities, transforming economic growth drivers, promoting balanced social welfare, and developing regional development cooperation are feasible paths to achieve sustainable urban development transformation.

## Impacts of Economic Structural Transition on Synergetic Control of CO2 and Air Pollutants in Guangdong Province

Ruxia Huang, Qiumeng Zhong, Sai Liang
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**Abstract:**

Under the pressures of rapid economic development and the control of CO2 and air pollutants, achieving synergistic control of CO2 and pollutants through economic structural transition is urgent for the sustainable development of Guangdong Province. This study assesses the synergy of changes in emissions of SO2, NOx, soot, and CO2 by the elasticity coefficient of emission reduction. Based on environmentally extended input-output model and structural decomposition analysis, we investigate the impact of economic structural transition on synergistic control of CO2 and air pollutants in Guangdong Province. The results show that: (1) From the production perspective, the electricity and heat power production and supply sector and the nonmetal products manufacturing sector are major emitters of all the air pollutants and CO2. From the consumption perspective, the final demand of the construction sector drives lots of air pollutant and CO2 emissions. (2) There is not a good synergy between pollutant reduction and CO2 emission mitigation effected by the changes in production structure and final demand product structure. This indicates the potential for synergetic control of CO2 and air pollutants through optimizing production structure and final demand product structure in the future. Thus, special attention should be paid to the transition of production structure and final demand product structure, to promote the synergetic control of CO2 and air pollutants. This can help achieve high-quality and sustainable development in Guangdong Province.

## Identifying Win-Win Pathways That Reduce Economic Costs and CO2 Emissions for China's Steel Industry

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**Abstract:**
Decarbonizing the steel sector requires substantial changes to the primary production process, either by redesigning the blast furnace—equipping it with carbon capture and storage (CCS) and using renewable energy where possible to replace coal and coke—or by replacing the blast furnace with a different technology such as the hydrogen direct reduction process, an alternative that has gained significant momentum within the industry in recent years. We construct a technology selection model based on nine low-carbon steel-making technologies to explore win-win pathways that reduce economic cost and CO2 emissions for China’s steel industry. The findings are as follows. (1) The sooner the blast furnace technology is replaced with low carbon steel-making technology, the lower the carbon neutrality cost in the steel industry. (2) When CCS technology cannot be applied on a large scale, the Electric arc furnace with scrap (Scraf-EAF)will be the first choice for the decarbonization of the steel industry. EAF with direct reduced iron (DRI-EAF) is the technology adopted in the early years (2022-2027) of steel industry decarbonization. After 2027, the electrolysis technology (ULCOLYSIS) will replace DRI-EAF and be adopted largely. The reason may be that the electricity price is much lower than the natural gas price. (3) With CCS technology available for large-scale application, all steel-making technologies are equipped with CCS units as much as

possible. Scraf-EAF will no longer be the choice for the steel industry's low carbon transition, while blast furnace steel-making technology is still the preferred choice. The low-carbon steel-making technologies are mainly DRI-EAF and ULCOLYSIS. Meanwhile, ULCOLYSIS will be applied on a larger scale and become a pillar technology in the future.

## The Economic Consequences of Carbon Capture, Utilization, and Storage Projects: Evidence from Housing Markets in The United States

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**Abstract:**
Carbon capture, utilization, and storage (CCUS) techniques are vital to reaching decarbonization goals. A total of 38 CCUS projects are completed, in operation, or operation in suspension in the U.S. as of January 2022. Despite the increasing CCUS development, the costs and benefits of developing CCUS projects in local communities are rarely assessed quantitatively.
Our study includes 27 CCUS projects that are not located in remote areas (i.e., have residential communities within 10 miles). Using nationwide spatial data on CCUS and property-level housing transaction records in the U.S., we first calculate the distance from every house to the nearest CCUS and establish a buffer defining what is close in terms of proximity. Then, we quantify hedonic estimates of property value impacts from nearby CCUS projects using DID approach.
The outcomes reveal three intriguing findings. First, in the six-kilometer radius surrounding a CCUS project, property values are positively impacted, but as the distance from the project increases, negative impacts start to emerge. It suggests that in the near vicinity of CCUS projects, positive effects, such as job growth and increased industrial activity, outweigh the adverse environmental effects. However, those living farther than 6 km (but within the buffer) from CCUS projects benefit less from its economic effects. When buying a home, they are likely to be more concerned with the environmental risks posed by CCUS, such as leakages and groundwater contamination. Second, carbon capture projects increase housing prices, while carbon storage projects decrease prices. The underlying reason is that carbon capture causes little environmental damage, but carbon sequestration may aggravate geological formations, resulting in earthquakes. Third, retrofitted facilities do not affect home prices, while newly built facilities produce the same significant results as our main model which uses all CCUS project data.

# DAY 3 Session 27

## Re-Investigating the Oil-Food Price Co-Movement Using Wavelet Analysis

Loretta Mastroeni1, Alessandro Mazzoccoli1, Greta Quaresima2, Pierluigi Vellucci1
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**Abstract**
We exploit the wavelet analysis approach to investigate oil-food price correlation and its determinants in the domains of time and frequency.
Wavelet analysis is able to differentiate high frequency from low frequency movements which correspond, respectively, to short and long run dynamics. We show that the significant local correlation between food and oil is only apparent and this is mainly due both to the activity of commodity index investments and, to a lesser extent, to a growing demand from emerging economies.
Moreover, the activity of commodity index investments gives evidence of the overall financialisation process. In addition, we employ wavelet entropy to assess the predictability of the time series under consideration at different frequencies. We find that some variables share a similar predictability structure with food and oil.
These variables are the ones that move the most along with oil and food. We also introduce a novel measure, the Cross Wavelet Energy Entropy Measure (CWEEM), based on wavelet transformation and information entropy, with the aim of quantifying the intrinsic predictability of food and oil given demand from emerging economies, commodity index investments, financial stress, and global economic activity. The results show that these dynamics are best predicted by global economic activity at all frequencies and by demand from emerging economies and commodity index investments at high frequencies only.

## Promoting Regional Sustainable Development by Optimizing City-Level Pv Deployment Strategy

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**Abstract**
Motivated by the carbon neutrality, the large-scale installation of low-carbon PV will be accelerated in the coming decades. Large-scale PV also interacts with sustainable development goals (SDGs), however, where and how much PV should be installed to promote local SDGs progress need to be thoroughly answered. Here we establish a scientific methodology framework with higher spatial details to identity practical and operational PV deployment path for a set of varied policy goal priorities. Further, we introduce a the bottom-up estimation framework to quantitatively assess and compare the multiple benefits and SDGs progress under different city-level PV deployment pathways. We find different goal-oriented deployment scenarios result in enormous variations in PV distribution. The PV deployment is congregated in the eastern regions and northern regions under

CO2 mitigation- and water-saving-oriented scenarios respectively. While, we observe a convergence across regions in PV capacity installation in the air quality- and the job creation oriented-scenarios. We highlight synergies/tradeoffs among different SDGs. The SDGs witness the biggest progress under the water-saving-oriented scenario which has greatest carbon-air quality-water co-benefits. Besides, if PV is deployed for CO2 mitigation, it brings notable air quality co-benefits. The job creation oriented-scenario creates 2.67 million local jobs at the expense of less avoided CO2, air pollutants emissions by 1.8%, 11.4% and water savings by 35.2%. SDGs in less developed cities gain greater improvement than that of rich cities under all scenarios. This study underscores the necessity of considering the spatial heterogeneity and the underlying synergies/tradeoffs between various SDGs and regions when formulating energy transition strategies.

## Developing A Framework for Monitoring and Assessing Circular Economy Progress in Urban Areas Based on the Urban Metabolism Approach

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**Abstract**
In response to the complex and pressing sustainability challenges of rapid urbanization, cities worldwide are increasingly embracing the circular economy (CE) concept in order to change their urban metabolism from linear to circular. In this context, appropriate tools to monitor this transition and to assess its effects are needed. The aim of this study is to present a new framework for monitoring and assessing CE progress in urban areas and demonstrate its application. The framework is developed based on the urban metabolism (UM) approach and CE principles. More specifically, the system boundaries of the urban area, its sectors and their potential linkages are defined based on the UM concept and the most significant material and energy flows of the urban system are mapped and quantified applying a Material and Energy Flow Analysis (MEFA). Next, indicators for monitoring CE development in an urban area are compiled from the literature, and the most relevant indicators are selected and integrated in an indicator-based framework. As a means to identify a practical and relevant framework design, the development of the framework is done in conjunction with its application to the urban area of Umeå Sweden. Overall, this study aims to contribute to the ongoing discussion of how CE development at the urban level can and should be assessed and monitored by showcasing how the UM approach can provide conceptual and quantitative foundations for developing appropriate monitoring systems.

## Will the Population Agglomeration and Technological Innovation Mitigate the Incremental Carbon Emission Caused by Internal Migration? the Evidence from China

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**Abstract**
China has witnessed an unprecedented urbanization in the past decades. Although the large-scale rural-to-urban migration accelerated China's economic growth, it also caused a rapid increase in carbon emissions. It is estimated that urban areas accounted for over 80% of China's carbon emissions by 2020. Hence, the mitigation of carbon emissions in urban areas is vital to the attainment of the dual decarbonization goals announced by China's government. However, previous studies scarcely examined the causal effect of internal migration on carbon emission at the county level. They also neglected the role of agglomeration and innovation in mitigating the incremental carbon emission caused by internal migration. This study purposes to explore the causal effect of internal migration on carbon emissions at the county level and investigate the mitigation effect of population agglomeration and technological innovation. A fixed-effect panel model is employed, using the predicted shift-share of migrants as the instrumental variable for internal migration. Our results suggest that the estimated coefficient of internal migration is positive and statistically significant, indicating that the internal migration indeed raises local carbon emission significantly. The carbon emission at the county level will increase by 3.02% if the migration proportion rises by 1 percentage point. Through analyzing the impact mechanism, we find that the incremental carbon emission could be mitigated by two channels. On one hand, the internal migration produces the effect of population agglomeration, which will raise the intensity of economic activities, increase the efficiency of energy consumption, and mitigate local carbon emissions. On the other hand, internal migration significantly promotes technological innovation, which will raise local production efficiency and mitigate carbon emissions. Therefore, our study contributes to the literature by identifying the causal effect of internal population migration on regional carbon emission and the mitigation effect of population agglomeration and technological progress.

## The Impact of Green Credit Policies on Corporate Technological Innovation in China's Clean Energy Industry

Zehua Tian, Xuesong Gu
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**Abstract**
The aim of this paper is to examine the impact of green credit policies on the technological innovation of clean energy enterprises. Constructing quasi-natural experiments during two different lengths of period (2008 – 2015 and 2008 – 2020) based on China's 2012 Green Credit Guidelines, this paper selects a group of A-share listed clean energy enterprises and non-clean energy enterprises

as samples. It further conducts mechanism tests as well as heterogeneity analysis on the basis of the results. The results show that green credit policies can promote technological innovation in the clean energy enterprises, and this effect is reinforced with the accumulation of years following policy implementation. The mechanism test indicates that green credit policies affect the level of technological innovation of clean energy enterprises through the channels of credit cost and financing constraints. The heterogeneity analysis demonstrates that the impact of green credit policies on clean energy enterprises' technological innovation is more significant in the non-state-owned enterprises and economically developed regions. This paper reveals the effect of green credit on technological innovation from a micro perspective of individual enterprises, providing insights for the subsequent promotion of green credit policy and the ultimate transformation of China's energy structure. At the same time, it has certain reference significance for developing countries and emerging economies.

## Do We Need New Space to Innovate? Rethinking Resource Demands of 'Smart' Precincts

David Ness, Ke Xing
Organization(s): University of South Australia

**Abstract**
To meet challenges such as climate change and resource depletion, most effort has been spent on increased efficiency of energy, materials and other resources. With outcomes falling short of goals, efficiency alone is not enough to contain global warming to 1.5 degrees. Thus, the IPCC advocates that avoiding demand for resources (sufficiency) should take priority over efficiency and renewables. Taking this as its starting point, the paper seeks to shift the focus from resource efficient and circular construction to examining initial drivers of service demands; to question the needs, examine whether these can be met by non-physical solutions, or discover if adaptation of existing or new facilities may be required. Such an interrogation process during the inception and planning phase may not only result in major cost savings and business benefits, but also realise opportunities for major reduction in resource consumption and carbon.
Following a review of literature concerning early planning and decision-making processes by client organisations, any gaps may be identified, and the research question formulated: 'Can deep enquiry and understanding of the nature of service demands lead to novel and alternative demand-side solutions, resulting in less consumption, carbon and cost?'
To test the proposition, a case study of 'innovation hubs' is conducted. This centres on a proposal for a 16-story building of 40,000 square metres to accommodate digital, high-technology and space-science services. The business case for this proposal will be examined, with comparisons made to similar innovation hubs and 'incubators' involving new, adapted, or minimalist facilities accompanied by remote work. Factors examined may include intensity of occupancy, the value of proximity to other occupants, performance outcomes, resource consumption and carbon footprints.

The findings are expected to have implications for planning of innovation hubs and similar facilities, highlighting the necessity to closely question real needs and examine alternative solutions.

## DAY 3 Session 28

### For the Love of Money and the Planet: Evaluating the Effect of Monetary and Environmental Co-Benefits Framing on the Intentions to Reduce Fruit and Vegetable Waste in Spain

Juliana Prelez, Ganga Shreedhar, Feiyang Wang
Organization(s): LSE, The UK

**Abstract**
Reducing consumer food waste is key to a sustainable food system. Past studies have tried to achieve this goal by highlighting either the monetary benefits or the environmental benefits of saving food for consumers. However, it remains unclear if environmental framing works better than monetary framing, or vice versa. More importantly, no previous research has considered combining the two, so cannot shed light on whether a co-benefit framing would lead to a stronger cumulative effect, or suffer from motivation crowding out.

To fill in this gap, the present study tests the effects of different framings in a randomised controlled trial conducted online (N = 1008, representative Spanish sample). Participants were exposed to one of our four messages (co-benefit vs. environmental vs. monetary vs. control), and then indicated their intentions to reduce household fruit and vegetable waste. Results show that co-benefit framing significantly increases willingness to reduce fruit and vegetable waste, while environmental and monetary framings have no significant effects on their own.

Drawing on the extended theory of planned behaviour (TPB) model, we also measured a set of psychological and behavioural factors relevant to food waste behaviours before our experimental manipulation, such as financial and environmental concerns about wasting food, perceived behavioural control, and food shopping habits. Consistent with TPB, those factors are all positively associated with household food-saving intentions, and sometimes interact with the framing effects. For instance, environmental concerns significantly moderate the effect of co-benefit framing, such that participants who are highly concerned about the environmental impact of wasting food are more strongly influenced by co-benefit framing. Interestingly, the effect of monetary framing is also more pronounced among participants with a higher level of environmental concerns, while the effect of environmental framing does not differ across all levels.

## The Application of Blockchain in Optimizing Urban Food Loss and Waste Management via Internet of Food (IoF): A Case Study of Bakery Supply Chain from Ninghai County of Ningbo

Tong Zou1, Chaoju Wang1, Ali Cheshmezangi1,2, Tongyu Zhou1, Eugenio Mangi1, Ayotunde Dawodu1
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**Abstract**
Most food wastes in developed countries happen on the consumer side, while developing countries lose most of their food during storage and transportation. 32% of all food loss and wastes happen in the primary production stage and 44% of all FLW in the stage of storage and processing, usually caused by delays in the supply chain and buyers' over-order. Moreover, over 98% of nutrients in food by-products and human waste generated in cities are directly being landfilled, incinerated, or discarded without reusing/recycling. To reduce FLW and improve urban food supply chain resilience, this study utilizes blockchains to track and synchronize each stage of the urban food supply chain from production to consumption while reducing information barriers of key stakeholders and consumers. By tracking the digital footprint of food products along the whole food value chain and providing smart contracts, food-related data will be bound with a data block. Contrastly, the whole process of food value-adding will be vitrificated, providing multiple benefits to all the stakeholders. This will help food producers and retailers better understand the dynamics of consumers' demand and aid their strategic decision-making and adaptive management to enhance cost-effectiveness, circularity, and sustainability. Meanwhile, consumers can easily access food-related information by querying each block in the blockchain, initiating direct communication with key stakeholders, and providing feedback. In short, blockchain applications can contribute to improving food quality and safety. At the same time, it reduces food cost and FLW and eventually fosters both food supply chain resilience and sustainability. The Internet of Food is proposed to shorten, localize, and decentralize the current urban food supply chain by improving the traceability, transparency, time efficiency, and time validity of food-related data along the whole supply chain. A case study of the bakery supply chain from Ninghai county of Ningbo city will be employed.

## Nutrient Status, Agricultural Application Effects and Farmers' Awareness of Different Food Waste Disposal Products in China

Xuejuan Fang, Bing Gao
Organization(s): Institute of Urban Environment, Chinese Academy of Sciences, China

**Abstract**

The recycling disposal and resourceful utilization of urban food waste (FW) is of great importance to sustainable and low-carbon urban development. Aerobic composting (AC) and anaerobic digestion (AD) are two main FW treating technologies adopted in China's FW treatment pilot projects. We focus on the solid residues of AC and AD, and discover three FW disposal products (FWDPs) of them. We compare the physicochemical characteristics and nutrient contents of the FWDPs with main traditional organic fertilizers in China; make a field questionnaire to investigate farmers' planting habits and awareness on FWDPs; meanwhile carry out a five seasons field experiment on 30% of the nitrogen (N) in FWDPs substituted for equal chemical N under conventional farmers' practices in a peri-urban vegetable field in subtropical China, to explore the impact of FWDPs on vegetable yields. The results manifest that FWDPs have favorable agronomic performances and huge agricultural potential: the FW aerobic compost (FWAC) and FW digestate residue (FWDR) are effective on crop yield as organic fertilizers, and FW digestate biochar (FWDB) could be used as soil amendment at low application amount to farmland. Besides, FWDB has many other value-added applications like being used as heavy metals/organic compound adsorbent, producing activated biochar. Applying FWDPs as organic fertilizers or soil amendments will reestablish a closed-loop of food resource cycle, and further realize the FW disposal target of reduction, recycling and harmlessness. Measures like formulating supportive regulations, expanding government propaganda, producing qualified and cost-effective commercial organic fertilizers with FWDPs will improve the knowledge and acceptance of farmers on FWDPs. Definitely, further research is required to monitor the specific impacts of different FWDPs on soil organic carbon, nutrient contents and greenhouse gases emissions, and examine their potential fertilization risks (salt accumulation, microplastics, antibiotics and antibiotic resistance genes (ARGs)) with long-term field experiments.

## Estimation of HORECA Food Waste Generation in a Tourism Destination

Zhao Chuan, Kazuyo Matsubae
Organization(s): Tohoku University, Japan

**Abstract:**
Food waste issues relate intimately to ecological and societal sustainability. Missing data on wastage hinders food waste management towards precise decision-making and benign development, particularly in developing economies. Based on field surveys and in situ weighing methods, this study strives to acquire volume data on food waste generated from HORECA (hotel, restaurant, café) in Xiamen—a noted tourist city in China. The results show that, in the year 2018, the magnitude of food waste generated from HORECA was in the range of 1311-1360 t d-1, with the overall waste from the small-scales accounting for up to half of the entire urban catering establishments, whilst medium-scales contributed the most significant proportion of food waste to canteens. Furthermore, disparities between practical data and modeling predictions at the beginning of the COVID-19 epidemic were combined to estimate food waste generated by tourists, which ended up at 126.7 g capita-1 meal-1, indicating that tourists were responsible for approximately 18% of the total HORECA food waste. The level stands close to the results of existing studies and higher than the

amount of food waste generated by local dwellers. The research highlights the economic and environmental challenges that food waste management would encounter regarding infrastructure, collection vehicles, and disposal options due to the increasing food waste. It also provides backup for policy decisions alongside new ideas for relevant data access.

## Influence of the Methodological Approaches Adopted on the Food Waste Generation Ratios

María Baquero, Eva Cifrián, Javier Rufino Viguri, Ana Andrés
Organization(s): Universidad de Cantabria, Spain

**Abstract:**
Food waste (FW) has become one of the critical waste streams in recent years in Europe, so establishing a homogeneous quantification methodology to measure it, is paramount. To contribute to harmonization, the European Commission established a set of guidelines and minimum quality requirements for the uniform measurement of FW generated in the Member States. Although the existence of these methodological guidelines is a great advance, questions as important as the definition of FW, the Food Supply Chain (FSC) stages considered or the measurement methods depending on the availability of resources, remain open. The aim of this study is to analyse different approaches taken in scientific studies and assess their effects over the obtained FW generation ratios. The importance of these approaches in the FW generation ratios has been analysed in this study, based on 93 ratios from the literature developed in different European frameworks. Among the relevant aspects to be considered, along with the FSC stages that are considered, the measurement method stands out as a factor that influences the results: while the direct methods give more accurate values, the indirect methods tend to overestimate the generation. In addition, a decision-support tool is designed, a superstructure that graphically represents the different alternatives to obtain a FW generation ratio, and that allows to quickly know the differences in the approaches in which they have been developed. Moreover, the superstructure eases the comparison among ratios that are available in bibliography, as well as the existing data (ratios) selection process, to make estimations or provide benchmarking based on what is needed or searched for. The superstructure that graphically represents the decisions that ought to be made to obtain each of the 93 FW generation ratios are shown: (i) FW definition, (ii) food categories and (iii) FSC stages considered, and (iv) used measurement method.

## Biotransformation and Life Cycle Assessment of Nutrients in the Food Waste Fermentation for Feed Production by Bacillus Spps.

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Organization(s): 1: Agro-Environmental Protection Institute, Ministry of Agriculture and Rural Affairs, Tianjin; 2: Organic Recycling Institute (Suzhou) of China Agricultural University; 3:

College of Biotechnology and Bioengineering, Zhejiang University of Technology; 4: College of Resources and Environmental Sciences, China Agricultural University

**Abstract:**
A novel valorisation strategy for biological protein feed production from food waste (FW) via fermentation by Bacillus and lactic acid bacteriawas investigated. Three Bacillus strains, B.licheniformis, B.subtilis, and B.ruris were selected and compared for theirabilityof FW fermentation and transformation.With the conversion rate of crude protein as the index, orthogonal experimental design was used to investigate the effects of inoculum amount, ratio of auxiliary materials (soybean meal) and moisture content on the fermentation process. The optimized fermentation conditions were as follows, the moisture content of 60%, the inoculum amount of 2%, and the ratio of FW to soybean meal was 2:1(w:w).The activities of protease, amylase and cellulase during fermentation were investigated and the acid-soluble protein and amino acid content of the fermentation products were also evaluated. In addition, fermentative effects of Bacillus were compared with commercial inoculants (consisting of yeast and lactic acid bacteria),compound lactic acid bacteria can promote the feed of pre-sterilized food waste more than single lactic acid bacteria.Life cycle assessment was used to evaluate the environmental and economic benefits of the biotransformation of FW with Bacillus. In order to have a broad overview of the environmental performance of FW digestion systems, a comprehensive set of environmental impact categories were considered, including human toxicity potential (HTP), global warming potential (GWP), fossil fuels depletion potential (FDP), ozone layer depletion potential (ODP), acidification potential (AP), and eutrophication potential (EP).
Part of the research work is in progress.The results of the study are expected to provide systematic and feasible technical guidance for the recycling of FW.

## DAY 3 Session 29

### Understanding Household Waste Separation Intention: Testing the Roles of Religion, Cultural-Ethnic Differences, and Information Intervention within the Theory of Planned Behavior

Miao, Ling, Qian, Xuepeng
Organization(s): 1: Sophia University, Japan; 2: Sophia University, Japan

**Abstract:**
Due to its unique topographical features and climatic conditions, Tibet has rich mineral resources and a diverse ecosystem. The rapid economic development and population growth have led to a simultaneous increase in the amount and type of household waste in Tibet. Meanwhile, due to low oxygen levels, the cost of waste disposal is high and disposal technology is limited, making the waste problem already a major issue in Tibet.
Previous papers have studied household waste segregation behavioral intentions in many regions, but rarely in the Tibet. And this is also the first time that Buddhism has been added to the extended TPB

and studied its relationship with household waste separation behavioral intentions. This paper aims to (a) identify factors that may influence residents' household waste separation behavioral intentions in Lhasa. (b) expand the model of Theory of Planned Behavior (TPB) with three new components - extended religion (RE), cultural and ethnic differences (CED) and information intervention (II) - in influencing household waste separation behavioral intentions. (c) interpret the modeling findings to promote behavioral intentions in waste separation.
This study involved the administration of a self-completion questionnaire to citizens in Lhasa, Tibet. Data were collected by using random sampling in September and October of 2021. The data was then subjected to factor analysis. The results showed attitudes, subjective norms, religion, and cultural-ethnic differences have a positive influence on behavioral intentions, while perceived behavioral control has a negative influence. The implications of the findings might help local authorities to encourage household waste separation at source, and provide unique data and observation in Tibet.

## Citizens' Waste Separation with A New Category: A Case Study of Plastic Separation at Source in Japan

Jiarong HU1, Xuepeng QIAN2, Weisheng ZHOU1
Organization(s): 1: Ritsumeikan University, Japan; 2: Sophia University, Japan

**Abstract**
The amount of plastic waste emission accounts for a significant proportion of total household solid waste generation. However, limited amount of total plastic wastes generated are disposed properly, causing severe pollution to the environment. In April 2022, Japan implemented the Law for the Promotion of Plastic Resources Recycling. To achieve success in plastic material recycling, residents' participation in plastic separation is a critical factor. The aim of this study is to investigate individuals' plastic waste separation intention and behavior including to identify the factors may influence citizens' behavior. This study extended Ajzen's theory of planned behavior by adding external factors of personal norm, plastic sorting knowledge and government policy. To collect data, a questionnaire survey was designed and conducted in Japan from December 6th to 16th, 2021. After questionnaire collection, the samples were divided into two groups according to whether the respondent's municipality has plastic waste separation regulations (Group A=Yes; Gorup B=No). The findings show that for Group A, the effects of personal norm, subjective norm, perceived behavioral control, plastic sorting knowledge and government policy on intention are significant; for Group B, the effects of personal norm, plastic sorting knowledge and attitude on intention are significant. Regarding the factor influencing behavior, intention and perceived behavioral control are significant for both groups. Overall, personal norm and plastic sorting knowledge are the common factors predicting residents' intention; intention and perceived behavioral control are the common factors influencing residents' final behavior. Overall, the findings imply that activation of individual's sense of self-ethical obligation to perform plastic waste separation and the provision of sufficient information and knowledge about plastic recycling are essential for residents to form

intention to separate plastic waste. Improving individuals' intention and reducing the difficulty in separating plastic waste can further help residents to perform the behavior with higher possibility.

## Decoupling Analysis of Carbon Emissions by Following a Zero Waste Management Approach in Istanbul

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**Abstract**
Zero waste (ZW) to landfill targets have become popular in recent years in many countries including Turkey. Resource decoupling is a key concept for understanding how human activities relate to resource consumption. Waste management (WM) related decoupling studies have largely analysed landfill diversion and few have considered environmental impacts such as carbon emissions. The study aims to understand whether the current policy targets of the ZW to landfill of Turkey's largest city, Istanbul Metropolitan Municipality (IMM) are enough to achieve carbon decoupling (i.e. to understand whether carbon emissions decrease as waste increases) by 2050. This study is introducing a new approach for WM decoupling analysis by using material flow analysis (MFA) and life cycle assessment (LCA). The functional unit (FU) of the study is annual waste production in Istanbul (6.3, 8.1 and 10 million tonnes in 2020, 2035 and 2050 respectively). The future WM strategies are based on IMM targets for 2050 which are landfill diversion of food and packaging waste, increased landfill gas capture, increasing recycling and establishing AD and incineration facilities. The changes for the baseline scenario from 2020 to 2050 is that landfill diversion by mass drop from 13.6% to 11.3%, and carbon emissions increase from 2.06 million ton CO2/FU to 3.68 million ton CO2/FU. The improved scenario conversely leads to an increase in landfill diversion from 13.6% to 83.7% and to a drop in carbon emissions from 2.06 million ton CO2/FU to 977 thousand ton CO2/FU. In addition to the IMM target, a future scenario for the year 2050 with high incineration will result in landfill diversion of 94.8 % and carbon emissions of -1.60 million ton CO2/FU (i.e. a net saving). Contribution results clarify that recycling capacity and energy recovery are key points for decoupling of WM emissions and uncaptured landfill gas is for coupling.

## Optimization Routes for Soundly Managing Building Decoration Waste in Shenzhen City, China

Wenwen Zhou, Yi Zhang, Huabo Duan, Huanyu Wu
Organization(s): Shenzhen University, China, People's Republic of China

**Abstract**

The generation of construction and demolition waste in Shenzhen has been kept large amount by 100 million cubic meters per year in recent years. However, existing studies mainly focuses on the demolition waste. There is relatively little work on building decoration waste. Therefore, this study has made attempts to examine the environmental impact from the overall lifecycle of building decoration waste, from generation to ultimate disposal, by using the Life Cycle Assessment approach. The results show that the average daily generation of building decoration waste in Shenzhen reaches approximately 40,000 tons. These building decoration wastes have been mainly transported to neighboring cities for landfill disposal after manual but simple separation of valuable materials. The flows of building decoration waste have not been well-tracked or managed. The findings of this study are conducive to improving the source reduction and recycling of building waste, which are beneficial for promoting the realization of low-carbon development in the construction sector and helping the construction of a "zero-waste city" in Shenzhen.

## A Systematic Review of Literature towards Photovoltaic Module Waste Management in the Philippines

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**Abstract**
The drastic increase in solar energy dependency would yield in the creation of a tremendous amount of waste worldwide, and there is a need to sustainably manage these emerging wastes to prevent potential environmental impacts and harm to humanity. This paper presents a systematic review of literature to determine the current body of knowledge on photovoltaic (PV) module waste management and identify research opportunities in the Philippines. The researchers have identified four key phrases searched through DOAJ and google scholar databases. The title and abstract of the resulting articles from 2012 to 2022 were screened based on selection criteria and relevance. There are 56 articles from 1,614 resulting articles that were selected in the study. The review presents three main themes: PV module waste assessment, existing and proposed regulatory framework and policies of PV module waste management, and end-of-life management of PV module wastes encompassing monitoring, collection, recycling, and supply chain for recovered secondary materials. Collaboration of all stakeholders, PV module waste assessment, the establishment of an optimized recycling network, utilization of efficient recycling technologies, and practical regulatory frameworks and approaches are vital elements for effective PV waste management. Specific PV module waste strategies and policies in the Philippines are critical to manage these emerging wastes effectively.

## Household Biowaste Management in Latvia: An Assessment within the Infrastructure, Socio-Economic and Environmental Context of Local Municipalities

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**Abstract**
European Union has committed to lead the way towards climate neutrality and resource efficiency. One of the closest targets includes introduction of a separate collection system for household biowaste (primarily - food waste and green waste) by the end of 2023. In practice, to develop such a system, municipalities in cooperation with waste management organizations must develop all the necessary infrastructure for the collection and recycling of biowaste (separate collection containers, transportation equipment, recycling facilities, information system, etc.), inform consumers, exchange data, and organize the whole process. It requires financial, time, and human resources. The establishment of such a system is a challenge for many EU countries, and those countries that started to implement the system earlier have now made significantly more progress. The aim of the study is to assess the implementation progress of the household biowaste management system in Latvia and five other EU countries, and to propose solutions for system's further development towards circular economy. In the study, the success of the Latvian regulatory framework and the measures taken so far for the development of the system towards the target are assessed. A calculation model is created for determining and forecasting the amount of household biowaste generated at Latvian municipality level. Furthermore, the existing and planned biowaste processing capacities in the waste management regions of Latvia are assessed for their compliance with the projected amount of biowaste generated. Considering the infrastructure, socio-economic and environmental context of the local municipalities an alternative solution is proposed for the development of a sustainable biowaste management system in Latvia, which currently has high risk to not be implemented on time.

# DAY 3 Session 30

## Potential Crisis behind the Greening of the China-Mongolia-Russia Economic Corridor

Xueqin Zhang1, Xiang Li1,2
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**Abstract:**
Ecological changes in politically or economically sensitive regions often attract global attention, such as the greening of the China-Mongolia-Russia Economic Corridor (CMREC), with the regional average vegetation coverage increasing at a rate of 0.2%/a since the 2000s. However, many potential

risks and crises are hidden behind superficial environmental improvements. On the one hand, the local vegetation degradation still exists, particularly in the west of Amur Oblast and the surrounding areas of Baikal Lake in Russia from 2000 to 2021. Significant vegetation degradation is often indicative of decreasing vegetation productivity and severe desertification, resulting in regional ecological instability and food shortages. On the other hand, temporary vegetation improvements are not necessarily sustainable and may even be detrimental in the long run. The land use/cover change in CMREC can be summarized as forest degradation into savanna (including woody savanna) and grassland, and grassland reclamation into cropland over the past two decades. Increasing cropland and agricultural technological advances are the most important causes of greening after precipitation. However, human-induced vegetation improvements tend to be unsustainable to some degree and could make the environment here less resistant to climate change. Meanwhile, although the apparent forest restoration in China can attribute to the lasting and effective afforestation, the total forest areas in CMREC still decreased, declining the regional biodiversity and carbon sequestration capacity. Furthermore, predictable warming and complex international political situation are expected to exacerbate the existing ecological problems and threaten ecological safety, especially in the high radiative forcing scenario (SSP 585 in CMIP6 simulations). Hence, the management alternatives that comprehensively consider climate adaptation, wildfire prevention, biodiversity conservation, food security, and carbon sequestration should be initiated to cope with the potential crisis in CMREC.

## Exploring the Potential of Achieving Sustainable Development Goals on Abandoned Farmland

Mengdi Li, Yaoping Cui, Yaochen Qin, Nan Li, Zhifang Shi, Wanlong Li, Sen Zhang
Organization(s): Henan University, China, People's Republic of China

**Abstract**
Agricultural land resources play an important role in achieving sustainable development goals (SDGs). With an increasing demand of population, food and resources, competition for agricultural land resources is intense. Agricultural land area is shrinking due to natural and socio-economic factors globally. Recultivating abandoned farmland might be one of the ways to optimize existing land resources with minimized social or political opposition. However, lacking the inventory of abandoned farmland and its impacts on environment and food security. Our study aims to identify the spatial distribution of abandoned farmland and quantify the contribution of abandoned farmland to the achievement of sustainable development goals. The specific objectives of this study were to 1) analyze trajectories of each cropland pixel by land use data in order to map a long-time series of abandoned farmland and identify the spatial distribution characteristics of abandoned farmland. 2) assess the impacts of long-term abandonment of farmland on carbon neutrality. 3) evaluate the effects of socio-economic and environmental factors on abandonment patterns by random forest model. This study stressed the trade-offs between the environmental impacts of abandoned farmland and its potential to achieve SDGs in the future, and provided scientific support for food security and climate change.

## Factors Contributing to Food Waste in Crop Farms: A Case Study in Levubu Farms South Africa

Lethabo Phasha1, Matodzi Michael Mokoena2, Lutendo Sylvia Mudau3
Organization(s): 1: Tshwane university of Technology, South Africa; 2: Tshwane university of Technology, South Africa; 3: Tshwane University of Technology, South Africa

**Abstract**
Introduction: Despite the challenge of hunger in most parts of South Africa, postharvest food waste is one of the neglected amicable challenges in farms. It is estimated that postharvest food waste contribute to 50% of the total food waste. The most contributing factor is poor farm management which ranges from storage, packaging, transportation, handling techniques, temperature and poor harvesting techniques. A study was conducted in reclaimed Levubu farms to identify factors that contribute to food waste.
Aims/objectives: To identify factors that cause food waste in reclaimed farms of Levubu
Materials ad methods: A total of 14 farms were purposively selected from four reclaimed Communal Property Association in Levubu. Observation was conducted for an average of four days per farm in summer and in spring. A self-developed observation tool focusing on management of harvest, temperature, transportation, hygiene, storage conditions and other factors was used. The findings observed from the field where harvesting took place to the pack house were recorded and captured into excel spreadsheet then analysed using strata package version 17.
Results: An average of 9.8% of the harvested Banana crops were wasted, making it the most wasted crop. Of that, 25.5% was due to animal damage, mostly monkeys, 44% were ripe and- failed to be harvested on time, while 12.5% were too small. A further 18% got spoiled during storage where crops were exposed to unmonitored temperature up to seven days.
Conclusion: The study was able to show beyond reasonable doubt that if temperature is not regulated and management fails to plan for harvesting then food waste will continue to increase. Furthermore, the study recommends training of workers on the factors of food waste as well as auditing and continuous monitoring of food waste to minimize the generation of postharvest food waste.

## Estimation of Household Energy Poverty and Feasibility of Clean Energy Transition: Evidence from Rural Areas in the Eastern Qinghai-Tibet Plateau

Chunyue Bai
Organization(s): Beijing normal university, China, People's Republic of

**Abstract**
Estimating household energy poverty is essential to regional sustainable development. Energy poverty is known as the access unavailability to an adequate and high-quality energy supply.

Regarding the large proportion of clean electricity and low efficiency in biomass utilization in Qinghai Province, this paper estimated the energy poverty line based on the household energy demand, further established two new scenarios to examine the possibility of replacing biomass with electricity and analysed the relationship and linkage of energy poverty in households facing income poverty risks to deepen our understanding of energy poverty. We find that the energy poverty line in Qinghai is defined as an energy share of 18.14%, including transportation, and 17.26%, excluding transportation. In addition, biomass still has a huge advantage in rural Qinghai because of its low cost and availability, which causes serious environmental and health problems. With the implementation of ecological restoration projects, households have gradually turned to commodity energy because of the inadequacy of obtaining biomass. We reveal that policy support is essential to households that are already in energy poverty in the energy transition of new scenarios. Although it is well known that a low-income level is linked to energy poverty, our findings show that a large portion of the population in rural Qinghai is in energy poverty, although they are not facing income poverty risks. While improving income levels to alleviate energy poverty matters, comprehensive energy-related programs can play a substantial role in reducing energy poverty.

## Is Ecological Protection and Restoration of Full-Array Ecosystems Conducive to the Carbon Balance? A Case Study of Hubei Province, China

Ying Wang
Organization(s): China University of Geoscience, China, People's Republic of

**Abstract**
The ecological protection and restoration of full-array ecosystems (EPRFE) is crucial for improving ecological environments in many respects. However, whether EPRFE can contribute to the carbon balance in terms of reducing carbon emissions and increasing carbon sequestration remains unclear. In this study, an indicator system is conducted to assess EPRFE levels, a net carbon emission accounting method is applied to measure carbon balance, and a coupling coordination model is employed to explore the relationship between EPRFE levels and net carbon emissions of cities in Hubei Province from 2013 to 2017. The results showed that Jingzhou and Jingmen achieved high EPRFE levels, whereas Shennongjia and Ezhou exhibited relatively low EPRFE levels. Moreover, the Wuhan Urban Agglomeration achieved higher net carbon emissions than western Hubei. Overall, EPRFE projects had positive effects on reducing net carbon emissions. The coupling degree between EPRFE levels and net carbon emissions was significantly high (0.85); however, the coordination degree was moderate (0.68) and needs further improvement. The results of this study can be an effective reference for improving EPRFE management strategies through adaptive environmental assessment and management to achieve low-carbon development.

## Greenness Changes and Drivers of Browning in Different Vegetation Ecosystems on Qinghai-Tibetan Plateau from 2000 to 2021

Huihui Wang1, Jinyan Zhan1, Chao Wang1, Wei Liu2, Zheng Yang1, Huizi Liu1, Chunyue Bai1
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**Abstract**
Monitoring and understanding natural and human-induced changes in vegetation is essential to help regional ecological restoration. Existing studies have mostly focused on changes in overall vegetation change, with less attention on the drivers of change in different vegetated ecosystem types. We used 22 years of satellite observation records to robustly assess changes in vegetation greenness on the Tibetan Plateau and used machine learning method to detect the drivers of greenness browning in different vegetation ecosystems. The results show an overall trend of greening in all seven vegetation ecosystems on the Qinghai-Tibetan Plateau over a 21-year period. The area of greening was 46.54 km2 and browning was 5.32 km2, representing a quarter and 2.86% of the natural vegetation area respectively. Areas with high altitude, reduced annual precipitation, high intensity of human activity, average annual maximum and average annual minimum precipitation of around 500 mm are most susceptible to browning. For different vegetation ecosystems, DEM and precipitation changes are important drivers of vegetation browning. These results reflect the spatial and temporal dynamics of vegetation and highlight the common and characteristic browning drivers of vegetation ecosystems. They provide support for understanding the response of different vegetation to natural and human impacts and for further implementation of site-specific restoration measures. The study provides support for understanding the response of different vegetation ecosystems to natural and human impacts and further developing site-specific restoration plans.

## DAY 3 Session 31

### Natural Versus Synthetic Dyes: Consumers' Understanding of Apparel Coloration and Their Willingness to Adopt Sustainable Alternatives

Letsiwe Mabuza, Nadine Sonnenberg, Nadene Marx-Pienaar
Organization(s): University of Pretoria, South Africa

**Abstract**
Recent years have brought to the fore the utter devastation that shrouds the textile and apparel value chain. Textile coloration, in particular, the production and use of synthetic dyes, has an immense impact on water bodies, with toxic effluent finding its way into the food chain and fostering severe repercussions for communities residing close to textile dye houses. Developing sustainable alternatives such as natural dyes is therefore critical, but also highly dependent on consumer acceptance and cognisance of the environmental benefits of natural dyes versus those derived from

synthetic origin. Against this backdrop, this study aimed to explore and describe consumers' understanding of environmental repercussions surrounding apparel coloration and their willingness to choose more sustainable alternatives. In adopting a qualitative paradigm, seven focus group discussions (including 6 to 7 participants per session), were used to gather in-depth insight surrounding consumers' perspectives on the topic of investigation within the South African emerging market context. A purposive non-probability sampling technique was used to recruit female participants aged between 20 and 55 years. Female consumers are generally more involved in households' apparel consumption decisions and are said to be more environmentally concerned, socially responsible, and willing to adopt sustainable alternatives compared to men. Discussions were transcribed and coded, identifying common themes and further analysed for differences, similarities and relationships between text segments. The subsequent findings revealed that despite participants' general beliefs surrounding the overarching environmental impact of the global fashion industry, they had limited factual understanding of apparel coloration and the implications surrounding the use of synthetic dyes. These dyes were seen as a lesser source of pollution compared to other textile processing operations. Participants' seemingly low levels of understanding add impetus toward developing relevant sources of information such as eco-labelling to encourage more sustainable apparel choices.

## Study on the Residents' Behavior of Household Waste Classification and Reduction Willingness: A Case Study of Shanghai, China

XinXin LONG1, Ji HAN2,1
Organization(s): 1: East China Normal University, China; 2: Ritsumeikan Asia Pacific University, Japan

**Abstract**
A number of waste management regulations proposed by the government have mild effect due to the lack of public cooperation. After entering the era of mandatory waste classification, household waste classification and reduction have becoming increasingly important for sustainable resource management. In this study, Shanghai was selected as the typical city under the rapid urbanization. The influencing factors of residents' behavior in household waste classification and reduction willingness were investigated by combining household survey and logistic regression model analysis with the comprehensive consideration of socio-psycho-economic factors. The results show that the household waste classification of Shanghai residents is well implemented, and the socio-economic attributes have no significant impact on the classification behavior. The external factors such as facility configuration have the most significant impact, and personal moral sense and subjective norms also play a positive role. When there is no need to pay fees, residents' moral sense promotes their stronger willingness to practice waste reduction policies. However, when residents are asked whether they are willing to pay extra management fees for their excessive waste generation, benefit consciousness becomes an important driver. Subjective norms have a positive constraint effect on both of willingness to pay and participation, while perceived behavioral cost has a significant and

negative effect on both of them. Policy implications for strengthening waste classification management and creating a waste reduction environment include improving classification facilities, strengthening knowledge popularization and moral education, and carrying out system innovation.

## Online Takeaway Ordering is Exacerbating Climate Change

Ya ZHOU, Aiqun GUAN, Tianle WANG, Qiuli LIU
Organization(s): Guangdong University of T echnology, Guangzhou, China.

**Abstract**
The growing demand for animal-based food increases huge pressure on the environment. Understanding how individual diet characteristics may help us in promoting the diet transition more sustainable food system, and online takeaway order provides important answers. By combining text mining techniques, online food ordering from the Chinese largest online food delivery platform Meituan, and takeaway recipe data from thirtheen provinces, this study proposed a data-driven computational framework to investigate the online takeaway food consumption patterns and greenhouse gas emissions of China in 2018. Results indicate that in takeaway food consumption pattern in China, grain constituted the largest proportion of food (55%), followed by animal-based food (31.8%) and vegetables (13.3%). Compared with household food consumption, the proportion of animal-based food consumption increased by 11.7%, while vegetables decreased by 21.1%. Online food consumption produced 1820 ktCO2eq in 2018, of which animal-based food contributed 71.5%. Jiangsu province consumed the largest beef and mutton , and its accounted for 15.1% of the nation'nal online takeaway food-related GHG, . This study provides a novel analytical framework to reveal what online takeaway orders say about individual eating habits and environmental impacts. Our findings provide a scientific basis to understand and optimize individual takeaway eating habits and promote sustainable food consumption under the influence of new consumption patterns.

## Introducing a Novel Concept for an Integrated Demolition Waste Recycling Center

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Organization(s): 1: RWTH Aachen University, Chair of Reuse in Architecture, Aachen, Germany; 2: RWTH Aachen University, Chair of Operations Management, Aachen, Germany; 3: Zukunftsagentur Rheinisches Revier, Jülich, Germany

**Abstract**
Using recycled aggregates has many positive environmental impacts as a result of the conservation of natural resources and minimization of waste. The use of recycled aggregates in downcycling processes is already common in Germany, whereas utilizing them to produce high-value products such as recycled concrete is scarcely applied in practice. Although the technical aspects of recycled

concrete have been extensively addressed in the literature, there is a research gap regarding the reasons behind the lack of industrial applications. Hence, this study aims at filling this knowledge gap via investigating the existing challenges and how they can be overcome.
The reasons behind this lag have been investigated based on a survey and interviews with stakeholders. The results show that, in addition to the regulatory and economic barriers, miscommunication and a high demand of information were identified in all groups. Therefore, establishing a robust network and facilitating knowledge transfer by specifying the demand on information been considered as prerequisites. Therefore, the paper presents a novel concept of a stakeholder network and framework for an integrated construction and demolition waste center. The conceptualization integrates the recyclers and construction product manufacturers in one venue with research, service and educational divisions based on a real case study in the Rhenish Revier region in German. The proposed concept shall not only establish a robust network, but also other advantages regarding logistical optimization and technical optimization. Additionally, the research also proposes other supplementary measures to be adopted for promoting the high-value applications of recycled aggregates.

## The Role of Social Capital in Chinese Pro-Environmental Behavior: Analysis by CGSS2010

YECHENG XIA, KEIKO HIRAO
Organization(s): Sophia University, Japan

**Abstract**
The root cause of environmental pollution in recent years, such as global warming and the garbage problem, are the needs of individuals for affluence and comfortable living and the economic and industrial activities supported by those needs. Hence, individual pro-environmental behavior is essential to solving these problems.
With the above background, pro-environmental behavior is a significant solution to environmental problems. However, in reality, the implementation of pro-environmental behavior is a difficult task. One of the reasons is the thought of "social dilemma" which is pointed out by Putnam. As one of the keys to solving the "social dilemma"， Putnam emphasized the importance of social capital.
This study aims to analyze various issues related to pro-environmental behavior in China by using the CGSS 2010（Chinese General Social Survey）survey data. In particular, the study will analyze the determinants of pro-environmental behavior in China, focusing on the effect of social capital.
This study confirmed the role of social capital in Chinese pro-environmental behavior. The variables of social capital, "social interaction level" and "neighborhood attachment level," were found to impact pro-environmental behavior. It shows that the stronger the "social interaction", the higher the degree of implementation of "purchasing organic vegetables" and "green consumption", and the stronger the "neighborhood attachment", the higher the degree of implementation of "waste sorting", "reduction of private car use", "fuel reduction", "water conservation behavior", and "green

consumption ". This study offers the possibility of how social capital can be used to guide the implementation of pro-environmental behavior in China.

## Recycling: A Sustainable Approach To Managing Clothing Waste

Esther Rotimi, Lester Johnson, Hassan Kalantari Daronkola, Cheree Topple, John Hopkins
Organization(s): Swinburne University of Technology, Australia

**Abstract**
Clothing is a necessary resource. However, with the rise of fast fashion and increased clothing consumption, more waste is being produced than ever before. These post-consumer waste products often end up in landfills resulting in air and water pollution. We consider recycling a sustainable approach to dealing with these waste issues. To do this, we adopt and extend the Theory of Planned Behaviour to understand possible reasons why consumers would participate in recycling. This understanding would allow various fashion stakeholders (industry, government, supply chain, partners, non-for-profit (charity) organisations and consumers) to become knowledgeable on ways to improve their sustainability through recycling. We explore attitude, perceived behavioural control, subjective norms, self-identity, eco-literacy, self-efficacy, and general recycling behaviour as predictors of behavioural intentions and subsequently, recycling behaviour. We collected and analysed survey questionnaire data from 481 Australian consumers then analysed the data using structural equation modelling. Our results confirm that all observed variables predict recycling intentions which further predicts recycling behaviour. The non-direct effects observed also showed significant partial or full mediation. Based on these results, recommendation can be made to fashion brands and retailers to develop marketing strategies that could educate consumers on which clothing can be recycled and how they can engage in recycling behaviours. Also, the study calls for more involvement by government through policy reforms to drive the fashion supply chain into taking more ownership of their consumers' waste. This could also be achieved through providing more convenient methods for consumers to partake in clothing recycling. Non-for-profit organisations could also partner with fashion brands to drive home their marketing campaigns. This partnership could help divert lower-quality garments away from non-for-profit organisations and directly to recycling.

# DAY 3 Session 32

## Waste Management for Livestock Manure

Syed Turab Raza
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**Abstract**

The improper management of livestock manure are becoming a new major issue for both terrestrial and aquatic ecosystems, the ditches and wetland plants have known to be a widely used technology for waste management. However, recycling of these nutrient-rich plants and manure is usually overlooked and less studied. In this study, we tested the vermicomposting technology by reusing ecological (wetland plants) and agricultural (maize residues and manure) and evaluated the soil fertility and plant growth after vermicompost amendments. A soil column experiment with a fully factorial design was conducted to investigate the effects of different vermicompost made by four species of wetland plants [Canna indica (CiV), Cyperus alternifollius (CaV), Acorus calamus (AcV), and Hydrocotyle vulgaris (HvV)] on maize growth across the growing season. Concomitantly, we compared the vermicompost effects with the conventional synthetic fertilizers (NPK) as well as the control treatment without any fertilizer (CK). Our results demonstrated that significant positive effects with wetland plants vermicompost on soil fertility and plant growth. Among the four species, combined Cyperus alternifollius (CaV) Hydrocotyle vulgaris (HvV) wetland plant-vermicompost as an organic fertilizer showed the higher values in plant total nitrogen (TN), soil organic matter (SOM), and shoot biomass in comparison to NPK and CK. This study revealed that vermicomposting with combined effects of wetland plants can be used as organic amendments and offers a novel approach by reusing the ecological wastes to promote the transformation of nutrient-rich organic fertilizers and crop productivity while reducing the environmental risk.

## Compaction, Nesting and Permeability Response of Thermally Recovered Carbon Fibre Structures

Hamza Ahmed Qazi, Krishnan Jayaraman
Organization(s): The University of Auckland, New Zealand

**Abstract**
Carbon fibre reinforced polymer (CFRP) products designed with minimal end-of-life (EOL) considerations have now started reaching their EOL, resulting in an increase in the CFRP waste. While recycling the valuable material makes sense, recovering carbon fibre is a sophisticated process, especially for the thermoset CFRP composites, due to the irreversible cure reactions of thermoset polymers. The problems of increasing CFRP waste and the importance of integrating a circular economy into the CFRP market have been recognised by researchers, recyclers, consumers and analysts. Thermal recycling of CFRP waste with fibre structure preservation has emerged as a technologically mature process to recirculate carbon fibre into the supply chain, with retained mechanical properties. The recovered fibre structure after thermal recycling has the fibre orientation, alignment, and length, well preserved and intact, ready for remanufacturing. In almost all the CFRP composites, the reinforcement structure is compressed at some stage of the manufacturing process, increasing fibre volume fraction and enhancing the composite's mechanical properties. However, compaction changes fibre architecture affecting its permeability, thus influencing resin flow. During thermal recycling, the sizing and stitching are burnt off along with some fibre degradation, thus, changing the way fibres interact with each other in the recovered structure, when compared to the

virgin fibre structure. In the current study, various experiments and analyses are conducted to understand and quantify the compaction, nesting and permeability variations between virgin and recovered fibre structures for different fabric types and stacking sequences. The study provides insights into the recovered fabric structure's behaviour during remanufacturing and assists in selecting the most suitable remanufacturing process parameters for enhanced mechanical properties of the composite part

## Activation of Bentonite by Sodium Carbonate Solution

Neshat Moradi, Riitta Keiski
Organization(s): Chemical and Environmental Research Unit, Faculty of Technology, University of Oulu

**Abstract**
Activation of bentonite by sodium carbonate solution is an important step on an industrial scale for the removal of cationic dyes from wastewaters. The role of extrusion in the activation of bentonite has not been investigated previously. Shear stresses seem to be a major factor in the transfer of sodium ions to the clay layers.

## Recycling of Discarded Mattresses through Extended Producer Responsibility: Is It More Cost-Effective Than Incineration?

Raymond Gradus, Bram Faber
Organization(s): Vrije Universiteit Amsterdam, Netherlands, The

**Abstract**
Driven by the circular economy, the government in the Netherlands stimulates mattress recycling by citizens. At the moment about half of Dutch discarded mattresses are recycled, and the other half is incinerated. Based on a recently negotiated extended producer responsibility, the recycling rate should increase to 75% in 2028. This study investigates the potential cost-effectiveness of mattress recycling through the reuse of materials, compared to the incineration of mattresses in energy-to-waste plants. The benefits of recycling include the avoidance of CO2 that would otherwise be released by incineration and the displacement of virgin material that would otherwise be used by producers as raw material. However, there are also significant costs associated with the collection and treatment of recycling of complex products such as mattresses. The study shows that the cost-effectiveness of Dutch mattress recycling is moderate. Taking all factors into account, the costs of saving of one ton of CO2 through mattress recycling are 138 Euros. This is higher than other CO2 saving alternatives such as wind energy, current ETS prices or carbon capture and storage. A sensitivity analysis is also done.

## Reverse Supply Chain for End- of- Life Vehicles Treatment: A Systematic Literature Review

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**Abstract**
Reverse supply chain (RSC) has long been acknowledged as an integral part of the holistic waste handling process. An RSC promotes flows of either obsolete or unusable products moving from end customers to initial suppliers, while incorporating necessary product treatment operations. Upon evident economic, environmental and social benefits, RSC has been broadly adopted to industries. Automotive is not an exception due to multiple components and materials found in end- of- life vehicles (ELVs) having potential recycling availability. Numerous published papers discussed aspects of RSC applied to ELVs separately. The authors therefore conducted a comprehensive literature review by utilizing extensive search strings, a combination of key words and Boolean connectors, namely, ("Logistics" OR "Chain") AND "Reverse" AND ("Vehicle" OR "Automo*" OR "Motor*"), to retrieve materials from SCOPUS and Web of Science, two largest world- wide used databases. A total of 151 peer-reviewed papers was finally included for review. This work develops a tailor-made methodology of data collection and analysis from PRISMA guidelines and process model prescribed by Marying (2001). The method involves four phases: Material collection, Descriptive analysis of Literature, Category selection, and Material evaluation. The papers are then classified by their methodology, which would overarch other groups including major research theme, types of RSCs and ELVs addressed, stages in RSCs focused on, country or region specific considered as the research context, and stakeholders' perspectives used for analysis. Future research directions are ultimately suggested based on research gap identification. The review may benefit academicians, researchers and industry practitioners in better understanding of how RSC is adopted to tackle ELVs in automotive industry and guidance for future research.

## Sustainable Recycling of Complex Waste Glass from the Vehicle Industry in Preparing Porous Glass Foams

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**Abstract**

Globally, about 7% of solid waste is waste glass (WG) which is destined to be landfilled, causing environmental problems. The complex WG coming from the automotive vehicle industry is one of the main parts of this landfilled waste. Thus, using these complex WG as a raw material in the construction industry reduces the need for landfilling and enhances sustainability in manufacturing industries. This research aims to develop a sustainable and eco-friendly method to prepare lightweight glass foams using the recycled WG from the window/windshield of vehicles. The ground WG powder from broken parts of windows/windshields is used as the primary precursor along with an additional precursor (fly ash) for developing glass foam. Following alkali-activation, a combined mechanical and chemical foaming method is applied to develop the foam suspension of the precursor mix. Stabilization of the foam is done by hardening it at 60℃ for 24 hours, and finally, sintering for one hour at 700-800℃ is applied. The developed glass foams achieved an excellent strength-to-density ratio due to the formation of uniformly distributed pores and stabilized structures after hardening and sintering. Quick activation of the precursors and combined foaming technique efficiently achieve the desirable pore characteristics in glass foam for insulating applications. Also, this method is more energy-efficient and sustainable than the other conventional methods, which require higher sintering temperatures (>1000℃) and lengthy processing time. This technique is industrially convenient for producing lightweight glass foams (density 300-400kg/m3) on large scale with desirable thermal conductivity (<0.1 W/m.K) and compressive strength (~2MPa). Therefore, the WG of automotive vehicles can be used as the primary raw material, and high-performance glass foams can be prepared using this industrially feasible, eco-friendly, and sustainable processing technique.

## DAY 3 Session 33

### Food Waste Upcycling via Livestock: Species-Specific Feeding Strategies to Upcycle Different Types of Food Waste

Zhengxia Dou
Organization(s): University of Pennsylvania, United States of America

**Abstract**
Huge amounts of food waste are generated at all stages of the food supply chain. As “misplaced” resources, wasted food embodies physical as well as biological resources. Recovering wasted food, coupled with proper treatment, can enable its safe use as valuable components of animal feeds. This would provide a viable solution to address multiple sustainability objectives: more sustainable production of meat, milk, and eggs to meet growing human demand; enhanced efficient use of resources such as land, water, fertilizer; and mitigation of food’s carbon and nutrients footprints. Many factors interactively affect the efficacy as well as legitimacy of the practice, including mainly the nature of food waste materials, the species of farm animals, and relevant regulations. Species-specific feeding strategies provide an innovative means to effectively and integratively address relevant issues. Fundamentally, food waste is not created equal. It can be plant- or animal-based

substrates, single- or multiple-source mixed materials, pre- or post-consumer culls or discards. Inherently, farm animals differ in their capacity in digesting different food waste biomass and extracting the embodied nutrients. Ruminants are adept at breaking down fibrous biomass such as fruit and vegetable discards and crop residues, whereas monogastric species require energy-dense non-fiber feedstuffs to meet their needs. Therefore, plant-based pre-consumer food discards can be recovered and re-purposed for ruminant feeding, while post-consumer food waste, typically mixture of plant- and animal-source materials, can be made into safe and nutritious feeds via appropriate treatments for pigs where legally permitted. Further, biological-based mechanisms such as insects or enzyme or fungal treatment of food waste can produce secondary products to be used as feeds for aquatic or other species. In essence, species-specific feeding strategies combined with appropriately matching food waste types can provide a workable pathway for upcycling food waste toward a more sustainable future.

## Culled Fruit Waste Fed to Dairy Cows: Production Response, Economic Implication, and Practical Insights

Linda Baker, Joe Bender, Dipti Pitta, Zhengxia Dou
Organization(s): University of Pennsylvania, United States of America

**Abstract**
Large amounts of fruit waste are generated at all stages of the supply chain. Opportunities for re-use and upcycling of wasted fruit depend on where it is generated as well as the biological and nutritional traits. Here, we report the results of a dairy cow feeding experiment that incorporated culled citrus fruit from a processing-repacking center. The 160 cows are divided into 4 lactation groups based on days after calving/days in milk (DIM) and the level of milk production. After calving, cows enter an early lactation group (fresh cow group); as lactation progresses, cows move either to a first lactation group (heifer group) or to a multiparous group (high group); when milk production declines, cows transfer to a lower production group (low group). Cows in each group were randomly assigned to and fed with control vs. fruit-treatment diets for three weeks. The control diets were total mixed rations (TMR) formulated to meet the animals' requirements, with corn silage, grass hay, ground corn, and a protein blend being the main ingredients. Fruit-treatment diets included approximately 7 kg culled citrus (fresh weight) /cow/day, proportionally reducing conventional feed ingredients. Cows adapted to the treatment diets within a couple of days. Compared to control, milk yields were greater for cows fed fruit-treatment diets: 45.9 (vs. 43.2 for the control) kg/cow/day for the fresh cow group, 43.2 (vs. 40.5) for high, 33.2 (vs. 31.8) for heifer, and 28.2 (vs. 25.0) for the low group, respectively. Milk fat and protein concentrations tended to be lower in the treatment groups than controls, however milk fat and protein yields were higher in the fruit fed cows vs. controls. The reduction of conventional feedstuffs plus higher milk yield in the fruit-treatment diets translates to economic incentives to farmers, meanwhile bringing about resource conservation and carbon footprint mitigation benefits.

## Comparative Environmental Benefits of Using Upcycled Supermarket Food Waste in Commercial Swine Feeding Programs in Major Pork Production Regions of the United States

Gerald Shurson, Rylie Pelton, Zhaohui Yang, Pedro Urriola, Jennifer Schmitt
Organization(s): University of Minnesota, United States of America

**Abstract**
Environmental impacts of 5 current and emerging feeding programs for growing-finishing pigs were assessed using an attributional LCA approach and a highly specialized, spatially explicit Food System Supply-Chain Sustainability (FoodS3) model to determine greenhouse gas (GHG) emissions, land use, and water consumption of each alternative in 3 major pork production geographic regions (Midwest, Mid-Atlantic, Southwest) in the United States. The 5 iso-nutritious, 4-phase feeding programs evaluated consisted of 1) standard corn-soybean meal (CSBM) diets with 0.15% L-lysine HCl and no feed additives or co-products, 2) CSBM diets containing 15% corn distillers dried grains with solubles (DDGS), 3) CSBM diets with phytase enzyme (PHY) added to provide 500 FTU/kg of diet, 4) low crude protein CSBM diets supplemented with synthetic amino acids (SAA), and 5) CSBM diets containing 8.6% thermally processed supermarket food waste (FW). The NRC (2012) model was used to estimate C, N, and P intake, retention, and excretion based on diet composition. The FW feeding program resulted in the lowest overall GHG emissions, land use, and water consumption compared with all other feeding programs. Feeding PHY had the greatest effect on reducing P excretion, and the FW, DDGS, and SAA feeding programs reduced N and P intake and excretion compared with feeding CSBM diets. The Midwest region had substantially fewer contributions to GHG emissions from both feed and manure, regardless of feeding program, compared to other regions. In conclusion, addition of only 8.6% FW to growing-finishing pig diets dramatically reduces GHG emissions, land use, and water consumption of U.S. pork production systems compared with current feeding programs.

## Potential of Fresh Vegetable Waste As Animal Feed: Research from China’S Traditional Wet Market

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**Abstract**
In order to improve the utilization rate of food waste and alleviate the serious pressure of feed shortage, this study assessed the feasibility and potential of fresh vegetable waste (FVW) as animal

feed. Considering the Hangzhou wet market in China as the research area, the FVW quality was investigated from July 2021 to January 2022 and the FVW output in China's wet market in 2030 was estimated using the grey model. The results showed that the nutritive value of FVW in the farmers' market was good, with the average crude fat, crude protein (CP), crude fiber (CF), acid detergent fiber, neutral detergent fiber, calcium, and phosphorous contents reaching 5.4%, 13.5%, 32.5%, 34.6%, 65.6%, 1.1%, and 0.4% of dry matter (DM) respectively. These nutritional parameters were comparable to those of good quality forages commonly used in animal feed. Therefore, the FVW was suitable for use as animal feed from the nutritional viewpoint. However, pathogenic bacteria, such as Bacillus cereus, Escherichia coli 0157, Listeria monocytogenes, Salmonella, and Shigella, were detected from China's perishable garbage cans in the range of 18.8–95.8%, while the average detection rate of total bacterial count and total mold count reached 7 log10 CFU/g FVW. These high microbial detection rates were not favorable to the safety of applying FVW as feed. Thus, FVW must undergo stringent product disinfection processes and quality checks to manage raw material quality prior to its utilization as feed. Further, the output of FVW in China's wet market was predicted to reach 4751 kt by 2030. And the CP and CF contents in these FVW was equivalent to 19419 kt corn and 12230 kt alfalfa forage, highlighting the potential of FVW as animal feed. These results have significance for developing new animal feed raw materials and establishing a flexible and sustainable food supply system.

## Challenges of Upcycling Food Waste Into Animal Feeds in the United States

Gerald Shurson
Organization(s): University of Minnesota, United States of America

**Abstract**
Enormous quantities of plant- and animal-based food waste are generated at each stage of the food supply chain, and nearly all of it could be effectively upcycled into animal feed to recover valuable energy and nutrients while dramatically reducing diet cost and the environmental footprint of meat, milk, and egg production. Unfortunately, the many environmental, social, and economic benefits of upcycling various types of food loss and waste into animal feeds have not been realized due to several real and perceived challenges. Efficient physical collection, handling, and processing is essential for preserving nutritional quality and biosafety along with integrating into existing feed and animal industry infrastructure. High moisture content and variability in nutritional composition, while avoiding physical, chemical, and biological contaminants can be significant barriers that can be managed for successful use of various sources of food waste. Biosafety concerns including potential risk of contamination of bacterial and viral pathogens, prions, and parasites have been the main factor influencing several Federal and variable state regulations for using animal-derived by-products in animal feed, including the U.S. Swine Health Protection Act (SHPA), Food and Drug Administration Ruminant Feed Ban Rule, and the Food Safety Modernization Act. Although heating animal-derived food waste at 100°C for 30 minutes, which is required by SHPA, is effective in completely inactivating all disease-causing bacteria, viruses, and parasites (except for prions

associated with transmissible spongiform encephalopathies), there continues to be reluctance for using animal-derived sources in swine feeds. The limited number and scope of approved AAFCO food waste definitions also prevent using certain types of food waste in animal feeds. Re-evaluation of biosafety risks of using all types on food waste sources in animal feeds is needed.

## Fungal-Based Fermentation to Enhance The Nutritional Feeding Values of Crop/Processing Residues for Sustainable Livestock Production

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Organization(s): 1: Bioproducts and Biosystems Engineering, University of Minnesota, United States of America; 2: Animal Science, University of Minnesota, United States of America; 3: School of Veterinary Medicine, University of Pennsylvania, United States of America

**Abstract**
Animal-source food (meat, milk and eggs) contributes to around 25% of human protein intake. Demands for such food items are projected to increase by 60, 57 and 48% by 2050, respectively. Feeds constitute the major cost in animal production, accounting for 60-70% of total cost in pork production for example. Production, processing and transportation of crops for animal feed can contribute to half of the greenhouse gas emissions from animal production. Given the socioeconomic as well as sustainability challenges, upcycling existing “low-value” agro-industry by-products and crop residues and exploring new sources for feeding materials could reduce animal production carbon footprint, reduce feed and animal production cost, and alleviate food-feed competition, therefore contributing to more sustainable production of animal-source food. Using selected fungal strains to process (bioprocess) potential feedstocks of traditionally low-value materials could improve protein quality and amino acids profile, increase bioavailability of fiber, nitrogen, phosphorous, and minerals, reduce anti-nutritional factors, mycotoxins, etc, which could permanently change the composition of the feedstocks for better feeding ingredients to monogastric and ruminant animals. In our study, feedstocks investigated include corn-ethanol co-products (e.g. distiller’s grains and solubles or DGS, whole stillage), oil cakes from canola, cotton seed, pennycress, camelina, crop residues (e.g. wheat straw, corn stover) and spent mushroom substrate. Through process optimization and different bioprocessing strategies such as sequential fermentation and co-culture fermentation, the protein content can be improved up to 30% in DGS, phytate reduced by 50-75% in DGS/ag-residue mixture, lignin degraded by up to 50% in wheat straw, and in vitro digestibility of dry matter and amino acids increased up to 38% and 36% in DGS/ag-residue mixture. Fungal bioprocessing could promote a more sustainable animal production in a low-carbon economy.

# DAY 3 Session 34

## Multi-Period Optimization Model for Enhanced Weathering Using Non-Hazardous Industrial Wastes

Yanmei Zhang1, Zhiwei Li2, Kathleen Aviso3, Raymond Tan3, Fang Wang1, Xiaoping Jia1
Organization(s): 1: Qingdao University of Science and Technology, China, People's Republic of; 2: Hefei University of Technology, China; 3: De La Salle University, Philippines

**Abstract**
Negative emission technologies (NETs) can contribute to mitigating climate change. Enhanced weathering (EW) is an NET with considerable carbon sequestration potential and is based on accelerated chemical reactions between alkaline minerals and water and carbon dioxide to generate bicarbonates that flow into the ocean with runoff to achieve long-term carbon sequestration. EW facilitates the carbon cycle of the Earth and removes greenhouse gases. Moreover, it improves agricultural soil quality and eases ocean acidification. Here, we selected non-hazardous industrial wastes (NHIWs) as the alkaline mineral of EW. Since crushing, transporting, and spreading NHIWs will produce additional carbon emissions and energy input, the net carbon sequestration effect and cost-effectiveness of EW should be considered. We developed a multi-period mixed integer nonlinear programming (MINLP) model to optimize NHIW flow between sources and sinks over the planning horizon, while considering the annual carbon sequestration target for orientation. Our results show that removing 1% and 1.5% of annual carbon emissions of Shandong province requires unit net carbon sequestration costs of $273 and $378 /t CO2, respectively. It is estimated that from 2020–30, the maximum carbon sequestration of NHIWs produced by Shandong province will be 305.78 Mt CO2. Further, we discuss sub-period planning and industrial restructuring impact on cost. The developed model can also be applied to other regions and countries as guidance for EW deployment.

## How Much Carbon Storage Will the Ecological Space Leave the Rapid Urbanization Area? Scenario Analysis from Beijing-Tianjin-Hebei Urban Agglomeration

Wenhao WU, Linyu XU
Organization(s): Beijing Normal University, China, People's Republic of

**Abstract**
Ecological carbon storage is of vital importance to carbon neutral by capturing and storing carbon from atmosphere. As one of global top agglomerations, Beijing-Tianjin-Hebei Urban Agglomeration facing with continuous carbon storage loss, it is necessary to balance the socioeconomic development and ecological space maintenance to alleviate gradually shrinking trend of carbon storage in the rapid urbanization process. In this study, ecological spatial quality was evaluated, with 25915.60km2 land recognized as ecological restricted areas. Coupling with socioeconomic factors, future spatial growth patterns under different ecological priority scenarios were simulated. The least ecological space loss predicted from 2030 to 2060 is 2899km2, of which scenario the ecological carbon storage decline from 2093.26Tg to 2059.60Tg. From the city level, Tangshan predicted to

suffer the highest carbon storage shrink rate of 6.52% while Baoding prone to loss the most carbon storage of 9.78Tg. Furthermore, regional dominant carbon storage maintenance implications were raised.

## A Low Carbon Future for Brazilian Steel and Cement: A Joint Assessment under the Circular Economy Perspective

Jhonathan Fernandes Torres de Souza, Sérgio Almeida Pacca=
Organization(s): University of Sao Paulo, Brazil

**Abstract**
Steel and cement industries are essential for developing economies and challenge global climate change mitigation. This work proposes a joint model for these industries in light of circular economy (CE) and industrial symbiosis (IS). CE and IS potentials regarding steel and cement emission reductions have been recently explored in the literature, but studies that forecast low carbon (LC) scenarios focusing on such concepts are scarce. Using a set of methods as econometrics, marginal abatement cost (MAC), and Monte Carlo uncertainty analysis; we built a LC scenario based on five CE strategies until 2050 for the Brazilian case. Findings point to charcoal-based steelmaking as the highest abatement CE measure, while the penetration of steel recycling route is limited. Through the sensibility analysis on IS, represented by the supplementary cementitious materials strategy, we investigated how the interactions between steel, cement, and power sectors affect CO2 emission reduction potential and costs. Even reducing total suitable slag applied to cement, the charcoal route expands total emission reductions. In parallel, the more fly ash is available, the lower is the average MAC, but it is not gainful for overall abatement given emissions from coal-fired power plants. CE and IS can avoid 2.75GtCO2e (52% of projected BAU emissions) until 2050 at US$ 10/tCO2e by only intensifying already applied processes in Brazil. CE and IS approaches extend the opportunities for economic savings and carbon reductions; therefore, they must be part of future LC options portfolios.

## Multi-Objective Synthesis of Carbon Capture, Utilization and Sequestration System Considering Inherent Safety and Economic Criteria

Fei Wang1, Zhiwei Li2, Xiaoping Jia1, Fang Wang1
Organization(s): 1: Qingdao University of Science and Technology, China, People's Republic of; 2: Hefei University of Technology, China

**Abstract**
Carbon capture, utilization and sequestration (CCUS) is one of various strategies of carbon management networks that captures carbon dioxide emissions from point sources and either reuses or stores it. It is also an important system for regional practice of low-carbon development. The

experiences from the process synthesis indicate that solutions can be obtained that have improved in both, often conflicting, criteria. This work presents multi-objective approach for the superstructural synthesis of CCUS system using mixed integer nonlinear programming method.
A superstructural model for carbon management network of regional CCUS system was proposed. According to carbon metabolism analysis, region-wide source-sink models are developed. Various emissions point sources are considered. Alternative capture methods (pre-combustion capture, post-combustion capture and oxy-combustion) and transportation using pipelines are included in the model. Utilization sinks (greenhouse, urea production, methanol production, and enhanced oil recovery) are also considered.
The economic objective is to minimize the total annual risk to the carbon management network, the inherent safety criteria are quantified based on safety risk consequence. To achieve trade-offs between different criteria, the economic and inherent safety criteria are identified for the multi-objective optimization to generate sets of Pareto optimal solutions. The case in Dongying of China is used to illustrate the optimal synthesis of CCUS systems.

## Integration of Saline Brine and Steelmaking Slag Utilization with CO2 Sequestration via Sodium Bicarbonate Production as A CCUS Process

Catarina Esposito Mendes1, Leonardo Gadelha Tumajan Costa de Melo1, Asif Ali1, Jinsheng Wang2, Rafael M. Santos1
Organization(s): 1: University Of Guelph, Canada; 2: Natural Resources Canada, Canada

**Abstract**
Carbon capture, utilization, and storage (CCUS) is an important technology to mitigate the accumulation of atmospheric greenhouse gases. To contribute towards this, steelmaking is an industry in need of novel approaches for hard-to-abate CO2 emissions. Additionally, geological carbon sequestration has proven difficult in locations close to major steel plants in Eastern Canada due to lack of deep and large saline aquifers. To utilize smaller or shallower saline aquifers for CO2 storage, removing part of the saline water to create space is required, producing a stream of brine in need of utilization. In the present work, we investigated the utilization of saline brine and CO2(g) in an accelerated carbonation process to produce precipitated sodium bicarbonate (NaHCO3(s)). We investigated two recently proposed approaches for NaHCO3(s) synthesis, utilizing Ca(OH)2 and KOH as buffering additives, as well as a modified version of the Solvay reaction (using (NH4)HCO3(aq) in place of NH3(g)), and worked with brines of two levels of salinity (typical of desalination and saline aquifer brines). Laboratory experimentation and geochemical modeling were used to assess the efficacy of each approach, under milder and intensified carbonation conditions (ambient/cooled temperatures and ambient/high pressures). Advanced characterization (XRD, SEM) was used to assess the composition and quality of the precipitates. It was verified that the Ca(OH)2 and KOH approaches do not produce high-purity NaHCO3(s), as they suffer from severe co-coprecipitation (calcite, sylvine, etc.). The modified Solvay process, at cooled and high pressure conditions, produced the highest quality NaHCO3(s), with Na2CO3(s) being the main co-product.

An identified opportunity for additive regeneration is the use of steel slag for recovery of NH4+ from the spent brine. The proposed integrative process thus has the potential to reduce CO2 emissions from steel plants, while stabilizing solid and aqueous wastes, and generating valuable products.

## Current Status and Potential Assessment of China's Ocean Carbon Sinks

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**Abstract**
The role of ocean carbon sinks within global climate change mitigation and carbon neutrality is still affected by research lacking. Aiming at overcoming present limitations, a comprehensive and holitic framework and accounting method of ocean carbon sink evaluation are proposed in this study, which consider both carbon sink types and their characteristic carbon storage cycle timescales. Results show that (1) China's total ocean carbon sink is 69.83-106.46 Tg C/yr, among which the mariculture, coastal wetlands and offshore carbon sinks are 2.27-4.06 Tg C/yr, 2.86-5.85 Tg C/yr, and 64.70-96.55 Tg C/yr, respectively; (2) ocean-based solutions such as coastal protection and restoration, mariculture development, ocean alkalization, ocean fertilization, marine bioenergy with carbon capture and storage have substantial mitigation potential, but further investigation are required before large-scale deployment; (3) although China's ocean carbon sinks only counterbalanced 3.27%-4.99% of its fossil fuel emissions, their tremendous enhancing potential and specific advantages can't be ignored, and enhancing measures must be taken according to regional characteristics; (4) some uncertainties and limitations still exist, and problems such as double counting, carbon sinks offset, etc., need to be further considered. In a word, this study provides a basis for the development of ocean-based solutions on closing climate mitigation gaps.

## Urban carbon footprint accounting and tracking based on consumption perspective

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**Abstract**
In China, most energy consumptions are concentrated in cities, reflected in carbon emissions through the supply chain. In this study, we calculated consumption-based CO2 emissions of 10 megacities

cities in China using the environment extended multi-regional input-output model. The differences between production-based and consumption-based accounting methods are compared, and the source regions and industries are traced. Except For Chongqing, the carbon emission based on consumption is greater than that based on production in other cities, meanwhile, the city's consumption-based emissions are mainly from the other three industrial sectors: manufacturing, construction and services. From the perspective of carbon emission flow, the top five transfer regions of urban consumption carbon emission are Hebei, Shandong, Jiangsu, Inner Mongolia and Henan, accounting for 35% of the total urban consumption carbon emission. In addition, the United States, Japan and South Korea are the major countries and regions where cities import carbon emissions. The results of this study provide a new perspective for cities to formulate carbon neutralization paths, and provide policy suggestions and management implications for cities to clarify their own carbon emission status and respond to carbon neutralization strategies.

## DAY 3 Session 35

### An Examination of the Relationships between European Circularity, Innovation, and International Trade

Deborah Elizabeth de Lange
Organization(s): Toronto Metropolitan University, Canada

**Abstract**
This research elaborates on recent work by de Lange et. al (2022) proposing that extending the circular economy to international trade could increase international trade while addressing environmental and social concerns, in compliance with the principles of sustainable development. “Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs” (Brundtland, 1987). Also, Murray et al. (2017, p. 369) define a circular economy as: “an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being”. This research will quantitatively and qualitatively explore the relationships between circularity and international trade of waste and scrap, examining chemical, metals, and plastic waste trade, within the European Union (EU) context. EU countries track their circular material use rates, termed “circularity”, whether policy- or industry-driven. Correlational and causal relationships are considered, for example, considering whether greater circularity within a country leads to more export trade in waste and scrap. Possibly, where there is a growing national motivation for circularity, then the related goods are exported. Alternatively, the logic could be reversed, where increasing external demand for goods from a circular system (e.g., recycled goods) could motivate industries to produce those tradeable goods. Thus, the national circularity rate increases driven by international market opportunities. Overall, the question addressed is whether circularity drives more international trade or whether international trade opportunities drive the circularity. Some interacting factors, such as research and development

investments (R&D), are also considered. For example, circularity could be enhanced by innovative solutions supported by investment into R&D, thereby, leading to higher rates of trade in waste and scrap.

## Research on the Evolution and Endogenous Mechanism of Cobalt International Trade Network from the Perspective of Industrial Chain

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**Abstract**
With the continuous growth of consumer electronics and the vigorous development of the new energy vehicle industry, the global demand for cobalt resources has increased dramatically. Due to the differences in resource endowments and production levels of countries around the world, international cobalt trade has been formed. Economic globalization has accelerated the complexity of cobalt trade in relevant economies and the formation of a network structure of mutual influence and interdependence. This article takes 168 countries (regions) in the world from 2012 to 2020 as the research object. From the perspective of the industrial chain, combined with material flow analysis and complex network, the cobalt trade networks of upstream, midstream and downstream are constructed respectively. Then it analyzes the overall scale of networks and the evolution trend of the trade structure from the macroscopic and mesoscopic perspectives. On this basis, the temporal exponential random graph model (TERGM) is used to analyze the endogenous mechanism of the formation and evolution of the cobalt trade network at each phase from the microscopic level. At the same time, considering the possible interactions between the phases in the cobalt industry chain, this article respectively analyzes the interaction mechanism among single phases (one to one) and superposed interaction mechanism of phases (two to one). The results show that the formation and evolution of the trade network at each phase of the industrial chain show structure dependent characteristics, which are significantly affected by the network's endogenous driving mechanism. Among them, the convergence is the most significant in the structure dependence in the upstream and midstream. Compared with the interaction among single phases, the interaction of considering two phases at the same time is weaker.

## The Influence of Mineral Resources' Trade Pattern on Their Prices: From the Perspective of Industrial Chain

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**Abstract**
Mineral resources are the raw materials of many commodities' industrial chains and an important material basis for the sustainable development of economy and society. Its importance makes it not only a commodity but also a tool in the game between nations. This means trade patterns such as the international community of resource trade, the countries that export or import mineral resources in large quantities, the intensity of the current competition for mineral resources, and the secondary trade of mineral resources may also have an influence on the price of mineral resources. This study takes copper resources as an example, constructs global copper industry chain trade network and extracts indicators reflecting trade pattern. Then impulse response function is used to study and test the influence of trade pattern on commodity prices. In the case of copper, upstream commodity prices were found to be most vulnerable to changes in their trade patterns. The influence of commodity trade pattern on downstream commodity prices is short in duration. The upstream commodity price is greatly influenced by the secondary trade of upstream and midstream commodities, the trading community of midstream and downstream commodities, and the status of downstream commodity trading country. The midstream commodity price is more easily influenced by the midstream commodity competition and the downstream commodity trading country status. Downstream commodity price is more influenced by the secondary trade of upstream and downstream commodity and the downstream commodity competition. This method can be extended to other mineral resources industry chain. Traders can take this as a reference to predict the resource prices and make reasonable decisions. This can promote the stable and sustainable development of mineral resource industry chain.

## The Effect of Global High-Tech Complexity Industrial Robots Trade on Industrial Carbon Intensity

### Xinzhan Jia, Lu Lin
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**Abstract**
In Industry 4.0 era, industrial robots, as a symbol of artificial intelligence, has penetrated the industrial production processes and affected economic growth, especially for the high-tech complexity industrial robots. However, economic growth is often associated with high energy consumption. Energy consumption can exacerbate various negative impacts, including environmental pollution and global warming. This paper establishes the global trade network of high-tech complexity industrial robots from 2000 to 2019. The social network analysis (SNA) is used to quantify countries' roles in the global trade network of high-tech complexity industrial robots. The spatial econometric model is then used to analyze the impacts of industrial and economic indicators and the trade network roles of the countries on industrial carbon intensity. The results show that the

trade networks of industrial robots have increased and expanded from 2000 to 2019. China and the United States are the countries with the largest number of import partners; Japan and Germany have the largest number of export partners. Germany and China are the central actors in the network; China and the United States are the most influential countries. Moreover, China has gradually become an important bridge and hub in the trade of high-tech complexity industrial robots. The industrial carbon intensity was significantly determined by some roles in the network, including the closeness centrality of symbolic influence. We also found that foreign direct investment and industrial employment significantly increased industrial carbon intensity. However, GDP per capita significantly dampens the industrial carbon intensity. The results of this paper can provide some inspiration for the balance between industrial intelligence and the environment.

## The Evolution of World Phosphorus Trade Network: A Production Perspective into Resilience

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**Abstract**
Phosphorus is an essential nutrient for plant growth and a non-renewable resource, so the resilience of its supply chain is crucial to global food security, which faces multiple risks, such as phosphate rock scarcity, poor efficiency, and geopolitical risks. Using information-based ecological network analysis (IbENA), this study builds the phosphorus trade network (PTN) from the production side. Using complex network analysis, it examines the relationships between countries and identifies the significant exporters and importers of phosphorus. Results showed that from 1990 to 2020, PTN is at a low level of resilience (0.24±0.02) due to excessive redundancy in trade paths, because many countries diversify their import sources to secure phosphorus supplies. With a 92.7% and a 35.7% increase in total trading volume and trading countries, the PTN has evolved to have more alternative trade routes for emergencies but at the same time increase trade integration, showing a simultaneous increase in system efficiency and redundancy. The trade structure of major countries, such as India, the United States, Morocco, and China, has changed over the last 30 years due to political and economic factors. In order to improve resilience, PTN must promote technological advances, industry consolidation, and trade facilitation at the production end. The supply of trade resilience as a public good and the openness of access to more transparent information on the phosphorus supply chain can help to reduce PTN resilience fluctuations. To help policymakers better understand and assess economic system resilience, this study links the trade network resilience, a systemic structural property, to micro-agent behavior and macro dynamics.

## Analysis of Multiple Virtual Water Dependence between Provinces in China Based on Ecological Network

Huan Wang, Bo Ren, Ning Ma, Huajiao Li
Organization(s): China University of Geosciences, China, People's Republic of

**Abstract**
The interprovincial circulation of goods and services has formed virtual water flows between regions, which can redistribute water resources. Based on the existing virtual water trade research, this article further explores the multiple dependence of virtual water between regions, that is, direct, indirect and complete dependence. This paper examines the direct, indirect and complete dependence of the virtual water among various provinces in China by constructing multiple dependence networks, and identifies the dominant regions and key paths of virtual water trade network. The results show that the direct dependence is the densest and has the largest overall dependence, but the indirect dependence is the most stable and orderly. Secondly, the dominant provinces are Guangxi, Hunan, Sichuan, Xinjiang and Anhui, referred to as "five core regions", and the flow relevant to them accounts for about 30% of the total virtual water. The seven provinces of Shanxi, Zhejiang, Shandong, Hubei, Guangdong, Shaanxi, and Gansu, depend both directly and indirectly on the "five core regions". Shanxi and Zhejiang have close direct and indirect dependence with more than one of the "five core regions". Guangdong is the target province with the most direct and indirect output of virtual water from the "five core regions". The study provides a scientific basis of multi-regional identification for collaborative management of water resources in China from the perspective of dependence.

## An emergy-LCA analysis of environmental sustainability in urban agriculture: evidence from food-energy-water-carbon nexus perspective

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Abstract
Urban agriculture is an important means of improving urban resilience and sustainability by promoting local food production. At present, most of the studies used Life Cycle Assessment or Emergy Analysis to evaluate the small-scale urban agriculture model. Our study used a joint Emergy-LCA method to evaluate the ecological sustainability of typical urban agriculture in Beijing (China). Considering the differences between on-farm and off-farm progress, two cases are analyzed and compared: Case1 (C1) is a traditional suburban farm, which sells food by supermarkets in the city center; Case2 (C2) is an aquaponics farm, which delivers fresh food directly to consumers' tables by express delivery in the form of "Farm To Table". The results show that in the on-farm phase, C2 shows great potential in water conservation. Its blue water consumption to produce one joule of food is only 12.55% of that of

C1. Although the emergy input, primary energy consumption and carbon emissions of C2 are not significantly different from those of C1, it shows higher economic benefits. The above indicators per unit of profit of C2 are all lower than those of C1. In the off-farm phase, "Farm To Table" shows stronger sustainability. The total emergy input of traditional food distribution in C1 is 14.51 times that in C2, the blue water consumption was 2.31 times, the primary energy consumption was 5.43 times, and the carbon emission is about 4.92 times. Generally speaking, both on-farm and off-farm progress of C2 demonstrate better environmental benefits. Based on the comprehensive identification of environmental impacts, this study investigates the changes in the system under the optimization of water and fertilizer for C1, and the optimization of electricity for C2 respectively, and provides suggestions for the improvement of the two urban agriculture models in the future.

## DAY 3 Session 36

### Two-Stage (Liquid-Solid) Anaerobic Mono-Digestion of Chicken Manure: Operational Strategy and Techno-Economic Assessment

Rajinikanth Rajagopal, Bernard Goyette, Prativa Mahato, Suman Adikary
Organization(s): Agriculture and Agri-Food Canada, Canada

**Abstract**
Chicken manure (CM) has a huge potential for biogas production, which was investigated in a high solids anaerobic digester (HSAD) by adopting the recirculation-percolation (R-P) mode of operation of the liquid inoculum at low temperature (20±1oC). The system was operated in a batch mode under different organic loading rates (OLRs) [4.3-8.7 gVS/L.d], at a high total solids (TS; 65-70%) and total kjeldahl nitrogen (TKN) concentration ranging 23.3- 32.8 g/L. It was noticed that the acclimation of liquid inoculum to high TKN (6.9 g/L) facilitated towards the faster degradation of CM, reducing the duration of start-up phase. The study performed for 282 days in four variable cycle lengths (71-d, 70-d, 70-d and 71-d for cycles 1, 2, 3 and 4 respectively) revealed that CM, rich in high solids and ammonia was tolerated by the system due to acclimated inoculum. The maximum cumulative average biogas production rate and specific methane yield (SMY) was found to be ~20 L/d and 0.80±0.12 LCH4g/VSfed respectively at an OLR and TKN of 4.4 gVS/L.d and 23.3 g/L respectively. Mono-digestion of CM was successfully conducted at a high ammonia concentration, resulting a methane content of above 60% with no signs of inhibition. Besides, maximum free ammonia nitrogen (FAN) of 0.27 g/L was observed at an OLR of 8.7 gVS/L.d and TKN of 32.8 g/L. AD operation at low-temperature have helped to avoid FAN accumulation, which is toxic to methanogens. Similarly, the R-P of acclimated liquid inoculum to solid waste could be a solution for large-scale operations: to process animal manures high in solids and ammonia, accelerate the AD process, avoid volatile fatty acids accumulation, and eliminate the requirement of mechanical mixing. Thus, this approach can contribute to mitigate develop manure management strategies adapted to Canadian farms that can achieve Carbon neutrality goals for the poultry sector.

## Integration of Struvite Precipitation and Anaerobic Digestion Biotechnology as a Solution for the Management of Chicken Manure

Seyyed Ebrahim Mousavi, Bernard Goyette, Xin Zhao, Rajinikanth Rajagopal
Organization(s): Agriculture and Agri-Food Canada, Canada

**Abstract**
Improper management of untreated chicken-manure (CM) is one of the Canada agriculture industry's environmental challenges considering the high volume of this agri-waste. One promising technology for treating different agri-wastes is anaerobic digestion (AD) which has been widely used for the purpose of producing biogas. However, utilization of this process for treating CM has been always very challenging due to its high-ammonia concentration that could inhibit AD process. Developing suitable strategies to mitigate ammonia inhibition is a major concern to maximize biogas production. Struvite precipitation is such technique for solving high ammonia concentration problem through recovering nutrients (N and P) from raw or digested-manure, which has been barely investigated for treatment of CM. Thus, the aim of this work was to investigate the struvite precipitation potential and to study the effect of this process on heavy-metal removal and pathogen reduction. The impact of pH, Mg:P:N molar ratio, and initial ammonia concentration on precipitation yield was investigated. Results confirm that initial ammonia concentration does not have any meaningful effect on Struvite precipitation yield which is considered as an advantage in commercial scale-up. The highest value of N recovery from AD-CM leachate was achieved at pH 11 with 86% and 88% of ammonia removal in control and filtered samples, respectively. For raw sample, pH 10 presented the highest TAN removal rate of 86.3%. Struvite precipitation can not only efficiently recover N from anaerobic digester leachate, but also have a positive impact on reducing heavy metal content of the leachate by 90.2%, 93.2%, 36.4%, 35.7%, 56.2%, and 93% for Zn, Cu, Pb, Ni, Cd, and Cr, respectively. Initial observations prove that this process not only removes heavy metal content of the leachate which makes it harmless to be discharged to the environment, but also show positive signs on reducing the pathogens in the sample.

## Analysis of the Regulatory Framework and New Business Models Based on the Application of Systems Dynamics in E-Waste Management

Emmanuelle Soares de Carvalho Freitas, Lúcia Helena Xavier
Organization(s): Center for Mineral Technology, Brazil

**Abstract**
The significant increase in consumption leads to increased waste generation. The damage caused by incorrect disposal of e-waste is significant due to the potential impact of hazardous substances that directly impact public health and the environment. Considering that the most latent problem of electronic waste is in the disposal, reverse logistics, and urban mining recent researches have sought better solutions in these segments. In order to discuss the important resources that can facilitate this

collection logistics, we propose the modeling of the system through the identification of flows and inventories through the application of system dynamics. The assessment of environmental impacts related to disposal and reverse logistics has the as main objective to present integrated solutions based on economic, technological, and regulatory criteria. The results are analyzed for a ten-year scenario and based on the integration of circular economy concepts. The potential for the recovery of secondary materials from electrical and electronic waste in new production cycles was verified. Thus, proposals for new business models and bases for the elaboration of a regulatory framework adjusted to the needs of the sector are presented.

## The Dynamic Analysis for Resource Recycling Potential and Environmental Benefits of E-Waste in Beijing-Tianjing-Hebei Region of China From 2000 to 2035

Xiaoqing Shi, Ying Wang
Organization(s): Research center for eco-environmental sciences, CAS, China, People's Republic of

**Abstract**
Driving by the digital transformation and rapid update of the digital products, e-waste amount are rising at the average speed of about 3% to 4% per year and has been becoming the most important urban mine that is crucial to deal with both resources shortage and eco-environmental problems. Estimating the resources recycling potential and environmental benefits are the significant basis to manage e-waste efficiently. Beijing-Tianjin-Hebei region (Jing-jin-ji) is the capital economic circle of China and it is transferring to digital and circular economy toward green and low carbon development. Gauging the e-waste amount and its recycling potential and environmental benefits are indispensable to manage e-waste of this region to meet the coordination development aims for both resources sustainable use and eco-environment amelioration. By using sales and lifespan model, stock and logistic model, market value method, material coefficient and pollution coefficient method, this paper analyzed the e-waste (washing machines, refrigerators, air conditioners, televisions, and computers) generation and the resource recycling potential and eco-environmental benefits of Jing-jin-ji region from 2000 to 2035. The results based on conservative estimate show: (1) Although the growth speed of the WEEE generated tend to be slowing down, the amount would keep continuous increasing from 2021 to 2035 at the average growth speed of about 3.4% per year. (2) There are significant potential for renewable resources recycling, raw materials economizing, energy saving, and environmental benefits for both pollution reduction (waste water, waste gas, industrial residues, heavy metal, and greenhouse gas emission). (3) There are gaps between the e-waste generated amount and qualified processing capacity in different areas of this region. It is necessary to improve the qualified processing capacity gradually while to enhance the cooperation management in the region to match the need of e-waste recycling in the future.

## Informal Electronics Repair, Remanufacturing And Refurbishment Networks in Gangxia Village, Shenzhen

Yuk Tung Chow, Benjamin Steuer
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**Abstract**
Circular Economy (CE) related approaches have emerged as a central strategy among urban governments and corporate actors involved in waste management (WM) and have been a focus of the China's administration ((NPC, 2008). While over the last 40 years the informal recycling sector (IRS)1 has been pivotal in shaping the value chain of urban China's WM have been played the important role and served as the loop of the whole value chain of waste. How to mitigate or integrate the intersections between formal and informal domains that exist in urban China's WM became the main challenge to implement the CE concept on the ground. While both sides operate within their respective systemic (rule-based) frameworks, the individually developed and mixed formal and informal recycling structures fulfil growing demands of the floating population in urban villages, such as Gangxia Shenzhen. However, the rapid urbanization and the formalization of the recycling sector have triggered contesting dynamics between municipal administers and the IRS. This raises questions pertaining to why local policies did not organically integrate this recycling sector via the official top-down approach. The inquiry pursued in this chapter shows how informal recyclers do in some instances contribute to a more inclusive urban WM system that features more social-environmentally sustainable CE practices than recycling. Moreover, the complex social fabric of this sector is inseparably intertwined with aspects of urbanization and employment options that lie at the root of the city's complex development pattern.

## DAY 4 Session 37

### How to Reveal the Impact of Energy-Water Nexus Based Joint Tax Management Policy on the Environ-Economic System: An Advanced Exploration of Interaction Effects and Response Mechanisms

Jinbo Zhang1, Lirong Liu2, Yulei Xie3, Dengcheng Han4, Yang Zhang1, Zheng Li1, Huaicheng Guo1
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**Abstract**
Faced with the contradiction between economic growth and environmental degradation, a static computable general equilibrium model-based factorial energy-water nexus policy analysis model

(SFNM) is first developed and applied to Shanxi Province, China (i) to explore the environ-economic impacts of multiple carbon tax scenarios and wastewater tax scenarios; (ii) to investigate the factorial interactions; (iii) to reveal the response mechanisms of the supply chains. All tax policies have negative impacts on economy and positive impacts on environment. The carbon tax of 10-40 yuan/ton and the wastewater tax of 1.4-14 yuan/ton can be options for mitigating carbon dioxide emissions and water-quality based water scarcity. Significant interactions suggest that the joint tax management policies for the construction and heavy industrial sectors will have compounded impacts. Policy support for technology-based enterprises contributes to the transformation of industrial structure. In addition, expanding diversified supply chain channels is necessary for Shanxi to enhance its anti-risk capability.

## A GIS-MCDM Based Inexact Programming Method for Regional Biomass Power Plants Planning Under Uncertainties

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**Abstract**
In the context of global climate change and energy security pressures, biomass power generation has been regarded as an effective way to supplement energy supply, reduce fossil fuel consumption, and alleviate environmental pollutants. This paper presents an integrated modeling framework to address the regional biomass power generation planning to facilitate biomass utilization in developing countries. By combining the GIS-based multi-criteria decision-making approach and the type-2 fuzzy inexact programming method, the proposed framework could assist the optimal decision-making for the specific site and size selection of biomass power plants in the whole region as well as the optimal operation strategies under deep uncertainties. The proposed modeling framework is applied to the particular context of Henan, an agricultural province in China with great biomass potential. The results suggested that biomass power plants with a total capacity of 2.4 GW could be established, which could satisfy 6% of local electricity consumption and avoid 18.51 million tons of carbon emissions. The sensitivity analysis of the main economic parameters indicated that higher feed-in tariffs and lower investment and operation costs were essential to stimulate the utilization of local biomass energy. Furthermore, the optimal strategies for biomass power generation planning under uncertainties could be suggested for different decision makers with various risk preferences to achieve a tradeoff between system cost and risk.

## A Future-Equitable-Decarbonised-Distributed Heating System through a Three-Layer Whole System Approach

Xinyao Liu, Floris Bierkens, Ishanki De Mel, Michael Short, Matthew Leach, Mona Chitnis, Lirong Liu
Organization(s): University of Surrey, United Kingdom

**Abstract**
Residential heating displays huge decarbonisation potential towards Net-Zero. While the cost of heating system upgrade might further exacerbate fuel poverty, especially for residents of social housings. This study develops an integrated model to understand how fuel poverty could be minimised in the UK whilst simultaneously delivering upon net-zero targets for home heating. Three policy scenarios, No Grant (NG), Business as Usual (BAU), and Proposed (PRO) are constructed covering the features of social housings and applicable grants of the case study area for heating and energy system optimisation. Whole socio-economic impacts and the cost-effectiveness of GHG emission reduction are investigated under different scenarios with consideration of multiple carbon intensity of gird (GCI) and emission reduction target (ERT) to secure the optimal solutions for tackling fuel poverty. Results show that more direct GHG emission reduction is achieved along with the decrease of GCI. The investments in heating and energy system would stimulate the economy with various extents among industries. Stronger increases are observed in electrical equipment, electricity, construction, fabricated metal products, metal, mining and machinery sectors. The higher ERT is, the more investments are required, which leads to higher direct GHG emission of industry system. Total GHG emission reduction of the whole socio-economic system demonstrates reverse pattern. When ERT is higher than 95%, capital cost of PRO is higher than BAU and NG. But the extra grant under PRO shares about half of the financial burden of local authority. Household energy bills under PRO is the lowest under the same GCI and ERT, followed by BAU. The same pattern could be observed in the unit capital cost and unit household energy bills of GHG emission reduction. Lessons of this study would shed light on other regions in tackling fuel poverty.

## Carbon Metabolism Among Industries and Its Society-Environment and Economy Implication under Uncertainties

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**Abstract**
With the over exploitation and utilization of natural resources especially fossil energy, environmental degradation caused by such activities have been drawn much attention due to their adverse impacts on economic loss and related climate change. In addition, energy has been a vital resource for industrialization and urbanization in many decades. In spite of the positive effects, energy processing and conversion resulted in carbon dioxide (CO2) and other air pollutants emissions, which are the bottlenecks for the improvement of socio-economic and environmental system. To combat climate change, the Chinese government has announced that the country will reach its national carbon

emission peak and neutrality within 2030 and 2060, respectively. In this study, a carbon metabolism model is developed to help support transformation of energy structure and examine CO2 emissions and their environment implications under uncertainties. This model quantifies the energy-related emissions caused by energy utilization of various sectors within economy, which can further identify the critical sectors with considerable emissions for subsequent emission mitigation. Emission-mitigation scenarios are set based on identified sectors which can assess such implications on the socio-economic and environmental system. The desired model will facilitate the carbon peak and neutrality of China.

## Economic Analysis of Hydrogen Production from Offshore Wind Farm in China

Chuanbo Xu1, Xinying Li2
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**Abstract**
Wind power hydrogen production is the direct conversion of electricity generated by wind power into hydrogen through water electrolysis hydrogen production equipment, which produces hydrogen for convenient long-term storage through water electrolysis. Offshore wind power has become an important field in China for the development and utilization of wind power due to abundant resources and wide area. However, the strong randomness and intermittent nature of offshore wind power bring many problems to the safe and reliable consumption of offshore wind power. Hydrogen production from wind power is an effective means to improve wind power utilization and alleviate wind curtailment, and it has become a focusing application in the development and research of offshore wind power. This paper comprehensively considers the scheme, equipment investment cost, operation and maintenance cost of hydrogen production technology, and gives the economic evaluation method of the China's hydrogen production technology from offshore wind power. This study establishes three technical schemes and economic models for hydrogen production on shore, hydrogen production from offshore platform with hydrogen transported by ships, as well as hydrogen and ammonia production from offshore platform with ammonia transported by ships. According to relevant research and literature data, taking a 300 MW offshore wind farm as an example, three kinds of hydrogen production technical schemes at different offshore distances are compared in terms of economic efficiency. The results show that among the three technical schemes, hydrogen and ammonia production from offshore platform with ammonia transported by ships is the most economic.

## Analysis of Influencing Factors of Energy Consumption in Beijing - Based on the IPAT Model

Zheng ZHANG, Xianzhong MU, Qin XU, Xiang LV
Organization(s): Beijing University of technology, China, People's Republic of

**Abstract**
Beijing is a typical energy-importing city. The study of energy consumption factors in Beijing is important for the sustainable development of Beijing. There are many influencing factors of energy consumption in Beijing, and the influence degree of each influencing factor is different in different periods. By constructing the IPAT model of energy consumption change in Beijing, this paper breaks down the factors which cause the change in energy consumption in Beijing into population, affluence, and technological progress. The results show that Beijing is a high energy-consuming city and the change in energy consumption in Beijing is the superposition of multiple effects. The energy consumption change caused by population growth in Beijing is greatly changed by using the data from 2006 to 2015, and the maximum energy consumption change is 361.1 million tons of standard coal. The largest change in energy consumption is caused by per capita GDP growth, which reached 8,988,000 tons of standard coal in 2006-2007, and the effect caused by affluence is greater than the impact of population changes. Technological progress always has a reduced effect on energy consumption. From 2006 to 2015, the improvement in energy efficiency due to technological progress was greater than the increase in energy consumption due to technological progress. To reduce energy consumption and improve environmental quality, the following two things need to be done: first, to control the population of Beijing, and second, to enhance the development and introduction of innovative technologies for energy conservation.

## DAY 4 Session 38

### Effectiveness of Oyster Shells for Anaerobic Digestion of Fishery Waste

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**Abstract**
Oyster farming is one of the important industries in Japan from economic and environmental perspectives. It is an urgent issue to handle the oyster shell waste because a large amount of the waste is beyond the demand of the recycle use of oyster shells. In addition, there are unused fish in the fishing port because the size is not even and they are not popular. If such fishery wastes can be converted to energy in the fishing port, it could lead to both energy self-sufficient port and resource circulation.
Anaerobic digestion is one of the promising approaches to convert organic wastes to energy. Main component of oyster shells is calcium carbonate, which stabilize anaerobic digestion process. This study considers efficient anaerobic digestion of unused fish with addition of oyster shells. The main objectives of this study are: (1) Evaluate the performance of anaerobic digestion with oyster shells; (2) Investigate the feasibility and possible benefits of our proposed anaerobic digestion methodology. Laboratory experiments using 100 mL vial bottles for batch-processing digestion and 1 L flask for continuous digestion were conducted. The results indicate that the more oyster shells input, the more

effectively methane was produced under the high organic loading conditions. In addition, the shape of the oyster shells affected the methane production efficiency. From the bacterial perspective, the ratio of the specific bacteria decomposing protein-rich biomass increased, which confirm the fact that more methane was produced at the beginning of the digestion process.
Energy balance analysis indicated that produced methane can replace the energy used in the oyster bar, which is held in the fishing port during oyster farming season. The proposed methodology contribute to reduce both carbon emission and cost for the incineration of oyster shells. In addition, it could reduce the discarded fish, which conserve marine environment.

## Liquid Fuels Production from COVID-19 Waste Surgical Masks by Catalytic Fast Pyrolysis

Wenfei CAI, Reeti KUMAR, Zhi ZHU, Jonathan Woon-Chung Wong, Jun ZHAO
Organization(s): Hong Kong Baptist University, Hong Kong S.A.R. (China)

**Abstract**
COVID-19 has caused a sudden surge in the use of surgical masks for personal protection, which further increases the environmental burden. Those plastic wastes may need hundreds of years to naturally break down. Pyrolysis could be an effective and simple pathway for converting waste surgical masks to valuable chemicals. This research synthesized Ni/Al-MOF-derived catalysts for the catalytic pyrolysis of surgical masks waste. Polypropylene (PP), the main component of the surgical mask, was selected as the feedstock to obtain the optimal pyrolysis conditions and explore the pyrolysis mechanisms. Then the surgical masks were pyrolysis under the same conditions to study the product of characteristics. The morphology, structure, composition, and acidity of the catalysts were studied by SEM, EDS, TEM, XRD, XPS, BET, and NH3-TPD. The results showed that the waste surgical masks were effectively converted to gasoline or diesel range chemicals. The oil yield from PP was up to 72.8% when using Ni/Al-MOF-derived catalysts with 5% Ni loading at 450 oC. At this condition, the oil yield from face musk was 58.9% with the wax yield of 32.7%. The characterizations of the catalysts showed that the MOF-derived Al2O3 has a high surface area, and the Ni particles were evenly distributed on the surface of Al2O3. Such a catalyst structure is beneficial to exposing as many catalytically active sites as possible, which is why the catalyst exhibits excellent performance. In general, the catalyst developed in this work can promote the conversion of the waste face masks to liquid fuels, which could reduce the negative impact of plastic products on the environment and promote the recycling of plastic wastes.

## A Bioelectrochemical System Based on the Filtration Composite Anode with Novel Electrodes for High-Efficient Wastewater Energy Recovery

Ting Xu, Xiaoyuan Zhang
Organization(s): Tsinghua University, China, People's Republic of

**Abstract**
Bioelectrochemical system (BES) can achieve energy recovery along with wastewater treatment. However, it is challenging to obtain high energy recovery and high-quality effluent simultaneously. In this study, based on the structure design and the active-sites optimization of electrodes, the iron-doped carbon fiber membrane applied in a filtration composite anode and the cobalt (Co) metal single-atom cathode were fabricated to achieve electricity generation with high-quality effluent of BES.
To enhance the microbe-anode interface interaction, the iron-doped carbon fiber membrane anode was fabricated with the fiber diameter similar to the size of electrogenic microorganism and the doping of iron element. This anode had good biocompatibility and electrochemical activity due to high specific surface area (328.9 m2/g) and low charge transfer resistance (19.8 Ω), which could enhance the microbe adhesion and electron transfer. At the same time, to enhance the catalytic activity of oxygen reduction reaction of cathode in BES, the cobalt (Co) metal single-atom cathode was developed with the fully exposed active sites at ultra-low temperature. This cathode could increase the nucleation barrier to inhibit the nucleation of metal atoms due to the ultra-low temperature, which exhibited 63% higher maximum power density than that of traditional Pt/C cathode.
On this basis, the BES assembled with a filtration composite anode (combining the iron-doped carbon fiber membrane and carbon fiber brush) and the Co metal single-atom cathode could achieve high power output and high quality effluent with the high maximum power density of 3222 mW/m2 and the organic degradation rate constant of 0.462 h–1. This integrated bioelectrochemical system shown great application potential in wastewater energy and resource recovery.

## Ship Recycling in Developing Economies of South Asia: Changing Liability to a Commodity

Bisma Mannan, Md Jahir Rizvi, Yong Ming Dai
Organization(s): University of Plymouth, United Kingdom

**Abstract**
In recent years, the world has seen a continuous growing outrage about maritime safety, and in response to those outrages, regulatory authorities are becoming more engaged in the design for safer operation and maintenance of ships. However, the end-of-life (EOL) of these ships is often neglected during the design phase and considered a liability by the developed economies of the western world. However, it becomes a commodity for the developing economies of South Asian countries like India, Bangladesh, and Pakistan in the last decade. Shipbreaking activities play a vital role in achieving the circular economy and sustaining the economies of these developing countries and provide employment opportunities on large scale to both skilled and unskilled labour and yet consider one of the most unsafe occupations by the International Labour Organization (ILO) which poses severe threats to human health and environment. So, there is an immediate need to identify opportunities

and threats faced by the ship recycling industry of South Asia. This study compares the recent development plans of ship recycling in the leading shipbreaking countries and illustrates the socio-economic benefits of ship recycling and assesses the current stats on ship recycling using the data of the United Nations Conference on Trade and Development (UNCTAD). In the last, conduct a SWOT analysis that includes the strength and opportunities which shows the tremendous potential of South Asian countries in the ship recycling industry and presents the weakness and threats that can be considered while performing shipbreaking activities.

## Estimation of Hydrogen Generation from Silicon Sludge Based on the Si-Water-Alkali Reaction

Taisei Kagawa, Shunsuke Kashiwakura, Shoki Kosai, Eiji Yamasue
Organization(s): Ritsumeikan University, Japan

**Abstract**
In recent years, the production volume of semiconductors has been increasing year by year due to the expansion of the high-speed communication standard "5G" and the expansion of demand for data servers, and it can be inferred that the production volume will continue to increase in the future. In the manufacturing process, only about 45-55% of single crystal silicon wafers are obtained, and the remaining is silicon sludge, which will be generated in Japan as of 2021 to about 8600 tons. At this stage, silicon sludge is only slightly cemented as an effective use, but most of it is landfilled or incinerated. Therefore, we decided to utilize silicon sludge, which is dominated by Si, for hydrogen generation.
($Si + 2H_2O \rightarrow 2H_2 + SiO_2$)
From the existing research, the reaction in which hydrogen is generated from silicon and water is used, but the reaction rate is extremely low. In this study, we tried to improve the reaction rate by adding alkali in this reaction.
The results showed that increasing the molar concentration of the alkaline additive, reducing the particle size of the silicon sludge, and increasing the temperature of the experimental environment were effective in improving the reaction rate. It was also found that alkaline $OH^-$ was consumed before and after the reaction.
($Si + 2OH^- + H_2O \rightarrow SiO_3^{2-} + 2H_2$ )
and
($SiO_2 + OH^- \rightarrow SiO_3^{2-} + H_2O$)
There is a possibility that KOH can be obtained by electrodialysis membrane from the waste in the cement industry. Also Si sludge is gathered in the cement industry. Therefore, the research was finally conducted with the aim of constructing a waste-based hydrogen production system in cement industry.

## Practical Approach to Recycling PET/HDPE Immiscible Polymer Blend for 3D Printing Applications

Rana Elazhary1, Siegfried Schmauder2, Amna Ramzy1
Organization(s): 1: German University in Cairo; 2: University of Stuttgart

**Abstract**
The increase in plastic wastes worldwide presents a problem to our environment, and one of the ways to limit the damage is to recycle the plastic waste for creation of a circular economy. Recycled Polyethylene terephthalate (RPET) and high density polyethylene (RHDPE) blend 80:20 ratio is compatibilized using two different methods: 5 wt. % of HDPE grafted with Maleic Anhydride (HDPE-g-MA) added as a compatibilizer, and 1% solution of Sodium Dodecyl Sulphate (SDS) is used for surface functionalization of PET, then combined for synergy evaluation. 10 wt.% glass fibers are also added for assessing fiber-matrix adhesion. The HDPE-g-MA compatibilizer proved to be the most ductile blend, with the highest thermal stability, due to improved interfacial adhesion, and provided better fiber matrix adhesion than the SDS. On the other hand, the SDS promoted the highest percentage crystallinity of both HDPE and PET in the blends and lowered the glass transition temperature of PET noticeably. Furthermore, the SDS showed smaller and more uniform shaped dispersion size in the morphology, and also exhibited the highest stiffness, tensile and impact strength without reinforcement. In addition, the combination of the functionalization and compatibilization proved to be unsuitable, as the dispersion size of HDPE was non-uniform and the tensile properties presented a large standard deviation. Hence, each method solely implemented provides simple and practical ways to compatibilize these two polymers, depending on the final blend properties desired. If high stiffness is desired, then SDS would be more suitable, while the HDPE-g-MA compatibilizer would be more effective if ductility is required or if reinforcement is needed. The compatibilization method is wound into filaments of diameter 1.75 mm then printed using an FDM extrusion based 3D printer. The developed recycled PET/HDPE-g-MA blend showed good printability and yielded 30% enhancement of mechanical properties over the control sample without compatibilization.

# DAY 4 Session 39

## Comparison of Life-Cycle Greenhouse Gas Emissions from Onshore and Offshore Wind Farms during China’S Wind Power Moving Southward

Mingyue Pang, Jiangling Zhou
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**Abstract**

In recent years, the new wind power deployment in China is gradually moving southward due to the serious wind curtailment in “Three North” areas. However, with the variation of wind resources and technological levels of wind power, how the environmental benefits derived from new wind farms will change requires rigorous quantification. Using life cycle assessment (LCA) method, this paper estimates the life-cycle greenhouse gas (GHG) emissions of three onshore and two offshore wind farms in Southeast China and compare them to that of one onshore wind farm in Inner Mongolia. Results showed that the life-cycle GHG emission intensity of the onshore wind farm with the nominal capacity of 1.5 MW in Southeast China was 8.44 g CO2-equivalent (CO2e)/kWh, slightly higher than that in Inner Mongolia with the same nominal capacity of 1.5 MW (5.90 g CO2e/kWh), which can be attributed to the difference of wind energy resources. When the wind turbines achieve the nominal capacity of 2 MW with the technological progress, they perform similarly to that in Inner Mongolia, i.e., 5.98 and 5.41 g CO2e/kWh, respectively. However, the offshore wind farms perform much worse than all the four onshore wind farms although they are equipped with larger wind turbines, 2 MW and 4 MW, respectively, whose life-cycle GHG emission intensity amounts to be 22.41 and 16.83 g CO2e/kWh, respectively. Furthermore, the GHG emissions of onshore wind farms are concentrated in the manufacturing process; whereas the construction process contributed more than 70% to the total GHG emissions in the offshore wind power systems due to their complex foundation structure in sea, which require more resources inputs. The results obtained in this study facilitate robust policy making of government authorities and contribute to the green deployment of both onshore and offshore wind farms during their moving southward in China.

## BIM-Based Life-Cycle Carbon Assessment for a Sustainable Tunnel Design

Mudasir Hussain, Hung-lin Chi, Bowen Zheng, Shu-Chien Hsu
Organization(s): The Hong Kong Polytechnic University, Hong Kong S.A.R. (China)

**Abstract**
Life-cycle carbon assessment of infrastructures is performed at the end of design, at which time design modifications are costly and time-consuming. This paper develops a parametric life-cycle carbon assessment (PLCCA) model for continuously and dynamically calculating CO2 emissions throughout the design process. Emission factors (EFs) are integrated into the BIM model as an additional design parameter. The whole life cycle CO2 emissions are computed based on parameterized inputs. The “Conduit” Rhino-Grasshopper plugin is employed to visualize the results in real-time bar charts and colour codes. A multi-objective optimization (MOO) based on actual design constraints is used to optimize the design parameters and support early design decision-making by incorporating CO2 emissions, materials, energy, and cost. The performance of the PLCCA model is evaluated using a case study of a tunnel in Yunnan, China. According to the findings, the operational stage is responsible for 65% of CO2 emissions, while the production stage is responsible for 30%. The BIM model is then remodeled with the optimal design parameters of the PLCCA model, and the CO2 emissions are recalculated to reduce the CO2 emissions of the tunnel. As a result, CO2 emissions are reduced by 28.39% during the operational stage and 32.95% during

the production stage. This study develops awareness and guidance in project stakeholders regarding sustainable design and low CO2 solutions in infrastructure projects to achieve carbon-neutrality in the future.

## Life Cycle Assessment of Different Disposal Options of U. Prolifera Green-Tide in China's Yellow Sea

Zhihui Chen, Min Liu, Wei Liu
Organization(s): Shandong University, China, People's Republic of

**Abstract**
The Ulva prolifera (U. prolifera) green tide has had a large-scale eruption in the Yellow Sea of China for 15 consecutive years. Qingdao is one of the coastal cities most affected by the green tide. This study evaluated the environmental and economic impact of U. prolifera disposal in Qingdao from the perspective of the whole life cycle, including salvage, transportation, harmless disposal, and resource utilization. The comparison of different disposal options (incineration, fast decomposition, stabilization and recycling) of U. prolifera indicates that the recycling for fertilizer production has produced the greatest environmental and economic benefits. In 2021, Qingdao salvaged a total of about 1.44 million tons of U. prolifera, and the disposal ratios of incineration, stabilization, fast decomposition and recycling are 0.03, 41, 44 and 15%, respectively. Qingdao spent 338 million CNY and consumed 46,686 t oil-Eq of fossil fuels and 145,647 t of freshwater in response to the eruption of the U. prolifera and emitted 331.0 kt CO2-Eq of greenhouse gases, 81.5 t SO2-Eq of acid gases, 62.4 t NMVOCs, and 43.5 t PM2.5-Eq of particulate matter. Scenario analysis shows that the optimistic scenario can reduce the total emissions of greenhouse gases, acid gases, NMVOCs, particulate matter, and ozone-depleting substances of U. prolifera disposal by 49.5, 29.4, 21.5 and 72.8%, respectively. Meanwhile, the life cycle cost of U. prolifera disposal can be reduced by 34.7%. The results show that comprehensive utilization is a crucial step to maximize the environmental and economic benefits of U. prolifera disposal, including recycling for fertilizer production and anaerobic digestion for power generation. This is a valuable lesson for China and other countries to maximize environmental and economic benefits in the process of U. prolifera disposal.

## Regional Planning of Solar Photovoltaic Technology Based on LCA and Multi-Objective Optimization

Jing Yuan, Xiao-zhen Xu, Bei-jia Huang, Yu-yue Wang
Organization(s): University of Shanghai for Science and Technology, China, People's Republic of

**Abstract**
As a dominant renewable energy, solar power plays a crucial role in combating the climate change crisis and accelerating the energy transition. Solar PV has nonnegligible environmental impacts in

the production process and the economic characteristics of different photovoltaic technologies are diverse. Although previous studies have analyzed the evaluation of photovoltaic sustainable development from environment or economy perspective, a photovoltaic technology planning approach incorporating the proportion of PV technology allocation and product selection at the regional level is limited. Therefore, this study combines the life cycle assessment and multi-objective optimization method to establish a photovoltaic technology regional planning model that can balance the environmental and economic goals. Choosing crystalline silicon photovoltaic panels as the research object, we establish the environmental impact database of each stage of the photovoltaic life cycle value chain, and identify the key environmental impact categories and their contribution ratios. The key environmental impact categories of crystalline silicon photovoltaic panels are identified as toxic environmental impacts. By considering both the environmental impact and the economic indicators as Electricity Supply Cost (ESC), a multi-objective optimization model for PV technology regional planning is established. Through the analysis based on NSGA-II genetic algorithm, the Pareto optimal solution set is obtained, and the optimal solution set with the least environmental pollution and the lowest economic cost in the whole life cycle of solar photovoltaic technology is revealed. Our results show that monocrystalline silicon photovoltaic technology is a more preferential option when considering both the environmental impact and ESC. Our research offers a planning methodology for regional sustainable development of solar photovoltaic technology.

## Improved Data on the Environmental Burden of Spun Yarns and Woven Fabrics Made from Different Materials

Sofie Huysman
Organization(s): Centexbel, Belgium

**Abstract**
This study evaluates the environmental burden of spun yarns and woven fabrics made from different raw materials – cotton, organic cotton, polyester, recycled PET, viscose and Tencel staple fibers – in a cradle-to-gate perspective, using recent industrial data for spinning and weaving processes located in western Europe.
When looking at available life cycle inventories (LCIs) related to spinning and weaving in well-known databases like Ecoinvent, it becomes clear that the necessary data is limited, too material-specific and not taking into account important textile metrics such as the thickness of the yarn.
For example: when consulting Ecoinvent, the available process data is in most cases already linked to a certain material (e.g. spun cotton yarns). Extracting and coupling the required data with a different material has to be done manually. Further, the processes are mostly situated in Asia, entailing country-specific utility inputs (e.g. electricity) which cannot simply be transferred to a European process. Most importantly, the data is only expressed per kg and does not specify the yarn size, which has a large influence on energy use (van der Velden et al., 2012)
Data gaps also occur at the level of raw materials. The environmental impacts of cellulose-regenerated Tencel, which is not available in the Ecoinvent database, were simulated based on

literature (Shen et al. 2010). To model the extrusion of recycled PET into staple fibres, LCI data was collected from trials on semi-industrial melt spinning lines.
Using all this on-site gathered data, this study provides a tool to calculate the environmental burden of intermediate textile products, made from different materials, in function of the yarn size.
The impact assessment is based on midpoint and endpoint indicators as suggested by the International Life Cycle Data system (ILCD) scheme.

## Life-Cycle Carbon Emissions of Shellfish Aquaculture: A Case Study in the Northern China

Yu Shi xiong1, Liu Chunli1, Li Jiashuo1, Feng Kuishaung2
Organization(s): 1: Shandong University, China, People's Republic of; 2: University of Maryland, United States, The United States of America

**Abstract**
Intensive shellfish aquaculture play a crucial role in the global carbon cycle. The emissions and sequestration of carbon dioxide (CO2) from shellfish culture have always been a hot topic. However, the indirect greenhouse gas (GHG) emissions due to the resource consumption, equipment input or biodeposit were hardly considered in previous analyses, which may mislead the mitigation policies. In this regard, this study quantitative assessed both the direct and indirect carbon emissions by incorporating the life-cycle inputs into shellfish aquaculture, taking Shandong, a key aquaculture producer in China as a example. The results showed the utilization rate of polyethylene equipment was the main source of the GHG emissions. The carbon emissions transformed from carbon source to carbon sink and GHG emission decrease by 38.6% if the equipment was reused during the shellfish culture. The CO2 release per ton of scallops and oysters was 49 kg and 97 kg, respectively. In comparison with land-based protein sources, production of per unit of protein in shellfish culture would cause 10 % less of GHG emissions in CO2 equivalent than the ones from the beef, milk, pork, and egg. This study could provide the management strategies to mitigate carbon emissions caused by shellfish farming, and help the government gain carbon credits by serving as a net carbon sink.

# DAY 4 Session 40

## A Circular Business Model for Sustainability and Resilience: Small And Medium-Sized Poultry Farms More Autonomous in Obtaining Energy and Fertilizer

Francesca Bartolacci1, Michele Marcantoni2, Rosalino Usci2
Organization(s): 1: University of Macerata, Italy; 2: 3P Engineering, Italy

**Abstract**
This research wants investigate how companies can react to restrictions of resources and the waste issue by implementing a new business model that embeds circular economy principles, with the aim to decrease emissions and waste, and reduce the vulnerability to sudden shocks in resource provision. In particular, the paper tries to explore how poultry farms can implement a new business model that make them more competitive, embedding circular economy principles and reducing vulnerability to sudden shocks in resource provision. After a literature review, a case study is analyzed with the aim to identify the main elements of a circular business model that can be employed by poultry farm companies, which intend to operate according to a strategic priority, such as realizing production and consumption processes compatible with sustainability, circularity, and resilience. The new business model comprises an innovative technology (Chimera) that reconceptualizes the role of poultry manure as a valuable resource capable of contributing to the realization of fertilizer and electric and thermal energy. These outputs can be used in the farm for its sustaining, while the surplus can be sold, replacing other products currently purchased by farmers, often imported, made with non-renewable resources, and only available in a few foreign countries. In fact, a supply risk is associated with these resources due to the dependence that can be created toward suppliers. These issues are a key concern given the great quantity of energy and chemical substances used and the challenges posed by current increasingly dramatic extreme events, such as Russia– Ukraine conflict and COVID-19 pandemic. This study is an attempt to fill a literature gap by examining a good practice that may be replicated by other companies that want to design and implement a circular business model to generate sustainability and resilience.

## Demand for Rare Earths from Wind Power Development in China Under Carbon Neutral Target

Ziming Hu, Biying Yu
Organization(s): Beijing Institute of Technology, China, People's Republic of

**Abstract**
Climate change has become one of the biggest environmental challenges in the world. China is always actively addressing the climate change and has promised to achieve carbon neutrality by 2060. Wind power is critical to mitigating climate change and achieving carbon neutrality. However, its development is subject to potential constraints of rare earth elements. Therefore, it is necessary to first project the rare earths demand for the wind power equipment under the context of approaching carbon neutrality and identify the potential obstacles.
There are some literature focus on the analysis related to the nexus between critical metals and wind power development, however, the demand for critical metals to achieve carbon neutrality is unclear, the analysis from technical and material perspectives is inadequate, and the resource circularity potential needs further analysis as well. In particular, the potential supply risk of rare earths and the viability of a secondary supply under the context of approaching carbon neutrality is lacked.

To that end, this study adopted a bottom-up dynamic material flow analysis (MFA) framework to quantify the demand for rare earths (neodymium, praseodymium, dysprosium and terbium) used for producing wind power equipment under different carbon neutral roadmaps in China's power sector. The results show that rare earths supply might be unable to suffice the requirements of wind power development, especially dysprosium and terbium. The rare earths demand in 2060 will be 5-11 times higher than in 2019. The cumulative rare earths demand during 2021-2060 would be 222-425 kt, and about 1/3 of the demand could potentially be obtained by circular usage from decommissioned turbines. Considering the extremely low secondary recovery rate of less than 1% of rare earths, attention should be paid to strengthening rare earths recovery technology development with lower cost and higher efficiency.

## Revelation from Global Experience in Mitigating Anthropogenic Methane Emission in Waste Sector

Zhaomeng Li
Organization(s): Chinese Research Academy of Environmental Sciences, China, People's Republic of

**Abstract**
Methane is the second largest greenhouse gas caused by anthropogenic activities after carbon dioxide and it alone accounts for nearly one-third of the warming observed to date. In November 2021, the United States and Europe jointly launched the "Global Methane Pledge" during The UN Climate Change Conference in Glasgow (COP26) where 111 countries and regions around the world have participated, with an economic aggregate exceeding 70% of the world's total and covering more than 50% of global methane emissions. Methane abatement has then been thrust into the spotlight. As one of the largest sectors that emit methane, waste management including solid waste and wastewater treatment is of great importance for countries and regions to reach its methane reduction target. In this paper, based on the greenhouse gas emission inventory data released by UNFCCC since 1990, the historical evolution and current status of methane emission in major countries including Annex I countries such as United States, Canada, Australia, Germany and Japan and Non-Annex I countries such as Brazil, India and South Africa were sorted out and analysed. Key emission sources for each country were identified with a focus on the waste management field including solid waste and wastewater treatment. Based on the National Communications and Biennial Update Reports submitted by these countries and the existing international methane related strategies and action plans, methane emission control policies and measures (P&M) in waste sector and their effectiveness were discussed and analysed thoroughly. Lastly, derived from proven emission reduction effectiveness, policy recommendations ranging from source reduction of waste, process and techinical advancement to end management were proposed to the international community to help construct national or regional methane strategy to mitigate anthropogenic methane in the waste sector.

## Study of China's WEEE Fund Subsidy Mode Based on Environmentally Sensitive Substances

Xiang Wang1, Dong Xiang2
Organization(s): 1: Dept. of Mechanical Engineering, Tsinghua University, China, People's Republic of; 2: Dept. of Mechanical Manufacturing and Automation, School of Mechanical Engineering, University of Science and Technology Beijing, China, People's Republic of

**Abstract**
The fund mode has effectively promoted the healthy and orderly growth of China’s recycling and disposal industry for waste electrical and electronic equipment, but some issues have gradually emerged: the fund is out of balance for a gap of 2 billion to 3 billion yuan annually; the audit process is cumbersome for a mix of normative supervision and subsidy certification; the environmental concerns are fading for the increasing attention of governments and corporations to dismantling quantity. Therefore, the disposal fund needs to be improved as soon as possible.
A new fund subsidy calculation model based on environmentally sensitive substances is established in this paper. In the model, the subsidy is distributed based on the weight of environmentally sensitive substances rather than dismantling quantity. Firstly, by analyzing the environmental characteristics of the dismantling substances, hazardous wastes and dismantling substances with environmental risks are identified as environmentally sensitive substances. Then, the subsidy standard based on dismantling quantity under corporations’ lowest profit margin is calculated considering the operating costs of the enterprise. Finally, considering the relationship between dismantling quantity and weight of environmentally sensitive substances, the material coefficient of environmentally sensitive substances is determined and the subsidy standard of weight is calculated. Based on the above model of waste refrigerator, insulation material and lubrication oil are determined as its environmentally sensitive substances. Subsidies for the two substances are calculated at 8.81 yuan/kg and 615.66 yuan/kg, respectively, based on a profit margin of 5%. The fund expenditure subsidized by weight of environmentally sensitive substances is estimated about 1 billion yuan less than that of dismantling quantity. The new fund mode containing audit, supervision and subsidy based on environmentally sensitive substances is established and it is proved that fund losses can be effectively alleviated with environmental concerns raising and auditing difficulties reducing.

## Geospatially-Refined Modeling of Secondary Resources in Belgian Pavements

Zhaoxing Wang, Amaryllis Audenaert, Wim Van den bergh, Zhi Cao
Organization(s): Energy and Materials in Infrastructure and Buildings (EMIB), University of Antwerp, Campus Groenenborger, Groenenborgerlaan 171, 2020, Antwerp, Belgium

**Abstract**

Road infrastructure ensures the mobility of people and connectivity of different economic sectors. Materials accumulated in road infrastructure could potentially serve as future resource providers. However, compared to our understanding of primary resource exploitation, our knowledge of the exploration and exploitation of anthropogenic infrastructure is extremely limited, and this is particularly the case for managing secondary resources in pavements due to their heterogeneous nature. Therefore, we aim to develop an exchangeable knowledge and data platform to inventory the 'material passports' that document the essential information of pavements. We first employ GIS tools (e.g., GeoPandas) to harmonize spatial data of Belgian pavements from authoritative and crowdsourced databases. Second, we add key design-relevant factors (e.g., climate, soil, traffic) to pavements in the spatial database. Next, inspired by pavement design principles, we harness supervised-learning algorithms (e.g., CatBoost) and an official database of Flemish motorways to train models that correlate pavement properties with key design factors. The trained models are then used to predict the thickness of road segments of which geometric info is less available. We find that the trained models show sufficient accuracy in predicting pavement thickness (R2 score: 0.916 for asphalt layer and 0.838 for base). For national roads, local roads, and cycleways, we use different pavement archetypes considering several design criteria, including road category, location, speed limit, lane width, and traffic flow. In total, we are able to estimate the amounts of secondary resources (e.g., bitumen, aggregate) in a road network of over 109,000 km. This high-resolution resource cadaster will support resource recycling and circular design in the road industry and enable relevant stakeholders to better utilize secondary materials for new pavement moving forward. Our analysis also demonstrates the potential of employing machine learning to reveal the heterogeneity in pavements and improve the assessments of secondary resources prospecting and mining.

## CCS Retrofit Costs for China's Coal-Fired Units in 2030 Considering the Impact of the Carbon Market

Kaiyuan LI, Jin Yang
Organization(s): China University of Geosciences Beijing, China, People's Republic of

**Abstract**
CCS technology is an effective measure to achieve carbon emission reduction in the power industry. However, CCS retrofitting of existing coal-fired units in China is facing the barrier of high cost, which preclude the large-scale commercialization. This paper evaluates the life cycle cost of 771 coal-fired unit after CCS retrofitting and considers the incentive effect of carbon market. The results show that under the free quota allocation, when the carbon price is 50$/ton or 75$/ton, the CCS retrofitting cost of coal-fired units is -5.51$/mwh - 281.51$/mwh and -22.38$/mwh - 265.18$/mwh, respectively, bringing about 13% or 73% carbon emission reduction. After auctions exceed respectively 16% and 39%, no units gain additional revenue from the carbon market.

## DAY 4 Session 41

## Exploring Business Models for Social Inclusion and Carbon Emission Reduction via Post-Consumer Recycling Infrastructures in China: An Agent-Based Modelling Approach

Xin Tong, Haofan Yu
Organization(s): Peking University, China, People's Republic of

**Abstract**
The potential for carbon emissions avoidance through post-consumer recycling has been highlighted in the "Zero-Waste City initiatives" in China, which calls for increasing household participation in the community recycling programs. A shift from a facility-oriented strategy to behavior-oriented norm building at the community level can provide local niches for emerging business models. This paper proposes a framework to incorporate the carbon emissions reduction into recycling infrastructures to raise the participation rate of households in residential communities in China. With insights from more than 10 years of participatory research in Beijing, a questionnaire survey based on the Theory of Planned Behavior was conducted in 2021 in the city of Beijing (N=1906) to test the key factors which affect household recycling behavior. An agent-based model for community-based recycling which was developed in 2016 was updated based on the questionnaire survey to incorporate the institutional change in the development of zero-waste city initiatives. The results highlight the diverse efforts to upgrade the urban recycling system towards a transition to a low carbon transitionwaste management system. In conclusion, theFinally, guidelines for infrastructure design to incorporate the norm-based policy at the community level were proposed to explore the potential for carbon emissions reduction through household recycling activities in urban transition.

## What is a Circular City? - A Study of Literature Review and Bibliometric Analysis

Daan Schraven1, Zhaowen Liu1, Quirien Reijtenbagh2
Organization(s): 1: Delft University of Technology, The Netherlands; 2: Erasmus University Rotterdam, The Netherlands

**Abstract**
The circular city as a new city label has attracted a lot of attention from academics and practitioners. A circular economy keeps material flows in the loop through the integration of actors, facilities, and systems within a bound area to achieve sustainable development. As an economic system with high consumption and emissions, cities are naturally the best laboratories for exploring the circular economy. To better understand how circular cities have been defined and developed by scholars, this paper reviews the academic literature related to circular cities. First, we set a search scope of relevant literature using a bibliometric approach to build a database with 215 peer-reviewed articles. Based on this, we identified the most influential topics in circular city literature by analyzing author keywords:

urban sustainability, adaptive reuse of the built environment, and circularity indicators. Further, we collected 23 definitions of the circular city and identified four main aspects: circular city principles, characteristics, components, and goals. We found a high degree of overlap between circular city principles and those of the circular economy, including the Rs framework and closing, narrow, and slow resource loops. The circular city components include stakeholders, resources, built environment, mobility, industries, technology, business models, and organizations, but lack attention to other important elements at the city scale, such as regulations and knowledge networks. Finally, the goals of circular cities are mostly linked to economic prosperity and the environmental quality of the city, and only a few definitions give attention to social well-being in cities. Overall, we hope that this study will provide a comprehensive understanding of the current central themes of circular cities and their shortcomings, and thus provide actionable insights for a circular city to come into effect.

## The Temporal and Spatial Characteristics, and Influencing Factors of Carbon Emissions from Municipal Solid Waste in China

Feiyu Chen, Xiao Gu, Haimiao Yu, Xiaolin Zhang, Yujie Wang
Organization(s): China University of Mining and Technology, China, People's Republic of

**Abstract**
Understanding the temporal and spatial characteristics of carbon emissions from municipal solid waste (MSW) and a quantitative evaluation of the contribution rate of the factors influencing the changes in carbon emission are important for pollution and emission reduction and the realization of the “double carbon” goal. This study analyzed the spatial and temporal evolution of waste generation and treatment based on panel data from 31 Chinese provinces over the past 15 years, and then applied the logarithmic mean Divisia index (LMDI) model to study the driving factors of carbon emissions from MSW. China's MSW production and carbon emissions displayed a rising trend, and the overall carbon emissions showed a geographical pattern of being high in the east and low in the west. The carbon emissions generated by landfilling presented an inverted "U" shape, while the carbon emissions generated by incineration increased rapidly. Food and plastics were the main sources of carbon emissions from waste, accounting for 49.45% and 36.9% of the total emissions respectively. Carbon emission intensity, economic output, urbanization level, and population size were positive factors that increased carbon emissions. The most important factors driving carbon emissions were carbon emission intensity and economic output, with cumulative contribution rates of 56.88% and 46.14%, respectively. Solid waste emission intensity was a negative factor in reducing carbon emissions, with a cumulative contribution rate of -24.06%.These results have important implications for the design of policies to reduce carbon emissions from MSW.

## Towards Inclusive and Circular Urban Waste Management: Mapping the Waste Infrastructure System in Almere, the Netherlands

Zhaowen Liu1, Daan Schraven1, Martin de Jong2, Marcel Hertogh1
Organization(s): 1: Delft University of Technology, The Netherlands; 2: Erasmus University Rotterdam, The Netherlands

**Abstract**
Converting waste into resources is an important sustainable development strategy that can save natural resources and reduce the impact of waste emissions on the environment and human health. Rapid global urbanization and urban renewal accompanied by changes in people's lifestyles have led not only to an increase in waste generation, but also to more complex waste types. This poses new challenges to provide adequate and sustainable waste management services in cities. The primary key to addressing these challenges is to develop an urban waste infrastructure system (UWIS) that matches the future waste generation scenarios and sustainable development goals (SDGs). In this study, we first conducted a literature review to analyze the development of UWIS and its relationship with urban sustainable development. We found that UWIS has an impact on urban circularity and inclusiveness. Second, we developed a framework to define the UWIS and analyze its components, functions, actors, and factors that have an impact on it, as well as its impact on urban circularity and inclusiveness. This is followed by a case study of the Dutch city of Almere, one of the fastest growing cities in Europe and a pioneer in the pursuit of waste-free cities. We mapped the UWIS in Almere and identified the enables for its development and the challenges faced. As a result, we recognize that government-led waste infrastructure is only one part of the overall system. Efficient resource recovery facilities established by businesses under market rules and waste reuse facilities constructed by social organizations and individuals based on their own needs are key pieces of the puzzle to complete the UWIS. Meanwhile, we found that a more inclusive and circular UWIS can positively influence people's awareness and behavior toward waste management, leading to better business models and social innovations toward waste-free cities.

## Designing a Dynamic Simulation Model to Diagnose Root Causes of Failing Urban Waste Collection in Developing Countries

Hans Breukelman, Harold Krikke, Ansje Löhr
Organization(s): Open University of the Netherlands

**Abstract**
Cities in developing countries struggle with providing waste collection services to their citizens. Research in this field has mainly dealt with the symptoms. Our research aims at designing a System Dynamics simulation model of the urban system that may serve as a diagnostic tool to find root causes and leverage points for interventions.
We used a literature review to draw up a complex causal loop diagram describing relevant urban variables (demographic, economic, social, financial, technical and governance related) and their relations. The diagram was analysed by using qualitative methods, partly derived from graph theory. It results in an evaluation of variables, paths, loops and branches of the model and finally in a

simplified model. This model appears to be useful in diagnosis. The model suggests that the root cause is in populations growing faster than their economies and that this downward spiral is enabled by poor governance practices that are unable to secure that tax-incomes keep pace with needed budgets for sound services. The model also provides a basis for formulating a new taxonomy that classifies cities with regard to the effect and delay that urban processes have on any progress on waste management. During our presentation we want to present the model and discuss whether it is at the right level of simplicity and detail.
Our current research is now (i) to test and calibrate the model with real world data and (ii) to use the model in case studies. The challenge is mainly in the absence of usable data at the city level. For this reason we are now using the model at the country level in 3-5 developing countries. Our presentation will aim at discussing this switch from city to country level. Also, we want to present and discuss some preliminary findings on needed interventions.

## Factors Contributing to Food Waste in Crop Farms: A Case Study in Levubu Farms South Africa

Lethabo Phasha1, Matodzi Michael Mokoena2, Lutendo Sylvia Mudau3
Organization(s): 1: Tshwane university of Technology, South Africa; 2: Tshwane university of Technology, South Africa; 3: Tshwane University of Technology, South Africa

**Abstract**
Introduction: Despite the challenge of hunger in most parts of South Africa, postharvest food waste is one of the neglected amicable challenges in farms. It is estimated that postharvest food waste contribute to 50% of the total food waste. The most contributing factor is poor farm management which ranges from storage, packaging, transportation, handling techniques, temperature and poor harvesting techniques. A study was conducted in reclaimed Levubu farms to identify factors that contribute to food waste.
Aims/objectives: To identify factors that cause food waste in reclaimed farms of Levubu
Materials ad methods: A total of 14 farms were purposively selected from four reclaimed Communal Property Association in Levubu. Observation was conducted for an average of four days per farm in summer and in spring. A self-developed observation tool focusing on management of harvest, temperature, transportation, hygiene, storage conditions and other factors was used. The findings observed from the field where harvesting took place to the pack house were recorded and captured into excel spreadsheet then analysed using strata package version 17.
Results: An average of 9.8% of the harvested Banana crops were wasted, making it the most wasted crop. Of that, 25.5% was due to animal damage, mostly monkeys, 44% were ripe and- failed to be harvested on time, while 12.5% were too small. A further 18% got spoiled during storage where crops were exposed to unmonitored temperature up to seven days.
Conclusion: The study was able to show beyond reasonable doubt that if temperature is not regulated and management fails to plan for harvesting then food waste will continue to increase. Furthermore,

the study recommends training of workers on the factors of food waste as well as auditing and continuous monitoring of food waste to minimize the generation of postharvest food waste.

## DAY 4 Session 42

### A Protein Sustainability Index Based on the Integration of Fuzzy Logic and Particle Swarm Optimization

Tabassum Abbasi1, Tasneem Abbasi2, B.M. Jaffar Ali2, S. A. Abbasi2
Organization(s): 1: University of Petroleum and Energy Studies, India; 2: Pondicherry University, India

**Abstract**
Most of the existing food indices are designed to reflect the nutritional content of food sources or diets. Only a few attempts exist to combine the nutritional aspects with food security and/or ecological sustainability. Additionally, the existing indices have been formulated using crisp and deterministic approaches. These approaches necessitate sharp cut-offs between acceptable and non-acceptable limits and are unable to account for imprecise or/and uncertain data, often of the kind encountered in the application of indices related to sustainability.
In this work, a new index has been developed to reflect the sustainability of food sources in terms of environmental aspects of food production along with climate-related concerns and nutritional benefits. To overcome the shortcomings of crisp approaches, fuzzy logic, a technique which enables twilight zones to be quantified and is particularly designed to handle uncertain and imprecise data, has been used in conjunction with genetic and particle swarm algorithms to develop a new index. Its applicability has been tested on six sources of food consumed for their protein - milk, eggs, beef, pork, chicken and mealworm. Mealworm was seen to acquire the highest score in terms of sustainability and was categorised in the ‘excellent sustainability’ range. Milk, beef and pork were among the worst, exhibiting ‘low sustainability’. The index shows that protein sources from mini-livestock such as mealworm are much more sustainable in terms of lesser damage to the environment as well as better nutritional quality in comparison to the conventional macro livestock typified by beef and pork.

### Digitalization and Perceptions of the Sustainable Development Goals: Micro Evidence from Chinese Citizens in Jinan, Shandong Province

**Zheng Yang**
Organization(s): Beijing Normal University, China, People's Republic of

**Abstract**

Digitalization offers promising opportunities for achieving sustainable development goals (SDGs), yet the relationship between the two is often not fully discussed. From a citizen's perspective, little is known about whether and to what extent digitalization enhances or jeopardizes sustainability. Based on survey data from Jinan, Shandong Province, China, this paper studies how citizens' different ways of using digitalization affect their satisfaction with SDG 1 (no poverty), SDG 10 (reduced inequalities) and SDG 11 (sustainable cities and communities). The results of the structural equation model (SEM) showed that online material acquisition significantly worsened their satisfaction with the three selected SDGs, while online information acquisition significantly promoted satisfaction. Hence, digitalization significantly affects citizens' perception of SDGs in Jinan, where digitalization is extremely prevalent, and it is the way citizens use digitalization that is the key. This study provides important insights into the links between digitalization and sustainable development, which may contribute to future policy and planning for digital applications.

## Consumers' Perceptions towards the Introduction of Extended Producer Responsibility (EPR) for Plastic Beverage Packaging in Malaysia

KHALILULNISHA ABU BAKAR, AHMAD FARIZ MOHAMED
Organization(s): NATIONAL UNIVERSITY OF MALAYSIA

**Abstract**
Increased consumption of beverages in single-use plastic packaging contributes towards the amount of plastic waste being generated and disposed into the environment. To address this, Malaysian authorities have agreed to adopt a mandatory Extended Producer Responsibility (EPR) approach in 2026 to reduce plastic waste and encourage plastic circularity. Consumers' participation is often imperative for EPR programmes to become effective. Therefore, a survey was carried out to gauge their willingness to participate and pay in the EPR programme and to identify consumers' expectations of the EPR programme. The results indicated that most of the respondents support the authorities' plans to implement EPR and provide other related inputs on factors that would encourage consumer participation in the programme. The respondents are also willing to pay a minimal fee if a deposit refund system (DRS) is in place to manage plastic beverage packaging. The respondents who do not agree with EPR and DRS indicated that system, infrastructure, mindset, awareness and education must be in place first before the implementation of EPR. The respondents are also less favourable towards the implementation of advance disposal fees or landfill tax. These findings are timely as it can assist Malaysian authorities and other related stakeholders in developing a suitable governance system ahead of the actual mandatory EPR implementation in 2026. The findings can also be extended to plastic packaging for other types of fast-moving consumer goods as well.

## Uncovering the Coupling Effect with Energy-Raleted Carbon Emssions and Human Development Variety in Chinese Provinces

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Organization(s): 1: Building Energy Big Data Group, International Research Center for Sustainable Built Environment, School of Management Science and Real Estate, Chongqing University, Chongqing 400045, PR China; 2: State Key Joint Laboratory of Environment Simulation and Pollution Control (SKLESPC), School of Environment, Tsinghua University, Beijing, 100084, China; 3: Key Laboratory of the Three Gorges Reservoir Region's Eco-Environment, Ministry of Education, College of Environment and Ecology, Chongqing University, Chongqing 400045, China

**Abstract**
Reducing energy-related carbon emissions has become the essential measure to mitigate global climate change and achieve Chinese carbon neutrality. This study is the first to construct the Difference in Carbon pressures-adjusted Human Development Index (DCHDI) model for exploring the coupling effect between carbon emission per capita and human development variety from 2000 to 2019 at the provincial level in China. We demonstrate the following. (1) The coal products in 17 fossil fuels and energy production in 47 socioeconomic sectors are the largest energy-related carbon emissions during 2000-2019, and provinces with the highest carbon emission per capita are InnerMongolia, Ningxia, and Shanxi. (2) At the provincial level, we observed the Human Development Index (HDI), which includes life expectancy, education, and income, has been rising, while Beijing, Shanghai, and Tianjin entered the super high HDI level before 2008. (3) The overall coupling effect of China's 30 provinces has been generally reinforced in the past 20 years, but the growth rate of DCHDI value in 2010-2019 is has slowed down compared with that in 2000-2010; the clustering phenomenon explained that this finding is related to historical peaks in total carbon emissions. Overall, this study provides guidance for the government on carbon emissions mitigation strategies and a valuable decision-making reference for other countries attempting to promote sustainable development.

## Which Battery Is Better Suited for China?-- A Life Cycle Risk Assessment Analysis

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**Abstract**
Lithium-ion batteries (LIBs) and alternative systems are transforming the world's energy infrastructure. To ensure the safe development of energy infrastructure and the smooth realization of carbon peak and carbon neutrality, it is necessary for China to ensure stable access to essential materials. In this paper, we used a method to quantify regional supply risks of China's lithium

batteries (LFP, NMC-111, NMC-442, NMC-532, NMC-622, NMC811, LR-NMC, NCA and NCA-955) and alternative systems (sodium-ion batteries, lithium-sulfur batteries, lead-acid batteries, lithium-air batteries, etc.). The examined battery materials include lithium, cobalt, nickel, manganese, iron, aluminium, sodium, sulfur, phosphorus, sulfur, titanium, vanadium, boron and other materials. The average risks and trend of battery technologies from 2010 to 2020 were analyzed. Contents to be explored: (1) the risk situation of various battery raw materials in China and how the risks change? (2) What kind of battery technology is more suitable for China? (3) What kind of development path is more suitable for China's battery technology?

## The Societal Strength of Transition: A Critical Review of the Circular Economy through the Lens of Inclusion

Zhaowen Liu1, Daan Schraven1, Martin de Jong2
Organization(s): 1: Delft University of Technology, The Netherlands; 2: Erasmus University Rotterdam, The Netherlands

**Abstract**
Realizing a circular economy (CE) is key for transitioning towards sustainability. Thus far the academic emphasis has been predominantly on economic and environmental aspects. However, the development and implementation of CE initiatives actually rely on extensive collaboration at the societal level. Hence, an understanding of how a more inclusive society can strengthen the CE transition is warranted. By systematically and critically reviewing the related academic literature, the results of this paper show that sensitivity to inclusion aspects is crucial to enable society to become less of a passive field full of victims but rather activated as a driving force for circularity transitions. Seven main aspects were discerned in inclusion: (1) informal waste pickers, (2) e-waste and health risks, (3) accessibility of services/materials/facilities, (4) consumer behavior, (5) corporate and institutional involvement, (6) technology application, and (7) governance measures. Following these insights, a strong sustainability perspective and a research agenda for the CE transition are proposed by identifying key actors and structuring their interrelationships as an inclusive CE system.

# DAY 4 Session 43

## Integrated Assessment to Explore Strategies for Swine Manure Management: A Case Study in Yunlin County, Taiwan

Liang-Chun Yeh, Zih-Ee Lin, Pei-Te Chiueh
Organization(s): National Taiwan University, Taiwan

**Abstract**

In Taiwan, water pollution due to swine manure has been a serious issue. To solve this problem and reduce greenhouse gas (GHG) emissions, policies have encouraged biogas-power generation from livestock waste in recent years. This study aims to evaluate the impacts of swine manure reuse strategies. Three manure management scenarios were designed. They are untreated wastewater (S1), three-stage wastewater treatment (S2), and biogas center (S3). Livestock farms and fertilizer plants in Yunlin County, Taiwan, were selected as a case study area.
We applied material flow analysis (MFA) to analyze the benefits of substituting nitrogen fertilizer with untreated swine manure or biogas residues. MFA results show that nitrogen fertilizer available for crop cultivation in three scenarios is 6.89, 0.68, and 5.17 kg N/year, respectively. Reusing swine manure can reduce the requirement for chemical fertilizers and green manure for feed cultivation. Optimum allocations of centralized manure treatment plants with minimum transportation impacts were derived by the geographic information system (GIS). Distribution results of fertilized farmland show that the treatment plant in Mailiao Township is prone to generate more manure than the farmland requires. Therefore, S2 is preferable from the aspect of nitrogen fertilizer substitution.
In the case study area, we suggested that centralized manure treatment plants should be built in Baozhong Township and Tuku Township, adjacent to Mailiao Township. To avoid GHG generation and harmful gas emissions, closed space for swine manure storage and improvement of manure irrigation methods are recommended.

## Study on Regulation Mechanism of Complex Adaptive System of Municipal Solid Waste Management

Tiening Cui, Mengdie He
Organization(s): Beijing University of Technology, China, People's Republic of

**Abstract**
In order to realize the reduction, resource and harmlessness of municipal solid waste, optimize the management system of municipal solid waste. Based on the theory of complex adaptive system, this study constructs the MSW management system, and uses couples multi-agent based models(ABM) and system dynamics(SD) models to simulate and optimize the MSW management system from the perspective of government management means and recyclables marketization. The optimal scheme combination is studied by simulating the government-resident-enterprise relationship and adjustment policies on municipal solid waste combination of various scenarios. Results show that the implementation of a single policy can increase the recycling collection promote the development of recycled materials industry chain, but there are still a lot of recycling cannot be recycled, in view of the possible future development in Beijing, three kinds of optimization of urban living garbage management system is designed, respectively is Business as usual scenario(BAU), Plan scenario(PS) and Integrated scenario(IS), under the IS, The recycling amount of municipal solid waste has been improved, the recyclable industry chain has developed better, and the urban household garbage management system of each IS is better than that of a single measure. By simulating different IS, the study found that the municipal solid waste management system was optimized, and it results

provided decision-making and research support for Beijing to realize national waste classification, recyclable recycling, and non-recyclable waste treatment and management.

## Evaluating the Waste and CO2 Reduction Potential of Packaging by Reuse Model in Supermarkets in Taiwan

Cian-Wei Chiang, Hsin-Yu Chang, Yu-Nien Ku, Hsin-Tien Lin
Organization(s): National Cheng Kung University, Taiwan

**Abstract**
The consumption of single-use packaging have been increasing globally and the waste produced causes negative impacts on both human and the environment. Bans or charges on plastic bags have been implemented in many countries to try to reduce plastic usage, but without much success. On the contrary, the change to bio-plastic or paper bags resulted in an increase of overall waste. New methods are sought, and many countries began to adopt the concept of circular economy and new business models. Retailers, such as supermarkets, developed quickly in recent years to provide for the modern lifestyle, using a lot of packaging in the process of distribution and sales. This research evaluates the waste and CO2 reduction potential of 10 different products sold in supermarkets in Taiwan when adopting different reuse strategies of Reduce, Return and Refill. In the suggested reuse strategies, a total of 8.2 kilotons of packaging waste and 22 kilotons of packaging CO2 can be reduced, which accounts for 53% and 57% reduction of the current situation, respectively. Consumers adoption willingness of different use strategies are found to be higher when they are more familiar with the consumption method. The degree of acceptance is also proportional to regulations or the accessibility of the reuse strategies in retailers. It is suggested that retailers provide different reuse strategies for consumers and hold experiential activities to increase consumers familiarity with new consumption methods. Significant impacts can be made with only a slight change in the small proportion investigated, which suggests considerable benefits if the scope is expanded.

## Artificial Intelligence Identification of Solid Waste Landfills Based on Multi-Source Data Fusion

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Organization(s): 1: College of Civil and Transportation Engineering, Shenzhen University, Nanshan, Shenzhen, China.; 2: Sino-Australia Joint Research Center in BIM and Smart Construction, College of Civil and Transportation Engineering, Shenzhen University, Nanshan, Shenzhen, China.

**Abstract**
Landfill is currently the most widely used disposal method of solid waste. However, the management of solid waste landfills is usually based on field surveys, which are time-efficient and wasteful of a

lot of human and financial resources. Remote sensing technology, with its low cost and high efficiency, is gradually being applied to various fields of the earth's ecological environment, providing data and technical support for the dynamic identification of landfill sites in large areas. Therefore, the aim is to combine multi-source remote sensing data for the artificial intelligence identification of landfill sites. This study uses CB04 and sentinel2A satellites to collect hyperspectral and temporal resolution remote sensing images of 348 landfill data that have been collated across China. By building a landfill remote sensing image dataset, dividing the dataset into a training set and a test set according to 7:3, and using a deep neural network model (deeplab3+ ) for image semantic segmentation, a novel remote sensing ground objects recognition model for typical landfill sites is constructed. The experimental results show that the deeplab3+ model can effectively segment the semantics of the landfill in the test set. This study not only constructs a landfill remote sensing image dataset but also facilitates the intelligent recognition of landfills.

## Assessment of Landfill Mining Potentials of Municipal Solid Waste in China

Yuehao Zhi1,2, Shijun Ma1,2, Chuanbin Zhou1,2
Organization(s): 1: Stake Key Laboratory of Urban and Regional Ecology, Research Center for Eco-Environmental Sciences, Chinese Academy of Sciences; 2: University of Chinese Academy of Sciences

**Abstract**
Utilization of stored waste in municipal solid waste landfills has become a emerging issue in urban material metabolism research and ecological restoration practice. For the post-closure landfills, landfill mining can not only reduce the environmental impacts such as leachate and odor, but can also extend the lifespan of landfills. However, at present, there is still insufficient methods and high-resolution datasets for assessing the potential of landfill mining and stored utilization at the national scale of China. Here, 346 prefecture-level cities and regions in China were selected as the studied case. Based on the quantification of landfill stock, eight indicators from two dimensions, i.e., resource benefit and environmental impact, were selected for assessing the landfill mining potential, and an entropy weight method was used to integrate those indicators. Main results are: (1) in the past 20 years, the material stock of landfills in China was 2139.71 Tg. Among them, soil-like materials and stones were the largest fractions of stored waste. The stock of carbon, nitrogen, phosphorus and potassium accounted for 31.85 %, 0.47 %, 0.85 % and 0.67 % of the material stock, respectively. (2) There were significant regional differences in resource benefits and environmental impacts of landfills in China, e.g., East and Central south China had higher incineration potential and lower utilization potential of key elements stock, while North, Northwest and Northeast China were much lower. This study proposes countermeasures and suggestions on landfill mining and eco-restoration for different regions and cities in China, which can provide scientific evidences for relevant policies, plans and projects of landfill restoration and utilization in China.

## The Economic Rationale for Adopting Waste-to-Energy in Sub-Sahara Africa

Nkweauseh Reginald Longfor1, ADUBA Joseph2, Ioan-Robert Istrate3, QIAN Xuepeng1
Organization(s): 1: Graduate School of Global Environmental Studies, Sophia University, Japan.; 2: Ritsumeikan BKC Research Organization.; 3: Institute IMDEA.

**Abstract**
The rapid growth in the world's population coupled with economic development poses several environmental threats, such as increased waste generation. The prevailing liner models of production and consumption promote single-use of materials and low levels of recycling, thus, resulting in several environmental issues. Waste management has a critical role in meeting the sustainable development goals due to its all-encompassing impact on the environment, people's health and well-being, and society. This study assessed the economic impact caused by stocks of accumulated GHG emissions from poorly disposed of municipal solid wastes in Sub-Saharan Africa. The assessment calculated the economic viability of emission-reduction strategy via waste management. A particular focus was directed towards the stock build-up and impact of negative externalities on Sub-Saharan African countries' economies over 60 years (from 2000 to 2060). Thus, urging stakeholders to invest in policies that will encourage proper waste management now, rather than wait for stocks to build up to extreme levels. The findings revealed a Net-Present Value of US $3.12 billion on Waste-to-energy projects - Sanitary landfills and Anaerobic digestion. The study recommended that investing in emission reductions now is more economical than investing in emission reduction in 50 years or more, when the concentration of GHG emissions may have reached very high levels. Furthermore, companies, governments, and consumers need to adopt and adapt to new sustainable waste management practices to tackle these environmental issues in Sub-Saharan Africa.

# DAY 4 Session 44

## Evaluating the Environmental Cost of the EV Policy in India

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Organization(s): 1: Institute for Global Environmental Strategies (IGES), Japan; 2: Waseda University

**Abstract**
Developing countries have announced ambitious Electric Vehicle (EV) targets. What will be the implications of the EV transition? Academic literature on the topic has not focused on challenges in Global South.
This study investigated the case of India. We evaluated the environmental cost of the EV policy based on the projected EV sales, the estimated battery wastes, and a lifecycle assessment model on battery waste treatment. We considered lead-acid batteries and lithium-ion batteries with NMC cathode (nickel, manganese, and cobalt).

We found that the sale of two-wheeler EVs will peak at around 20 million units at 2030, continue at this peak till 2042. The sales of four-wheelers EVs will increase to 10 million units in 2050. The battery waste problem will happen sooner because two-wheelers like motorbikes with cheaper but shorter-lifespan. Lead-acid batteries dominate the market during the early transition; the lead-acid battery waste will peak in 2025.
Recycling lead-acid batteries and NMC batteries will save several materials though their environmental impacts must be managed. We normalized the environmental impacts of the anticipated battery waste treatment industry against the steel industry in India. We found that by 2050, the global warming potential, damage to ecosystems and damage to human health (ReCiPe method) will reach more than 1% of the steel industry from a nationwide perspective.
Most lead-acid batteries are currently recycled in the informal sector where occupational safety for workers remains a concern. A formalised recycling system needs to be established to improve the situation, especially for the emerging NMC batteries.
Globally, as we discuss net-zero mobility options, relevant stakeholders shall consider the implication of this work – an urgent focus on the battery waste management in Global South. Failure to establish and enforce systems will lead to health impacts, pollution, and other consequences.

## Tracing Metal Footprints through Global Renewable-Power Value Chains

Rao Fu1, Kun Peng1, Peng Wang2, Honglin Zhong1, Pengfei Zhang1, Yiyi Zhang3, Xi Liu1, Kuishuang Feng4, Jiashuo Li1
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**Abstract**
The globally booming renewable power industry has stimulated an unprecedented appetite for metals as key infrastructure components. Many economies with different endowments and technology levels participate in global renewable power value chains (RPVCs) at different production stages, making it difficult to tell who supplies metals for whose low-carbon power generation. Here, we employed a quantitative framework to gauge metal footprints (MFs) and value-added of major global economies' renewable power sectors by combining the multiregional input-output model (MRIO) with a value chain decomposition model. Then, a structural decomposition analysis (SDA) model were applied to investigate the driving force of the metals embodied in trade to uncover the drivers of growing MFs inequality along the global RPVCs. We found the MFs of global renewable power sector increased by 1/3, and the outsourced metals increased by 44% during 2005-2015, mainly driven by developed economies. Specifically, to meet ambitious renewable energy targets, developed economies occupy the high-end segments of the RPVCs, while transfer metal-intensive but low value-added production activities to less developed economies. The metal footprints (MFs)

inequality rises with expended outsourcing of metals demand for renewable power sector. For instance, the quantity of embodied metal transferred doubled between developed and developing economies and the gap of metal use per unit of export-induced value added grew by 13 times. This findings relates partly to the fast growing demands for renewable power in developed economies leading to the embodied metal transfer increment within RPVCs, though partly offset by declining metal intensity in less developed economies. Therefore, joint efforts such as establishing metal-efficient and greener supply chain for upstream suppliers and downstream renewable power installers are in urgent need to ensure a just transition in power sector across the globe.

## Optimal Production and Maintenance Strategies for Manufacturing/Remanufacturing Leasing System Considering Uncertain Quality and Carbon Emission

Yanping Liu, Biyu Liu
Organization(s): Fuzhou University, China, People's Republic of

**Abstract**
This paper studies the production and maintenance decision of manufacturing/remanufacturing system, by considering the impact of the quality level of end-of-life leased products on manufacturing and remanufacturing equipment and remanufacturing rate. Due to the differentiated demand of the lessees, the quality of the end-of-life leased products is uncertain. The recycled products of different quality will influence the production, maintenance and carbon emission of the manufacturing and remanufacturing equipment by affecting the remanufacturing cost and the remanufacturing equipment degradation. A production and maintenance decision-making model aiming at maximizing the lessor’s profit is formulated with respect to constraints like production, maintenance, carbon emission and inventory cost of production equipment and the maintenance cost of the leased products. The optimal production quantities and preventive maintenance intervals of production equipment, and remanufacturing cost threshold of recycled leased products are obtained by solving the model with particle swarm optimization algorithm.
The results show that: (1) With the increase of remanufacturing cost threshold, more remanufactured products with lower price and better environmental protection will replace new products, which will accelerate the remanufacturing equipment degradation and shorten the preventive maintenance period. The increased equipment maintenance cost is offset by the saved production cost and carbon emission cost, so the lessor’s profit increases first and then decreases; (2) As the remanufacturing cost threshold rises, the quality deviation of the recycled leased products intensifies, resulting in an increase in carbon emission from remanufacturing equipment. While, the carbon emission from remanufactured products is lower than those from new products, the production equipment achieves the goal of carbon reduction; (3) By appropriately extending the lease period of the leased products, and strengthening the preventive maintenance of production equipment, we can reduce the carbon emission generated in the production process, and achieve the synchronous growth of economic benefit and environmental protection.

## Underestimated Environmental Benefits of Solid Waste Resource Utilization: Evidence from a Life Cycle Perspective

He Xu, Dongfang Guo, Huimin Hou
Organization(s): College of Environmental Science and Engineering, Nankai University, Tianjin, China

**Abstract**
China's rapid urbanization and industrialization process is accompanied by the generation of a large amount of solid waste. So far, the historical stockpile of bulk industrial solid waste in China has exceeded 60 billion tons, and the large amount has become a stumbling block for the low-carbon development. Under the background of circular economy, "Zero-Waste city" construction, and "Carbon Peaking and Neutrality Goals ", solid waste resource utilization can not only avoid environmental problems caused by end-of-pipe treatment, but also have multiple functions such as synergizing the reduction of pollution and carbon emissions. Solid waste resource utilization is also a common issue for sustainable development worldwide. However, as for the current practice of solid waste management in China, there is an extremely lack of basic data on the metabolism of bulk industrial solid waste for recycling, and the environmental impact of its resource utilization is unknown. Material flow analysis (MFA) can clarify the material metabolism law of bulk industrial solid waste resource utilization process, identify the key nodes of each link in the construction of circular economy, realize efficiency evaluation, and provide basic data for subsequent management and intervention. Life cycle assessment (LCA) can quantitatively evaluate the environmental benefits brought by solid waste resource utilization based on the whole life cycle perspective, which can help in climate change mitigation and sustainable management, promote the co-reduction of pollution and carbon emissions and the overall green transformation of economic and social development. This study takes tailings, which is the largest volume of industrial solid waste, as an example, and demonstrates the feasibility of solid waste resource utilization to help reduce pollution and carbon, develop circular economy and build a "Zero-Waste city" through a combination of MFA and LCA, and provides a framework and methodological reference for the management of other solid waste.

## Separation of Cathode Material and Aluminum Foil Using an Eco-Friendly Deep Eutectic Solvent

Jiahui Niu, Haifeng Wang, Zhenxing Zhang, Jinlong Li, Chang Xiao, Zihui Zhang, Yaqun He
Organization(s): China University of Mining and Technology, China, People's Republic of

**Abstract**
In the field of cathode material recycling in spent LIBs, the separation of aluminum foil and cathode material is an important prerequisite for subsequent recovery processing. There is a strong binding force between cathode and aluminum foil, as well as particles, because of the binder polyvinylidene

fluoride (PVDF). Traditionally cathode material dissociation technology, usually use strong alkali, organic solvent, mechanical crushing or high temperature roasting and other technologies. However, it is easy to cause the aluminum foil to be difficult to recover or produce harmful gas, which is harmful to the environment and health. In this study, an economical and eco-friendly deep eutectic solvent (DES) was proposed for the separation of cathode materials from aluminum foil. The separation effect of DES on cathode material and aluminum foil was investigated by controlling the ratio of choline chloride-xylitol-water DES system, heating time, heating temperature and the amount of anode sheet. The results show that under the conditions of 2:1:13 molar ratio, solid-liquid ratio of 40:1 g/L, heating temperature of 140 °C, heating time of 20 min, the peeling percentage of cathode material reaches 90.13%. Scanning electron microscope (SEM) shows that, complete and clean LiCoO2 particles can be liberated after DES dissolution. In the mechanism analysis, it is found that the separation of cathode material and aluminum foil is due to the inactivation of PVDF binder, the main reason is that the alkaline hydroxide produced by choline chloride acts on the acidic hydrogen atom in PVDF and destroys the molecular structure of the PVDF. This study has the characteristics of economy and eco-friendly, which proposed widely used for the recovery of cathode materials of spend LIBs, and has a great application prospect.

## What Does an Adaptable Building Look Like?

Henry Watt1,2,3, J Buick Davison1, Peter Hodgson2, Chris Kitching3, Danielle Densley Tingley1
Organization(s): 1: The University of Sheffield; 2: Tata Steel Europe Ltd; 3: Mott MacDonald Ltd

**Abstract**
In recent years, the structural engineering field has become increasingly focused on the climate crisis, resulting in a heavy focus on operational efficiencies and initial material optimisation. A risk of this solely optimisation-focused design, however, is the lack of future-proofing of the structure if it were to be subject to changing usage, occupancy or environment. This is where adaptability comes into play.
The exact definition of adaptability in the built environment is contentious, with many researchers highlighting a lack of consensus as a blocker to the adoption of adaptive designs. Nevertheless, the definitions typically allude to a building's ability to accommodate changes throughout its life without the need for significant refurbishment.
Proposals of adaptable building characteristics have been suggested by academia; however, many of these strategies are, as of yet, untested in industry. The proposals include, but are not limited to: optioneering of the structural layout (grid spacing and floor-to-ceiling heights), a layered approach to design and the careful use of overdesign or overspecification of certain building elements.
As some adaptability strategies conflict with optimisation, there is an apparent need to balance adaptability and optimisation; balancing the potential increase in initial carbon costs in order to reduce the overall extent of carbon emitted over the whole structural life cycle.
The authors of this research propose that the adoption of these design strategies will be limited without a full understanding of their application in a live design project, i.e. what does an adaptable

building actually look like? This research explores some of the adaptable design strategies, highlighting their potential benefits and costs (both financial and carbon), exploring how they could be employed on a feasible design, and concluding with suggestions for further research into each of these proposals.

## DAY 4 Session 45

### Generation and Management of Municipal Solid Waste in Top Metropolitans of China and in Comparison with Singapore

Hongping He1, Xiaofeng Gao2, Xunchang Fei3
Organization(s): 1: Shenzhen University, China, People's Republic of; 2: Chongqing University, China, People's Republic of; 3: Nanyang Technological University, Singapore

**Abstract**
The rapid urbanization in the last decades, especially after the year of 2000, gives birth to several metropolitans e.g., Beijing, Shanghai, Guangzhou, Shenzhen, Tianjin and Chongqing that located at four world-class megalopolises across China. The generation and management of municipal solid waste (MSW) are important constitutes for city development, both of which should be spatiotemporally heterogeneous among these metropolitans, as a result of diverse social-economic statuses. This study attempts to sufficiently reveal the spatiotemporal heterogeneity by determining the MSW per capita, MSW composition, and proportion of each management strategy (landfilling, incineration, and compositing) as a function of time. Singapore is taken for comparison, for it is a Chinese community and well-known for the outstanding performance in environmental sanitation. The results show that MSW per capita is highly dependent on GDP per capita, and exerts an increasing tendency with time, but can be relieved with MSW mass reduction policy. For each metropolitan, the developments of landfilling and incineration fit to the Kuznets curve well, and government policy is more than the determinant factor than GDP. The MSW composition is also time- and location- dependent, and the source classification uniformly favors the subsequent resource utilization including the mainstream incineration. In addition to MSW generation and management, the action, goal, and experience in Singapore are expatiated, which is believed of referential significance for these metropolitans.

### An Environmental and Financial Comparative Assessment of 3D Printing and Injection Moulding of Plastic Packaging

Cheryl Marie Bezzina, Paul Refalo
Organization(s): University of Malta, Malta

**Abstract**

The drive towards sustainable manufacturing has led companies to opt for environmentally conscious technologies. 3D printing has been introduced as a technology that could potentially reduce the environmental burden caused by conventional manufacturing processes.
The aim of this study was to assess the environmental and economic feasibility of using 3D printing to mass produce cosmetic plastic packaging. Fused deposition modelling (FDM) as the 3D printing technology was compared to injection moulding (IM). A life cycle assessment (LCA) was used to assess the impacts of raw material production and manufacturing processes for both technologies to produce eighteen million compacts made from ABS over twelve years. Results obtained showed that using FDM generates a five times larger environmental impact, with printing electricity consumption accounting for more than 80% of the total impact.
A life cycle costing (LCC) exercise was carried out to assess the economic feasibility of implementing FDM instead of IM to produce the compacts. Using costing models, the cost per compact when using IM and FDM were € 0.09 and € 1.58, respectively. The largest contributor to the cost of the FDM compact was the material, which is more expensive than granules for IM. Moreover, a net present value (NPV) model was used to understand the costs incurred over twelve years of compact production. The total NPV using FDM resulted to be 17 times greater than if IM was used. This further led to the conclusion that FDM is still not a financially viable alternative compared to using IM to mass produce the compacts. Finally, quality testing was also carried out, showing that the moulded compacts were of superior visual and functional quality compared to the printed compacts. In summary, this study concluded that currently 3D printing is not a feasible alternative for IM to mass produce the compacts.

## A Comparative Analysis of Closed-Loop Recycling Technologies for Most Common Plastics


### Taylor Uekert
Organization(s): National Renewable Energy Laboratory, United States of America



**Abstract**
The United States generates an estimated 42 million metric tons of plastic waste each year - the most of any country - resulting in pollution and lost chemical and energetic resources. Recycling strategies will play a pivotal role in recapturing this wasted material. As the plastic recycling landscape expands, it is crucial to implement novel technologies in an environmentally and economically beneficial manner, yet there is currently no database to guide the holistic making of such decisions. This work utilizes a rigorous modelling framework combining techno-economic, life cycle, and material flows analysis to quantitatively compare current and next generation recycling technologies. The scope includes mechanical recycling, solvent-based dissolution, glycolysis, methanolysis, and enzymatic hydrolysis of the top four most widely utilized polymers: high- and low-density polyethylene (HDPE, LDPE), polypropylene (PP), and polyethylene terephthalate (PET). The technologies are assessed across environmental (greenhouse gas emissions, energy use, water and land use, toxicity, waste production), economic (minimum selling price), and technical (material

quality, material retention, circularity index, contamination tolerance) metrics to capture key benefits, disadvantages, and trade-offs. Multi-criteria decision analysis highlights preferential applications for the different recycling technologies, and sensitivity analysis allows for the identification of future research directions for improving the viability of these techniques. This work provides a baseline for the current and upcoming plastic recycling landscape and establishes a robust methodology for characterizing future recycling breakthroughs.

## Exploring Citizens' Adaptive Capacity for Sustainable Plastic Waste Programs

Thi Thanh Thuy Phan, Van Viet Nguyen, Chun-Hung Lee
Organization(s): National Dong Hwa University, Taiwan

**Abstract**
To cope effectively with the reduction of plastic waste, the community will need to change existing practices or behaviors. However, each community may offer different perspectives to adapt plastic waste management (PWM) strategies. So, raising a key point for policymakers is how to respond to changing circumstances and adaptability to reduce plastic. Based on the aspects of adaptive capacity and community capital framework, we adopted the choice experiment to explore the citizens' preferences for PWM strategies by estimating the heterogeneity of citizens' preferences and their willingness to participate (WTP) under multiple proposed PWM scenarios. The results provide strong policy implications for PWM, as citizens prefer to engage with alternative PWM strategies over the current ones. The strategy of adopting a zero-waste lifestyle is the foremost concern of respondents, followed by empowering community organizations and using recycled or eco-friendly materials. It also confirmed the existence of heterogeneity in the preferences for adaptation strategies in PWM, as evidenced by their willingness to separate at home, participate in campaigns to protect the environment, and a WTP in adaptive strategies to manage PW. Also, the scenario of adapting plastic waste management generated the highest marginal WTP among PWM scenarios. These findings could be utilized to develop tailored made policy, management, and adaptation measures for plastic waste reduction in the future, resulting in a more resilient community.

## Identifying and Mapping the Hotspots of Plastic Takeaway Packaging Waste Generation in Chinese Cities

Liu Qiuli, Zhou Ya, Wang Tianle, Guan Aiqun
Organization(s): Guangdong University of Technology, Guangzhou, China

**Abstract**
With the booming development of e-commerce, online food delivery services have been praised for their convenience and efficiency, which lead to a large amount of plastic packaging waste (PPW) and environmental impacts. This study proposed a top-down data-driven approach to estimate street-

level PPW generation for different food consumption categories in China cities. The online food ordering data and vector data were combined in a GIS environment, and kernel density analysis is combined to identify the PPW hotspots. The results showed that the countrywide total PPW came to 132.72 kilotons in 2018. 36% of PPW came from home-style food, followed by wheaten food (29%), hot pot and grilled food (17%), Chinese local snacks (13%), and western food (5%). City clusters in the Yangtze River Delta, Jing-Jin-Ji and Pearl River Delta account for 54.72% of total PPW. This indicates that people living in coastal cities prefer takeaway food and generated more PPW and face rising risks of plastic leakage. The findings identify spatial distribution characteristics and hotspots of takeaway PPW in China, and provide scientific basis for targeting plastic pollution in food delivery service.

## Learning Our Way toward Sustainability in the Plastic Food Packaging Sector: Designing for High Circularity and Low Environmental Impact

Yucheng Fu1,2, Elizabeth Kurucz2
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**Abstract**
The plastic food packaging sector has been continuously growing worldwide. EOL (end of life) disposal for plastic packaging and related environmental and social impacts have been identified as a societal crisis, yet solutions for how to address this are underdeveloped.
In this paper we engage in a review of multi-level governance processes (state, civil and corporate) overseeing sustainability issues in the plastics industry and identify strong, yet primarily undercoordinated, initiatives to improve the sustainability of plastic food packaging. In recent years, global efforts have acknowledged plastic packaging circularity as the main means to address plastic packaging sustainability issues. However, current policy and regulations leave companies unclear on how to navigate the complex trade-offs among environmental, performance, functionality, and commercial viability. We describe more sustainable plastic packaging as having a low environmental impact with packaging waste needs circulated back to the industrial system for high circularity. Building on our detailed stakeholder mapping, this paper develops a roadmap for plastic food packaging sustainability to direct organizations as to how they might initiate and focus their efforts. Using a single, double, and triple-loop learning framework we inform organizations how to respond to sustainability issues by systematically asking different levels of questions to drive related levels of innovation (from incremental improvement to game-changing transformation). A five-step methodological framework adapted from Design for Six Sigma is developed to guide packaging designers on how to design for plastic food packaging sustainability.
We conclude by recognizing how the long-term achievement of the UN Sustainable Development goals, eliminating social and environmental harms & shifting toward more sustainable values, requires a transition from the current socio-technical systems approach toward more sustainable modes of production and consumption that challenge existing societal norms.

## DAY 4 Session 46

### Energy Wars - Costs and Consequences of Continued Trade of Fossil Fuel Energy Resources

Amanda Kramer, Jie Zhuang
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**Abstract**
The invasion by Russia of Ukraine focuses on regions rich in fossil fuels, indicating economic motivations. The economic and political ramifications of this conflict threaten global food security both directly through the disruption of trade of agricultural products such as wheat and sunflower oil, and indirectly through the availability of potassium and nitrogen fertilizers and the loss of labor due to civilian evacuations. The damage done and yet to come underscores the imminent need to replace fossil fuels with alternative and diverse energy sources to remove market demand for fossil fuels and reduce monetary motivations of potential future conflicts. To do so in a responsible manner, key exporters of aluminum, glass, steel, and lithium require protection and the encouragement of fair trade agreements to avoid replacing one conflict with others. Promoting new ways to achieve local food production can increase stability of impoverished countries.

### Assessment Index of Energy Consumption Related to Industrial Waste

Marina Monteiro Mendonça1, José Arnaldo Frutuoso Roveda1, Andrea Trianni3, Eduardo Verri Liberado2, Sandra Regina Monteiro Masaslkiene Roveda1, Fabio de Oliveira Neves2
Organization(s): 1: São Paulo State University, Brazil; 2: Federal University of Alfenas, Brazil; 3: University of Technology Sydney, Australia

**Abstract**
Improving sustainability of energy consumption is vital for increasing the environmental quality of a given sector, since it has an enormous potential for the control of emissions that cause the greenhouse effect. The relationship between energy consumption and waste emissions is often linked to the type of sector and contribution. Especially in the industrial sector, there is not a methodology that can streamline the assessment of energy consumption during the emission of waste, and it would be helpful in reducing pollution, as well as contribute to energy efficiency improvement. In this way, this work has as a neuralgic point to build a metric to assist in the evaluation of energy consumption from polluting waste in an industrial production system. By using fuzzy logic, 8 sub-indices were constructed (operations, equipment, minimization, water use, recycling, waste disposal, maintenance, and raw material) which, when aggregated, generate the index to evaluate energy consumption coming from industrial waste. The indicators used to generate the methodology were retrieved

through the industrial assessment center report. The results of the criticality index, considering a scale of 0 to 10, show 5 scenarios: High criticality (10-8), Tolerable (8-6), Adequate (6-4), Desirable (4-1.5) and low criticality (1.5-0). In addition to the development of the index, there were indications of what actions should be taken so that companies complement or reach the energy consumption that is considered satisfactory. The developed model proves to be an important tool for decision making in industries due to the different approaches contained in its structure, in addition to determining as a scientific value in the academic discussion, a successful transition to the industrial sustainable energy system.

## Coupling Effects of Cross-Region Power Transmission and Propulsive Technologies on Power Emission Reduction in China

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**Abstract**
In China, the power system has always played a key role in CO2 emissions due to its fossil-based electricity generation. Low-carbon transition of power system has become an inevitable option under the carbon peak and neutrality targets. China's power system will need to accelerate the large-scale development of renewable energy and deploy the propulsive technologies. China has a spatial and temporal mismatch between electricity demand and power generation resources, especially renewable energy resources, which brings challenges to power balance. We improved the integrated resource strategic planning (IRSP) model to study the coupling effect of the technologies on CO2 emission reduction, which considers both supply and demand sides and is a powerful tool in power planning. The new model, IRSP considering cross-region power transmission and propulsive technologies (IRSP-cptpt), aims to achieve fossil energy replacement and emission reduction through technology coupling effect. Multiple comparative scenarios are constructed to study the low-carbon transformation path of China's regional power system during 2021-2060, and the phased impact of cross-region power transmission, energy storage and carbon capture and storage (BECCS) on power system emission reduction are comprehensively analyzed. The results show that the coupling development of cross-region power transmission and propulsive technologies will reduce CO2 emissions by 163 billion tons from 2021 to 2060. Enhance cross-region power transmission and energy storage configuration will contribute the most to CO2 emission reduction and increase renewable energy generation by 13460 TWh during 2021-2045. Energy storage will scale up after 2035, facilitating increased use of local renewable energy. BECCS will also gradually realize scale application after 2035. Although renewable generation will be squeezed, BECCS will accelerate the decarbonization of the power system to zero emissions by 2050 and remove 240 million tons CO2 by 2060, bringing a cumulative total of 55.8 billion tons negative CO2 emissions.

## Preliminary Results on Systemic Study and Integrated Options to Promote Sustainability in Design, Use and Operation of Firewood Pottery Kilns in Ixtaltepec (Oaxaca-Mexico)

Diana Margarita Bohórquez Catalán, Ricardo Jorge de Albuquerque Martins
Organization(s): Universidad de las Américas Puebla, Mexico

**Abstract**
Currently, approximately 2.7 billion people still rely on firewood and charcoal for cooking and heating in developing countries. In 2010, 4.1 million Mexican households (15% of the total) used firewood or charcoal as their main fuel source, including about 50% of households in rural areas. In particular, at Asunción Ixtaltepec (Oaxaca Istmo, Mexico), there is relevant cultural and economic pottery sector composed mainly by artisan family workshops with brick firewood kilns (BFK). These workshops produce large clay pieces (over 1.4m high and 60kg) using around 1336.8kg/kiln every fifteen days. While BFK support many families economically, there are very few studies relating the pottery activity with energy resources and BFK operational practices, design, and materials. This work overcome this knowledge gap presenting the preliminary results of a systemic and participatory study and engineering alternatives implemented to BFK at Asunción Ixtaltepec. The systemic study assesses the natural resource use in terms of the associated supply chain and BFK energy, design, materials, and operational efficiency. More specifically, the study addresses the dynamics of the natural resources supply chain, the BFK thermodynamic performance, the properties of the BFK building materials and the social-economic impacts (cost, market, value chains; cultural practices). The engineering options include new building materials, BFK designs and operation procedures and are evaluated in terms of energy efficiency, social acceptability, cost and resources use. To improve social acceptability, both the study and engineering alternatives are carried in close collaboration between the authors and the BFK builders, users, and other relevant actors. Furthermore, the quantified evidence of the social, economic, and environmental impact of the BFK (construction and use) and the evaluation of engineering alternatives presented in this work have the potential to reduce and use more effectively natural resources in other widely used firewood technology (e.g., ovens, stoves, fireplaces) in Mexico.

## Unraveling the Effects of Domestic and Foreign Trade on Energy Use Inequality within China

Quanzhi Xia, Xiaofang Wu
Organization(s): Zhongnan University of Economics and Law, China, People's Republic of

**Abstract**
Energy underpins economic and social development, access to which is however highly unequal due to regional heterogeneity in resource endowments. To ensure an equitable and just distribution of

energy use requires a comprehensive understanding of the impacts posed by domestic and foreign trade of goods and services with energy use hidden in. Here we construct a multi-scale input-output model to explore the direct and indirect energy use of Chinese provinces along regional, national, and global supply chains. The Gini coefficient is employed and decomposed to determine the degrees and sources of energy use inequality in China. Results show that China's inland provinces have higher per capita energy use at the local scale, while coastal provinces receive higher per capita energy use at the national and global scales. With the help of domestic and foreign trade, the inequality of energy use embodied in provincial final demand is reduced by 65.84%. The decomposition analysis illustrates that energy use related to domestic imports, especially for products from the sectors of Construction, Manufacturing, and Service, is the key to mitigating total energy use inequality across Chinese provinces. Policy inferences are given towards a more even energy use allocation.

## DAY 4 Session 47

### Regeneration of LiNi0.6Co0.2Mn0.2O2 from Spent Lithium-Ion Batteries Cathode Materials

Shuai Gu, Jiao Kong, Xiaoran Zhu, Jun Xu, Canyu Chen, Ziyang Zhang
Organization(s): East China University of Science and Technology, China, People's Republic of

**Abstract**
The boom of the electric vehicles industry significantly aggravates the demand for power lithium-ion batteries (LIBs), especially, ternary cathode materials, however, the majority of end-of-life (EOL) LIBs on the market are batteries utilized in customer electronics. Here, we utilize the mixed EOL LIBs from cellphones and laptops, which are mainly composed of LiCoO2, to remanufacture LiNi0.6Co0.2Mn0.2O2 (NCM622) cathode material with an emphasis on the optimization of leaching conditions and interpreting the mechanism with thermodynamic calculations. A feasible, high efficiency (99.98% Co, 99.98% Ni, 99.99% Mn, and 99.99% Li), and ultra-fast leaching of EOL LIBs cathode are achieved with the mixture of 0.5M hydrochloric acid, 0.25M nitric acid, and 0.25M L-ascorbic acid as part of reducing the costs of the hydrometallurgy process. Thermodynamic calculations suggested that the coordination species facilitate the high leaching efficiencies and fast leaching kinetics. The coordination number, coordination species concentrations, and fractions have significant effects on the apparent activation energy and the equilibrium of the leaching reactions. The remanufactured NCM622 cathode material demonstrates a well-ordered layered hexagonal structure with a low degree of Li+/ Ni2+ mixing ratio, which facilitates the reliable reversible capacity, low polarization, high rate capabilities (163.8mAh/g), and capacity retention ratio (94.3%).

### Efficiency Ni-Co Alloy Electrodeposition for Retired Lithium-Ion Battery High-Value Transformation through pH and Mn2+ Collaborative Dynamic Regulation

Guangzhen Liu1, Liming Yang2, Xubiao Luo2
Organization(s): 1: Nanchang University, China, People's Republic of; 2: Nanchang Hangkong University, China, People's Republic of

**Abstract**
High-value transformation of metals nickel (Ni) and cobalt (Co) is the important channel to reduce the recovery cost and realize sustainable utilization of retired ternary lithium-ion battery (LIBs) cathode. Cause the Ni and Co with close reduction potentials, the one-step electrodeposition recovery of Ni-Co alloy provides an industrial feasibility. However, the complex and high concentration acidic leach solution background presents a fundamental technical challenge for efficiency recovery of high-purity Ni-Co alloy. Here, we reveal a correlation law of the influence of pH and Mn2+ ion concentration changes on electrodeposition efficiency and purity of Ni-Co alloy, and achieve the efficiency electrodeposition of high-purity Ni-Co via dynamic pH adjustment and Mn2+ ion supplement. The deposition rates of Ni and Co were increased by 8.6 times and 21.3 times, reaching 534.2 mgL-1h-1 and 529.7 mgL-1h-1. And the deposited Ni-Co alloy has up to the purity of 99.8%. The preliminary voltage and pH optimization is developed by calculating the redox potential of the transition metals Ni, Co and Mn, and to ensure the initial purity of Ni-Co alloy. The dynamic pH adjustment effectively inhibits the competitive reduction of H+ ions on the cathode and raises the reduction potential of Mn2+, thus directly improves the deposition efficiency and purity of Ni-Co alloy. In addition, the oxidation of anode Mn2+ as the main electron donor further accelerates the deposition of Ni-Co alloy through dynamic supplementation. And relies on the regulation of pH to block the negative impact of H+ ions produced by the anode on the deposition of Ni-Co alloy. This strategy is suitable for recovering high purity multiple components metals, and provide a new prospect for reducing the cost of hydrometallurgy recovery and putting forward a new economic sustainable utilization path.

## Nickel Supply: Will Primary Processing Capacity Be a Bottleneck?

Jamie Faubert, Steven Young
Organization(s): University of Waterloo, Canada

**Abstract**
To support a clean energy economy, more primary nickel will be needed—even with increased recycling—both in conventional applications (e.g., stainless steel, specialty alloys, plating) and in electric batteries for vehicles and stationary storage. Previous research suggests we have sufficient geological availability of nickel reserve; however, after mining, we do not know how much nickel can be provided to different demand markets. Particularly, the downstream nickel market bifurcates into high purity class 1 (>99.98%) versus lower-grades (e.g., ferro-nickel used for stainless steel). There is concern that nickel supply for lithium-ion batteries may be constrained by primary processing capacity.

We comprehensively identified and systematically catalogued 60 nickel metallurgical operations around the world that process feedstocks (e.g., sulphidic or lateritic ores). Information was obtained from company financial reports, material specifications, and cross-referenced to academic and industry reports. For 2021 as the reference year, information included operation history, ownership, location, processing technology, feedstock sources, product outputs, historical production, and current production capacity.
Results showed that the 60 nickel processing facilities are owned by 37 different companies and produce 137 different nickel products. Of these, only 46 facilities produce high grade metal or chemical products (e.g., sulphates, hydroxides) that have potential to be used as lithium-ion battery cathode material. This production capacity is assessed and compared to projected future nickel demand. Geographically, over 70% of class 1 nickel capacity is associated with Western countries (e.g., Australia, Canada, Norway, Japan), followed by China with 15% and Russia with 10%. China and Southeast Asian nations, in contrast, have developed their greatest capacity in ferro-nickel production, not suitable for batteries.
A growing number of new operations in Indonesia have potential to provide battery materials; however, these face technology risks and business uncertainty. How the industry will react and evolve to growing nickel demand is a challenge.

## Battery Materials and GHG Emissions from Us Electric Vehicle Adoption Scenarios

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**Abstract**
Electric vehicles (EV) are essential technological measures to mitigate climate change impacts from personal travel. Therefore, they are projected to significantly penetrate the light-duty vehicle (LDV) market. However, this requires a substantial increase in the production of lithium-ion batteries (LIB), that largely rely on critical metals and contribute to EV life cycle emissions. This study aims to evaluate pathways to reduce metal consumption and greenhouse gas (GHG) emissions associated with EV battery production. We created different battery production scenarios by varying three parameters: recycling technique, battery cathode market share and the electricity grid mix projection. We then combined these scenarios with a fleet life cycle assessment (LCA) model to evaluate the battery material demand and GHG emissions implications from high EV penetration rates for the US LDV fleet from 2020-2050. Our findings highlight that if the US relies primarily on EV deployment to reduce its LDV emissions to be in line with a 2˚C warming climate goal, potential supply

challenges for cobalt, lithium, and nickel may arise over the next decade. While recycling is a potential strategy to decrease metal consumption by mid-century, we found that shifting to an iron-based battery cathode results in larger reductions in critical metal consumption over a shorter period (2020-2035). From a GHG emissions perspective, increasing recycling, shifting battery chemistry, and adopting renewable energy sources for battery production can achieve 330 million metric tons in cumulative GHG emissions reductions from 2020-2050.This is almost equivalent to the US light duty trucks annual GHG emissions in 2020.

## Recycling of Solid Oxide Electrolysers or Fuel Cells Waste Materials

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**Abstract**
For the first time, a strategy for recycling and recovery of Solid Oxide Cell (SOC) components is presented. From commercial cells, electrodes and electrolyte are separated by mechanical scraping and grinding, followed by thermal and chemical treatments. Materials of the solid oxide fuel cell (SOFC) components including air electrode (LaxSr1-xCoO3), nickel oxide (NiO), which accounts for about 50% of the cell weight, and yttria-stabilized zirconia (YSZ), which is coming from both the fuel electrode and the electrolyte, were successfully recovered. The recovered materials are characterized by several techniques: X-ray diffraction, scanning electron microscopy, thermal analysis, chemical analysis and surface area measurement. The conductivity level of the recycled electrolyte materials was measured in air by electrochemical impedance spectroscopy from 300°C to 750°C and compared with different compositions of commercial YSZ materials. A total electrolyte conductivity of 9.8 10-3 S cm-1 was measured at 750°C. The contributions of grain and grain boundary conductivities to the total conductivity are clearly distinguishable at lower temperatures. The contribution of grain boundary resistance increases with the presence of impurities.

## Fast Charging Lithium-Ion Batteries for Recycling

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Organization(s): 1: Ames National Laboratory, Ames, Iowa, United States of America; 2: Iowa State University, Ames, Iowa, United States of America; 3: Indian Institute of Technology, Kanpur, India

**Abstract**
The rising demand for portable electronics and electric vehicles is creating substantial end-of-life batteries and improper disposal in landfills can lead to the accumulation of toxic materials. Conversely, end-of-life battery management by incineration or acid treatment can release harmful

chemicals that can pose serious environmental and health hazards. Added to this, critical materials such as Lithium, Cobalt, and Nickel have limited global reserves, sparse availability, and soaring material costs. It is thus imperative to develop eco-friendly, cost & energy-efficient, and highly productive methods of recycling these end-of-life batteries. The extraction of battery materials may restore the critical materials into the supply chain and support efficient, sustainable recycling and reuse methods.
In this study, we have used lithium-ion batteries consisting of lithium metal oxide as cathode and graphite (C) as an anode, which are widely popular in the industry. We have used a fast charging protocol in fresh and aged/used batteries, reaching their end of life under normal operating conditions by accelerating lithium electrodeposition on the graphite anode. The cell voltage was monitored immediately after charging, which proved that lithium plating occurred during charging. The batteries with electroplated lithium were discharged, safely disassembled, and treated to extract the lithium, carbon, and cathode materials. We also compared the amount of lithium and carbon extracted from cells reaching multiple cycle life conditions. Industrial adoption of this energy-efficient method can help restore the critical materials from lithium-ion batteries into the supply chain and broaden our understanding of the science of fast-charging and its impact on recycling end-of-life batteries.

## DAY 4 Session 48

### Heterogeneity Analysis of Carbon Intensity Influence Factor and Low Carbon Economy Path in East of China

Miao He
Organization(s): Hebei University, China, People's Republic of

**Abstract**
This study take east of China as an example, analyzed the deep influencing factors and heterogeneity of forming a unified market, reducing carbon emission intensity, and influencing the decoupling of carbon emissions from economic development view .Based on the STIRPAT model and provincial panel data (2003-2019), screening the influencing factors of carbon emission intensity through the OLS gradual regression method and analyzed heterogeneity based on the GTWR model. The study involved three aspects： technical level, prosperity and population, and considered the influence of the dual factors of marketization and urbanization.The study shows that the overall carbon emission intensity in the eastern region is lower than the national average level, and the overall technical level is higher than the national average level, but there are some differences.Empirical studies show that the improvement of regional GDP and technical efficiency is conducive to the decrease of carbon intensity.Market segmentation has a negative impact on carbon intensity, promoting the market integration process is conducive to the decline of the overall carbon intensity. The interaction between urbanization and market segmentation will significantly improve the impact of market segmentation on carbon intensity, and strengthen the role of the market integration process in the

decline of carbon strength, upgrading, and population migration. However, the evolution trend of carbon decoupling also indicates the differentiation of carbon decoupling types in the eastern region after 2018, which can be explained by the spatiotemporal heterogeneity of influencing factors derived from GTWR regression.Accordingly, this paper puts forward the measures to reduce carbon emission intensity according to the characteristics of different regions, strengthening market role, adjusting industrial structure and developing low-carbon economy, advocating low-carbon consumption, enhancing the connection between regional industries and resources and narrowing the regional gap, so as to realize the decoupling of carbon dioxide and economic development, and effectively achieve carbon neutrality.

## Factor Decomposition Analysis and Causal Mechanism Investigation on Urban Transport CO2 Emissions in Chinese Mega Cities: Case Study of Beijing,Shanghai,Shenzhen and Guangzhou

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**Abstract**
In order to cope with the environmental problems such as greenhouse effect, we need to actively promote the construction of low-carbon cities, and low-carbon transportation, as the main driving force of low-carbon cities, plays a particularly prominent role. Investigation of driving factors and analysis of the causal mechanism of carbon dioxide emissions from urban passenger transport will help to provide a reliable basis for the formulation of low-carbon policies. Up to now, many emerging case studies have been analyzing China's urban traffic carbon dioxide emissions. However, they lack an in-depth decomposition and causal mechanism analyses as well as a comparative study. To fill this gap, this study aims to conduct a decomposition analysis and causal mechanism investigation study on the urban transport sector with comparative studies on four Chinese mega cities, Beijing,Shanghai,Shenzhen and Guangzhou.The outcomes of this study provide critical insights to recent practices in China as well as practical guidance to low-carbon urban planning in developing countries.

## State of the art in the recovery of secondary materials from post-consumer batteries

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**Abstract**
Li-ion batteries are the main source of energy for different devices and are currently studied due to the energy transition. The development of electric vehicles requires specific technology which, in

turn, requires critical materials in its composition such as lithium, cobalt, nickel and niobium. Different productive sectors are mobilized to meet the international demand for electric vehicles, but the mining sector is especially dedicated to seeking mechanisms to provide the necessary inputs. The scarcity of resources or economic value can make entire production lines unfeasible. In this way, this research presents an overview of the potential to produce automotive batteries for electric vehicles based on the optimal economic blocks based on a literature review. The conclusions suggest that the provision of natural resources is an important aspect in the decision-making process regarding the energy transition, along with economic and regulatory aspects related to critical materials.

## Different Trends and Driving Factors of PM2.5- and Ozone-attributable Impacts in China's Cities

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**Abstract**
Ambient PM2.5 and surface ozone pollution showed different trends in recent years in China. Consequently, the health and economic impacts attributable to PM2.5 and ozone may also have varied in different ways. We investigated the changes in PM2.5- and ozone-attributable health and economic impacts in 337 China's cities during 2015-2020. Premature deaths attributable to PM2.5 and ozone exposure were estimated using the global exposure mortality model and log-linear exposure-response model respectively. Age-adjusted value of statistical life measure was used to quantify related economic losses. The results showed that the annual premature deaths attributable to PM2.5 exposure decreased by 10% from 2015 to 2019, however, the annual premature deaths attributable to ozone exposure increased by 48% during the same period. Average per capita economic loss of PM2.5 exposure increased by 11%, while that of ozone pollution increased by 74%, much higher than the 40% growth of Chinese residents' individual disposable income. Exposure level change and residents' disposable income growth are two major driving factors which determined the different trends of PM2.5- and ozone-related impacts. Concerted but various air pollution control measures are suggested for different cities. Future strategy towards curbing air pollution would require reinforce of ongoing efforts to keep PM2.5 reduction as well as develop effective ozone control measures.

## Development of CleanTech Solutions to Treat Agricultural Wastes Using Two-stage Liquid-solid Anaerobic Digestion at Low-temperature

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**Abstract**

Objectives of this study were to explore eco-friendly and clean technology for processing multiple agricultural organic wastes, this was accomplished in 2 Phases. Phase 1 undertook the development and adaptation of liquid and solid inoculums to high N concentrations in two different feeding cycles (Cycles 1 and 2 for 100 days and 77 days respectively) wherein chicken manure (CM) was mono-digested and CM plus dairy cow manure (DM) was co-digested in two different digesters. Phase 2 utilized fraction of inoculum from the previous phase to digest multiple substrates in different mix proportions. Phase 2 consisted of Cycle 3 with two different multi-substrate digestion experiments; the multi-substrate mixture M1 and M2 comprised of solid inoculum, cow and chicken manures with corn silage; with an addition of swine manure in M2. A two-stage (liquid-solid) anaerobic digestion system (20-L active volume, in duplicate) operating at 20±1°C in batch feeding mode was used for all experiments. The cycle length was reduced (from 100 days in Cycle 1 to 68 days in Cycle 3) and by Cycle 3 the organic loading rate (OLR) for M1 and M2 had been pushed to 5.1 gVS/Ld and 4.6 gVS/Ld (OLR was 4.3 gVS/Ld and 2.8 gVS/Ld respectively for mono- and co-digestion initially in Cycle 1). The lowest and highest specific methane yields achieved were 0.088 ± 0.011 LCH4/gVSfed and 0.148 ± 0.025 LCH4/gVSfed respectively. Ratio limits like TVFA/TA, C3/C2 and C4+C5/C2 were used to monitor the stability of the anaerobic digestion process and in almost all phases of this study, these ratios remained within the threshold level and thus no inhibition was observed.