Kankanamge Dona Nethmi Sewwandi

University of Ulsan

ISIE abstract number: 1138

Category: Text

Creative abstract:

A poem

Official ISIE abstract:

Eco-industrial parks (EIPs) strive to promote sustainable industrial development by integrating environmental, economic, and social objectives. Despite the limited success of many national EIP programs, China, Japan and Korea have reported significant achievements in this field. This paper aims to characterize the three countries' national EIP projects to draw specific focus and implementation strategies. This study consists of two interrelated parts: 1) bibliometric analysis; and 2) the characterization of EIP development through a literature content analysis. The combination of ScienceDirect (Scopus), Web of Science (WoS), and Dimensions publication databases from 1998 until 2022 were used in this study. The bibliometric analysis was done by refining only the most-related literature based on the typical keywords and content, then visualized by using the VosViewer software for the keyword co-occurrence analysis. It was performed to analyze the EIPs research trend from 1998 to 2022. Based on the keyword co-occurrence analysis, the most popular keywords for EIP research in China are "industrial symbiosis" and "network". Meanwhile, "waste" is the most popular keyword in Japan Eco-town's publication; and "eco-industrial park" and "industrial symbiosis" are the most popular keywords for Korean EIP scientific publications. Based on further analysis, the focus of EIPs in China is resource efficiency and industrial upgrading through industrial symbiosis and networking. Korean model EIPs have a strong focus on innovation and technology in EIP transition, with a particular emphasis on industrial symbiosis development by business model based on triple bottom-line benefits. EIPs in Japan, or Eco-town projects, are characterized by a focus on waste recycling and the reuse of resources, as well as the development of sustainable infrastructure. Overall, the characterization of EIPs in China, Korea, and Japan is similar in selection and approval of EIP and business approaches, but they may differ in terms of their specific focus, priorities, and funding mechanisms.

Laura Buarque Andrade

HZDR

ISIE abstract number: 1191

Category: Audio

Creative abstract:

Adapted from the original song "Forever young", this parody combines the principal author's main passions: karaoke and future supply. The most improtant message of the song, extracted from the abstract, is that in order to have more lithium, we will need to have more mines, bringing the importance of minerals for enabling the green transition, and questioning if they really last forever.

Official ISIE abstract:

Whether primary lithium (Li) sources will be able to supply the rapidly growing needs of the electric mobility transition has recently caused considerable controversy. Existing assessments need to be improved by a lack of consideration for the decision-making processes occurring at the level of individual mining projects. In the present contribution, we demonstrate how these processes and associated uncertainties can be incorporated into an assessment of the likely future evolution of the global Li market. Our method uses Monte Carlo simulations to achieve this goal. A global database of existing Li mining projects (all development stages, including case histories) is used to build models to estimate the likelihood of each project proceeding to the next development stage in any given year, depending on specific project characteristics such as location, deposit type, and ore grade, as well as market conditions, i.e., Li price and demand. Iterative stochastic simulations are then run, in which projects are moved through the development pipeline according to these estimated likelihoods, year-by-year, up to 2050. Discoveries are also included in the model to achieve realistic results over the relatively long period covered. Simple, functional models estimate future Li demand, including uncertainty. The simulations generate a large set of equally probable scenarios (1,000 or more) of which projects enter production when, whether primary supply can meet demand in any given year, and what the likely mean Li price is for that year. Summarising the data from all scenarios provides an impression of the likely evolution of the Li market up to 2050. Besides this likely market evolution, the simulation outputs can be used further to assess the probable environmental impacts of future primary Li supply

Dr. Tim Werner

University of Melbourne

ISIE abstract number: 439

Category: Visual

Creative abstract:

This visual abstract is a landscape painting, depicting metal mine areas as seen in false-colour satellite imagery. It was the result of a year-long collaboration with fine artist Ches Mills. I wrote code to produce imagery for selected metal mines that would be used as inspiration. I then consulted with Ches on the arrangement and representation of mines and their impacts on surrounding areas in this painting. The piece she produced depicts open cut pits, mine wastes, surrounding rivers and vegetation, as well as roads and human settlements. These are all aspects that can be detected and delineated using image processing algorithms to assess mine footprints. The painting invites viewers to consider the range of impacts that mines can have on surrounding landscapes, and the tensions between the need for mining to underpin global supply chains, versus the localised impacts that can be seen from above.

Official ISIE abstract:

Towards automated mapping of global mining land use Advances in the quality and accessibility of satellite imagery have prompted rapid growth in research mapping the land footprint of mining. Multiple research teams have recently compiled open datasets with more than 150,000 polygons covering mining activities worldwide. These data help to explain the size, spread and nature of land use challenges linked to global material supply chains. Yet so far, it has only been viable to gather such data through a time-consuming manual process that requires trained analysts to visually recognise and delineate mine areas. Consequently, published updates on global mining land use are limited to approximately every two years. Meanwhile, mines are highly dynamic, constantly changing and expanding into new land. To keep pace with the real-time changes in mine areas globally, efforts to automate the task are needed. This presentation outlines recent advances in the use of machine learning algorithms to automatically detect mine areas in satellite imagery. Building from this, we will discuss barriers and progress towards automating the global mapping of mine areas. Through a series of mapping case studies, we will also illustrate what levels of geometric and categorical accuracy can be achieved for different types of mine features, and for different parts of the world. Finally, we will discuss the implications of access to timely global mine land use data on broader field of industrial ecology, on governments, and the mining industry itself.

Ali Abdelshafy

Chair of Operations Management

ISIE abstract number: 1518

Category: Video

Creative abstract:

The video illustrates one of the models presented in the study (i.e. Dynamic-Locational material flow Analysis). The derived approach is used to model the supply and demand of the construction materials along three dimensions (material, location and time). The model also considers several parameters that can influence the construction and demolition activities such as the portfolio of the housing stock and demographic changes. The model has been used to estimate the relevant material flows in the German federal state of North Rhine-Westphalia in the coming decades.

Official ISIE abstract:

Material flow analysis (MFA) has been an effective approach for industrial ecology. Due to the increasing number of research questions and fields of industrial transformation, more methodological integrations and extensions are still required. Herein, this study presents three integrated MFA models, which have been derived and applied on three case studies. First, an intersectoral MFA model is developed to investigate the impacts and interdependencies of the transition of the energy system and the implementation of a circular economy. For example, the shift towards green steel will have an impact on the availability of blast furnace slag, which is used to produce CEM II and III. Also, the coal phase-out act in Germany will affect the amounts of fly ash and FGD gypsum. Herein, the model's framework consists of three consecutive steps. First, the production processes are studied and the relevant inflows, outflows and stocks are determined. Second, the identified inflows and outflows are quantified. Finally, the alterations caused by the industrial transformation are analyzed. The presented model and analyses can help the policymakers and strategists to understand the intra- and intersectoral relations, impacts of relevant policies, and the associated changes in the material and emission flows. As the location has a crucial impact on the construction activities and relevant transportation costs, integrating the spatial dimension can be essential for certain analyses. Hence, the second model (spatial MFA) has been developed to consider both the locations and quantities of the relevant materials. Herein, the presented case study investigates the potentials of coupling a carbon capture and utilization technology (i.e. carbonation) with the supply chain of construction sector. Similar to the first model, the framework is composed on three phases. First an MFA model of the regional construction sector has been used to identify and quantify the construction products suitable for carbonation. Thereafter, detailed atlases of the relevant construction products and waste streams have been derived to determine the locations and quantities of the relevant flows. Finally, location-allocation models have been developed to optimize the routes between the CO2 sources and relevant flows. Therefore, besides the quantifying the CO2 sequestration capacities, the analyses also quantify the impact of transportation on the prospective carbonation supply chains. Besides location, the time dimension is essential for some material flows and supply chains. Linking recycling operations with construction activities is mandatory for promoting circular economy in the construction sector. Hence, similar to the preceding model, integrating the spatial aspect is important for minimizing the transportation costs. Additionally, the temporal dimension is also important due to the changes in the patterns of supply and demand over time. Herein, the dynamic-locational MFA model has been derived to integrate both dimensions into one framework. The first step in the framework is identifying the relevant parameters and collecting the databases in order to conduct the empirical analysis. The survival and construction functions are then derived to forecast the future demolition and construction activities. Finally, the associated material flows are estimated in each locational and temporal unit. Accordingly, the supply and demand of secondary resources can be matched and the relevant strategies can be developed.

Ali Abdelshafy

Chair of Operation Management

ISIE abstract number: 1217

Category: Video

Creative abstract:

The video depicts the transformation of the steel industry in the German federal state of North Rhine-Westphalia. Due to the high carbon footprint of the blast furnace process, hydrogen-based direct reduction has emerged as a promising low-carbon technology. Nonetheless, such alteration is associated with significant changes in terms of processes, infrastructure and raw materials as well as a huge demand of renewable energies. Hence, the study aims at presenting an approach to quantify these changes and demonstrating it on a real case study.

Official ISIE abstract:

The production of primary steel is characterized by a high emission intensity. Due to its high coal consumption, the steel industry is responsible for around 30 % of industrial greenhouse gas emissions and thus for 5 % of total German emissions. In North Rhine-Westphalia, steel production accounts for up to 30 million tonnes or even more than 10 % of the state's total emissions. The enormous coal consumption is not only due to the high energy demand, but also to the process-related coal dependency of the classic blast furnace process. For a far-reaching decarbonisation of the North Rhine-Westphalian industry, the introduction and rapid diffusion of new technologies and processes in steel production is essential. Two approaches are feasible: one is to maintain existing processes with retrofitted Carbon Capture and Usage or Storage, and the other is to avoid emissions through process changes (i.e. Carbon Direct Avoidance). Herein, direct reduction has emerged as a promising Carbon Direct Avoidance technique in the steel industry. All major German steel producers have announced specific steps to substitute coal-based feedstocks by switching to hydrogen-based direct reduction processes. If the hydrogen production and utilization of the steel producers are supplied by renewable energy sources, emissions can be largely avoided. However, this path is associated with far-reaching technical and procedural changes as well as a substantially increased demand for renewable electricity. Hence, this study presents a case study from Western Germany via quantifying the changes in the regional material and energy flows in the state of North Rhine-Westphalia until the planned decarbonisation in 2045. The quantitative analysis firstly presents a detailed material and energy flow model that depicts the existing supply chain of the regional industry and intersectoral relations. Thereafter, a detailed process simulation model of hydrogen-based steel production is developed according to the industry's detailed technological plans to track the regional impacts of such a transformation to achieve zero-emission steel. In combination with different assumptions on the availability of green hydrogen and complementary climate reduction measures, the results of the process simulation are integrated into the material and energy flow model to map possible stepwise transformation paths until 2045. Here, the analyses show that with a maximum focus on hydrogen, more than 47 TWh of electricity from renewable energies could be required per year for these structural changes. Consequently, our work quantifies different approaches by which the decarbonization of the steel industry can be achieved with lower amounts of renewable electricity. For example, partial reliance on natural gas as a reducing agent in combination with the use of CCUS technologies can significantly reduce electricity demand for the transformation, especially in the medium term.

Abhimanyu Raj Shekhar

Purdue University

ISIE abstract number: 752

Category: Text

Creative abstract:

Avengers Assemble: The Epic Saga of Lithium-Ion Battery Recycling from Electric Vehicles

Official ISIE abstract:

The recent advancements toward national electrification of the US have led to rapid manufacturing of massive quantities of electric vehicles (EVs) that utilize high amounts of lithium-ion batteries (LiBs). Such development poses the risk of rapid exhaustion of primary critical metals and excessive waste battery generation. Critical metals like cobalt, nickel, and manganese serve to be excellent precursors in the battery manufacturing industry as they can be recycled indefinitely without losing their physical or chemical characteristics. The circularity of these critical metals in an economy can be advanced by analyzing potential reverse logistics scenarios based on the spatial construction of cost-optimized battery recycling facilities. Here, we demonstrate the development of a regional structure of battery recycling facilities and spent battery collection centers in the US under deep future uncertainties correlated with the variation in market share of LiB chemistry composition and the changes in recycling technology. Using RELOG: Reverse Logistics Optimization, a simulation of battery collection and recovery was created over a 40-year timeline, with a LiB chemistry composition of 62% NCA and 38% NMC reflecting the current market share of cathode chemistries in the EV sector. Simulating three specific recycling technology cases, viz. pyrometallurgical, hydrometallurgical, and direct, the preliminary result provided the spatial distribution of collection centers, disassembly plants, and battery recycling facilities, along with the cost and emission data for each case. Principally, the development of direct recycling facilities across the nation came out to be the most cost-optimal solution when including recovered material resale value. A comparative assessment is anticipated to be carried out for this baseline scenario with two extreme future scenarios, one where the market share comprises 12% NCA, 38% NMC, and 50% LFP; and the other being 12% NCA and 88% LFP, which complies with the current trend towards reliance on LFP-based batteries.

Catrin Böcher

CML - Universiteit Leiden

ISIE abstract number: 735

Category: Physical

Creative abstract:

The glasses comparatively show the amounts of sand used and flowing out in 2019. They are meant to give a feeling of the amount and especially the proportions of the numbers. The wooden plate gives an easy overview of the different uses of sand. On the little red flags, one can read the amount of sand used per application.

Official ISIE abstract:

While often considered abundant, sand is currently being used at an unsustainable rate as the amount of sand used exceeds natural replenishment rates. Furthermore, sand mining can have serious environmental consequences. Considering the globally increasing rate of construction, land reclamation and coastal protection projects, together with other industrial uses of sand, global demand for sand will only increase in coming decades. Research on sand from a sustainability perspective has only started to emerge in recent years. In this research, we look at the stocks and flows of sand in the Netherlands. The Netherlands is an interesting case study, as it is a country that will be at high risk by rising sea levels resulting in a great need for coastal protection. This risk exposure is likely to considerably increase the demand for sand in the Netherlands. Furthermore, the Netherlands, together with Belgium, is an important player in the global sand dredging industry. Using material flow analysis (MFA), we quantify the current stocks and flows of sand in the Netherlands. This will help to get a better understanding of the types and quantities of sand used and understand some dynamics around it. This research will help to identify inefficiencies and losses in how we use sand. These insights will contribute to a better understanding of how we can manage our sand resources in more sustainable ways.

Jan Christian Koj

Forschungszentrum Jülich

ISIE abstract number: 1524

Category: Visual

Creative abstract:

Graphical Abstract containg illustrations of dimensions, research questions, methods, and results of the presented work.

Official ISIE abstract:

Water electrolysis technologies to produce green hydrogen are discussed as a promising option for the decarbonization, diversification and security of supply of future energy systems. In the recent past, technological maturity of water electrolysis technologies has increased. Despite this progress, further technological improvements are expected in the long term. This study examines the trends in technology readiness, critical raw material use and electricity consumption of the three most mature water electrolysis technologies, polymer electrolyte membrane, alkaline, and solid oxide electrolysis cells, up to the year 2050. To date, there is a limited number of prospective Life Cycle Assessment (LCA) studies that consider all three technology options. In addition, changes in projected material requirements for electrolysis construction in general and potentially critical raw materials in particular are rarely used in existing LCA studies. Using LCA and trend extrapolation, this study provides new insights into the potential reduction in environmental impacts by technological improvements in electrolysis technologies. Historical, current, and projected data from the scientific literature are used to extrapolate these parameters. For critical raw materials and electricity consumption, trends are assessed using exponential trend curves. The assessment of the projected technology readiness shows that all three electrolysis technologies are expected to reach the highest level of technological maturity already in 2030. Regarding the demand for critical raw materials, there is data available in literature, especially for iridium, platinum, and titanium. The literature-based trend extrapolation suggests that demand for these materials could fall by more than 55% between 2020 and 2030. By 2050, the use of various critical raw materials is expected to decrease by more than 90% compared to today. The reductions in electricity demand for electrolysis technologies are much lower due to their physical limitations. Depending on the technology, the reduction in electricity demand between 2020 and 2050 ranges from 6 to 17%. Considering the impact of these changes on the environmental impact of hydrogen produced by wind power (green hydrogen), further reductions in the global warming potential of more than 20% are possible by 2050. With shares up to 90% the electricity demand clearly dominates the contributions to the global warming potential of hydrogen production in the years 2020 and 2050. The knowledge gained from the detailed technological and environmental assessment of the water electrolysis technologies and the insights into their future development can also be used as a starting point for criticality analyses and sustainability assessments.

Leo Lamy-Laliberte

Ecole Polytechnique Montreal

ISIE abstract number: 537

Category: Visual

Creative abstract:

Energy and Flows, a Visual Guide of the creation of an EIP in Bécancour Canada

Official ISIE abstract:

In recent years, there has been a growing interest in the use of quantitative tools for the analysis and optimization of industrial symbioses and by-product exchange networks. However, while there is a significant amount of literature on the optimization of material exchanges, there is less literature on the optimization of energy exchanges. This research addresses this gap by focusing on the specific problem of optimizing energy exchanges in the Bécancour industrial park, Québec, Canada. The analysis of literature shows that existing tools do not fully address all necessary considerations, such as long-term investment and profitability for individual actors. To address this issue, we extended the capabilities of a model and validated the resulting tool in the specific case of the Bécancour industrial park. More specifically, the project adapts a mixed integer linear programming (MILP) model called AnyMOD.jl to optimize industrial symbiosis and energy by-product exchange. For instance, the proposed model has been enhanced to incorporate forecasting of future energy outflows through the application of concepts from time series analysis. Additionally, constraints have been added and modified to reflect the properties of physical infrastructure required for facilitating energy exchanges. Furthermore, the model has been adapted to include a stochastic approach, not present in the original. Our goal is to identify the optimal network of economically viable energy by-product synergies between industrial companies. The optimization model considers various aspects such as the long-term energy consumption profile of companies, the supply and demand of energy by-products within the industrial park and economic factors associated with the engineering requirement of the implementation of such a network including capital and operational expenditures of infrastructures. In other words, the model finds the optimal composition of an energy exchange network by combining energy conversion technologies, energy storage solutions, possibilities of mutualizing infrastructure, energy by-product flows treatment and the potential of adding complementary companies. To conduct the research, multiple interviews were conducted with industrial actors within the Bécancour industrial park to gather data about their energy and production profile. This information was then used to model their energy by-product flows over a 10-year period. Other parameters used in the algorithm include investment and operation costs associated with the exchange of energy by-products and multiple functions depicting the dynamic nature of the innovation in terms of conversion and storage technologies. The output of the model is then further investigated in a techno-economic study that provides valuable insights into the technical feasibility and profitability thresholds for the industrial park's actors, making it a valuable tool for decision-making and planning for industrial parks looking to implement circular economy strategies and significantly reduce their environmental impact. Preliminary results show that the adjusted model can find an optimal network for economically viable synergies leading to a significant reduction in greenhouse gas emissions and an increase in energy efficiency. In specific circumstances, some synergies can even have the potential to increase the maximum production capacity for certain industrial companies, giving the solution the potential to increase competitiveness.

Dafna Gilad

NTNU

ISIE abstract number: 46

Category: Video

Creative abstract:

The transition from fossil energy to renewable energy has the potential to reduce greenhouse gas emissions and mitigate the impacts of climate change. However, increased renewable energy production can also put pressure on ecosystems and biodiversity. Communicating these complex trade-offs to the general public is a challenge. To take up the challenge, we developed a board game set in a diverse world of landscapes, where players must supply enough energy to a growing city while minimizing negative impacts on local biodiversity. Can you navigate the way to find the optimal balance between meeting energy demands and conserving our biodiversity?

Official ISIE abstract:

A key to mitigating climate change is the reduction of our dependence on fossil fuels by transitioning to cleaner, renewable energy sources. However, the foundation of a sustainable energy system is its electricity grid. Today, about 80 million kilometers of power lines cross countries and continents worldwide to provide us with electricity. The current electricity network must inevitably expand within the next decades: new transmission lines will link new renewable power plants to the local grid, while additional distribution lines will ensure the delivery of stable and reliable electricity to consumers. Yet power lines act as a physical barrier for bird species: around the globe, hundreds of millions of birds are killed annually by power lines due to collision and electrocution. Life cycle assessment (LCA) is a suitable framework to provide a holistic view of the environmental impacts of energy systems. Indeed, life cycle impact assessment (LCIA) models were recently developed to evaluate the impacts of hydropower and wind power on biodiversity. However, these models assess only the effects of electricity production, overlooking the impacts of electricity transmission. Furthermore, current LCA studies on power lines focus on certain impact categories, neglecting the potential damage to ecosystem quality. We present the first LCIA models to quantify the impacts of electricity transmission on birds. Our models produce maps of the potentially disappeared fraction of species (PDF), which predict the risks of collision and electrocution on a large scale. These maps show how these impacts vary spatially, identify susceptible bird species, and indicate how efficient electricity transmission is across different areas. To validate the methodology, we applied them to the energy system of Norway. The majority of Norway’s energy system is based on electricity from renewable sources, and the country leads a low-emission energy policy that aims to reduce its emission by half before 2030. Overall, the characterisation factors ranged between 3.9 x 10-15 and 8.4 x 10-16 (PDF*yr/kWh) for collision and 1.9 x 10-16 and 6.5 x 10-16 (PDF*yr/kWh) for electrocution. Gallinaceous birds, waterfowl, and waterbirds were the most susceptible to colliding with power lines, and electrocution posed a greater threat to raptors, owls, and corvids. Transmission lines had higher collision impacts in densely populated areas in southern Norway, while the electrocution effects of distribution lines were greater in northern Norway. Our models are not limited to Norway. By obtaining appropriate input data, they can be applied to any region. The integration of these models in LCA is essential, not only because they introduce two new impact pathways but because they take us a step further in assessing the impacts of energy systems in a holistic way: addressing both the effects of the production and transmission of our electricity on biodiversity.

Amelie Müller

Leiden University, Institute of Environmental Sciences (CML), Netherlands

ISIE abstract number: 629

Category: Video

Creative abstract:

Cement: The silent climate killer that haunts your consciousness once you become aware. What can a scientist do, if she is hooked by a specific research question? Join me on an unconventional quest to uncover climate-friendly pathways in cement production.

Official ISIE abstract:

With an annual production volume of 4.3 Gt, cement is an important construction material, indispensable for the provision of various socio-economic services. Cement is a major driver for climate change, emitting 8% of the global energy-related greenhouse gases (GHG). Moreover, direct GHG emissions from cement production have increased by 1.5% per year between 2015 and 2021, jeopardizing the sector’s efforts to reach the emission reduction targets of the Paris agreement. Thus, long-term transition pathways towards a global low-carbon cement industry are needed. Ideally, these pathways are developed using a systemic approach, e.g. in coherence with macro-economic developments, such as decarbonization of other sectors, and considering biophysical limits, such as availability of resources. Moreover, they need to overcome the carbon-tunnel vision of existing studies by also considering burden shifting to other environmental impacts. The goal of this study is to assess potential environmental impacts of possible transition pathways to low-carbon cement production for different climate targets using prospective LCA (pLCA). We use global cement production scenarios from the Integrated Assessment Model (IAM) IMAGE to improve the macro-economic coherence of the transition pathways. We assess 3 scenarios: a business as usual (SSP2-Base), 2°C-compliant (SSP2-2.6) and 1.5°C-compliant (SSP2-1.9) scenario. They cover 26 world regions and the years 2020 to 2060. The IAM scenarios are integrated into the life cycle inventory database ecoinvent v3.8 using the python package premise. They are complemented with IMAGE-based background scenarios for electricity, fuels, transport and steel, to include supply chain decarbonization effects. This prospective LCA study is cradle-to-gate and, for consistency, only includes technological changes foreseen by the IAM. As such, technologies at low technological readiness level or demand-side mitigation options are not considered. Our results show that by 2060 the climate change impact of the cement sector is substantially reduced in the more climate-ambitious scenarios compared to the business as usual scenario. This reduction is mostly caused by a large-scale roll-out of CCS and a higher share of bio-fuels, while efficiency improvements only contribute to a lower extent. We found that decarbonizing electricity generation in the background can considerably reduce CO2 emissions for cement production. Despite substantial reductions in CO2 emissions, net-zero cement production is not reached globally by 2060. The residual emissions between 2020 and 2060 claim a significant part of the remaining global carbon budgets of the scenarios. Furthermore, we found that the reductions in climate change impacts coincide with a burden shift towards other impact categories, such as land use and material resources, and a higher future energy demand. Rapid and drastic measures are required to close the gap between the currently slow deployment rate of CCS in the cement industry and the high CCS adoption rates required in the climate-ambitious scenarios over the next decade. Policy makers must also ensure that the high demand for biofuels and low-carbon electricity required for economy-wide decarbonization can be met. Future research could explore if expanding this production-focused model to include mitigation levers along the entire cement value chain could lead to feasible pathways to net-negative cement production.