1st AMPEA-E3S joint workshop on "*Sustainability Assessment of materials and technologies for a clean energy transition*"

BOOK OF ABSTRACTS

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Supply risk analysis of silver for solar thermal power plants. An analysis of global value chains

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Abstract

Europe is currently facing the challenge of achieving a fast sustainable Energy transition in the next decades. The deployment of Concentrated Solar thermal Power (CSP) with storage can play a relevant role in this context by providing renewable and dispatchable energy. However, material availability constraints for renewable deployment such as the solar technologies have been identified in the recent literature as a potential bottleneck, including Silver scarcity. Therefore, it is essential to expand the currently used sustainability assessment frameworks in order to identify material supply risks. In addition to the amount of material needed for deployment, other risks on supply can be associated to the characteristics of the potential suppliers of key components along the value chain. Multiregional Input-output analysis models are indeed especially suitable for this kind of analysis since this methodology allow identifying the countries and sectors involved along the global value chains. Thus, in this research we expand an environmentally and socially extended multiregional input-output framework to include an indicator of supply risk. We undertake the analysis of six scenarios for the deployment of a 200 MW solar thermal power plant in Spain considering different technologies (parabolic through and central receiver) and different alternative suppliers of key components (Spanish, European (German), and Chinese). First, we quantify the level of silver extraction differentiated by origin required for the deployment of the solar thermal plants. Then, we apply an indicator of supply risk associated to the value chain combining two components: a diversity metric that considers number of suppliers, and the quality of governance in these countries and regions using six governance criteria. Results show that central receiver plants tend to be more intensive in the extraction of silver per MW installed. When comparing supply scenarios, substantial differences arise revealing that the European supply scenario would require lower extraction of silver around the world. This is especially relevant in the case of central receiver technology, which shows better silver efficiency probably due to the higher use of recycled silver in the German economy. Also, this scenario would entail lower risks of supply, since it performs better in all the governance criteria assessed, despite being less diverse within its own frontiers and considering that European partners not always perform better in terms of governance (i.e. Bulgarian contribution). Among the pure Spanish and the Chinese supply scenarios there are not big differences in terms of risks for most of the indicators. The advantage of European supply scenarios is remarkable in political stability and absence of violence, as well as regulatory quality, being aspects especially pertinent for well-functioning trade between silver suppliers and CSP components manufacturers such as reflectors and receivers.

Implementing sustainability in laboratory activities: A case study on magnetron sputtering deposition synthesis based on Life Cycle Assessment approach

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Abstract

Life Cycle Assessment is a structured and internationally standardized analytical tool to quantify all relevant emissions and consumed resources (ISO 14040-14044). Using Life Cycle Assessment is possible to analyze issues related to environmental and health impacts, and to the depletion of resources, associated with any good or process. Life Cycle Assessment covers the whole chain starting from the mineral extraction, and passing through the production, the use, the recycling, up to the disposal of the final wastes. This approach is known as “cradle to grave” analysis, indicating that the environmental impacts of the entire life cycle of products is considered. However, in research field, the typical approach is a “cradle to gate” analysis, where some phases are not considered, such as the use and the end of life ones, for instance.

Life Cycle Assessment studies of experimental activities are useful to identify the critical steps in terms of environmental impacts and can be useful to support the design and the optimization of the experimental set-ups, addressing to more sustainable laboratory activities.

In this work, a “cradle to gate” Life Cycle Assessment was carried out analyzing the experimental campaign of aluminum titanium nitride coating of commercial steel sheets by reactive physical vapor deposition magnetron sputtering. Aluminum titanium nitride is widely used material in many industrial fields as wear resistant coating in cutting tools, in bio-implants, in the aero-engine sector, as diffusion barriers in integrated circuits. The Physical Vapor Deposition is a scalable technique, and an environmental impact analysis assuming a great importance thinking to a technology transfer. Life Cycle Assessment is a suitable tool for this purpose, and it has been already widely used in many scientific, industry and policy sectors. Life Cycle Assessment results highlighted that the main driver of environmental impacts of the laboratory activities was the electricity used for instruments operations. The most energy consuming impact is related the vacuum keeping in the deposition chamber. In the second part of this study, several optimization strategies were evaluated to reduce the overall electricity consumption, with the aim of improving the environmental profile of experimental activities.

Challenges in the Recycling of Printed Circuit Boards in WEEEs

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Abstract

Conventional recovery and recycling of Printed Circuit Boards (PCBs), requires first a labor intensive process for their isolation, followed by mostly manual retrieval of high value electronic components (ECs), prior for the reminder to be crushed for further processing by hydrometallurgy and electrorefining processes. This allows for the recovery of the main elements (by weight or value), but all other elements are oxidized, mixed, diluted and therefore lost in post-processing wastes or ashes. To retrieve these elements, we are studying a change of paradigm: the disassembly of WPCBs combined with the sorting of ECs, followed by the fast development of physical and chemical treatments specific to each sorting bin [1, 2]. This enables ECs to be separated by composition and to significantly increase their chemical element's concentration and simplifying the waste's composition, thus making minority metal's recovery economically viable. In this presentation, we will rapidly present current state-of-the-art processes for PCBs' dismantling and subsequent ECs sorting. We will then identify research and business opportunities in the case of some elements such as refractory metals (Ta, Nb, W, Mo), gallium, or lanthanides, including new results from our laboratory.*

[1] « Dismantling of Printed Circuit Boards Enabling Electronic Components Sorting and Their Subsequent Treatment Open Improved Elemental Sustainability Opportunities » Ange Maurice, Khang Ngoc Dinh, Nicolas Charpentier, Andrea Brambilla, Jean-Christophe P. Gabriel, Sustainability 13(18), 10357 (2021) https://doi.org/10.3390/su131810357 .

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* This abstract is adapted from the abstract published in reference [1].

Outlooks and current limitations of tools for sustainability-driven decision-making in manufacturing

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Abstract

The world of manufacturing is rapidly evolving fostered by innovative highly-digitalised technologies and experiencing the need for a quick implementation of the transition towards sustainability. These transformations affect all the industrial fields and require proper tools to support the users of these new technologies to reduce the impacts of the production.

The studies on manufacturing sustainability processes have always suffered from the so-called “eco-design paradox”, i.e. an accurate assessment of the technological impacts can only be made after the production takes place. At this stage, the opportunities to modify the process are extremely limited. Therefore, the need for predictive tools to estimate the production impacts at the early design stage arises. These tools rest on historical production data to forecast the effect of design modifications on the process impacts. Such a strategy presents intrinsic limitations, being the relations between process data and sustainability impossible to demonstrate.

The general trend of digital manufacturing processes is to limit or avoid fixed equipment to enable maximum design freedom. This characteristic magnifies the issues discussed above. In fact, the data considered from the manufacturing cycle might significantly differ from the case in which the predictive tool is applied. It is thus necessary to develop parametric models that can be adapted to various products. The necessary parameters can be acquired from the digital environment while preparing the process.

Once predictive impact assessment methods are available, it is possible to implement computer-aided solutions to support decision-making. Since sustainability is a multidisciplinary topic, it is generally not possible to determine a single productive scenario minimizing all the impacts. Two main approaches are used in the existing literature to face this problem. In the first, the user is asked to previously define the relative importance of each sustainability indicator. In the second strategy, different solutions are proposed to the user, who has to operate the final decision. Both these strategies suffer from major limitations and are highly vulnerable to human discretion.

Materials and sustainable nuclear energy

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Abstract

Nuclear energy invariably triggers discussions in connection with the clean energy transition. While undeniably it provides continuous and secure supply of energy, especially electricity, at stable price, without emitting any greenhouse gases, it raises concerns that are related with: safety of operation and severe accident risk; management of long-lived nuclear waste; economics (especially for initial investments and back-end costs) and long construction times; limitation of fuel resources; and possible misuse of fissile materials. These issues are already being addressed with current generation reactors, by continuously improving operational practices and through R&D to enhance safety, performance and economics, while deep geological disposal is recognized as a suitable long-term solution for nuclear waste. Small and medium-size modular reactors are moreover expected to further improve economics and also safety. Next generation reactors are, on the other hand, meant to represent a sharp step forward in terms of drastic reduction of both quantity and hazard of nuclear waste, while significantly enhancing safety, performance, and possibly also economics. They will apply circular economy principles, by closing the fuel cycle, thereby drastically reducing the need of mining and virtually eliminating geopolitical issues related with fuel supply, thus enhancing energy security. They will also enable more effective policies to avoid misuse of fissile materials and the exploitation of nuclear energy beyond, strictly, electricity production. Both in the case of current generation reactors and, even more, in the case of next generation reactors, materials science practices related with accelerated materials development and qualification, as well as with modelling and monitoring materials behaviour in operation, making use of modern digital techniques, are crucial to make nuclear energy more sustainable and thus to provide additional tools and measures to counteract climate change. In my presentation I'll try to overview all these aspects, focusing on the importance of materials and materials science for sustainable nuclear energy.

Net Energy Balance Assessment of a Coupled Photoelectrochemical H_2 Production and Hydrogenation Device

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Abstract

Coupling hydrogenation with photoelectrochemical (PEC) water splitting is a promising technique for upgrading hydrogen to higher value chemicals. The co-generation approach offers a potential route towards achieving a levelized cost of hydrogen (LCOH) that is competitive with the current market price of hydrogen and increases the overall economic feasibility of the PEC technology. In this study, we conducted a net energy balance assessment to address the feasibility of co-producing hydrogen and methyl succinic acid (MSA) by coupling the hydrogenation of itaconic acid (IA) into MSA inside a PEC water splitting reactor. A PEC device that uses $BiVO_4$ as the top absorber and a silicon solar cell as the bottom absorber was considered.[1, 2] Our results show that the energy demand of our PEC device is *ca.* 3800 MJ/m^2, and the most energy intensive components are the photoelectrode (~70%) and the membrane (8%). Under the base case condition (i.e., STH = 5%, device longevity = 10 years) and when H_2 is the only product, a negative net energy balance of *ca.* -160 MJ/m^2/year is obtained. However, with a coupled hydrogenation reaction, a zero net energy balance (i.e., energy breakeven) can already be achieved when only 2% of the produced H_2 molecules are converted into MSA. When the H_2-to-MSA conversion efficiency is 0.4, which is within the range already experimentally demonstrated in our lab, the net energy production is *ca.* 3500 MJ/m^2/year. This translates to a cumulative energy demand of *ca.* 13 MJ/kg of MSA. This is much lower compared to MSA produced using conventional hydrogenation methods (i.e., ~90 MJ/kg MSA), which underlines the attractiveness of the coupled PEC approach. Finally, further possible improvement by e.g., replacement of device components will be proposed, and perspectives for larger-scale system level analysis will be presented.

References

[1] I. Y. Ahmet et al. Sustain Energy Fuels. 2019;3(9):2366–79.

[2] F. F. Abdi et al. Nat Commun. 2013;4:1–7.

Consumers' preferences for nanocarbon heating & cooling devices

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Abstract

Structure and preliminary results from an interdisciplinary project will be presented. The project aims at fabricating by additive manufacturing engineered modules composed of nanocarbon ceramic composites for the containment of Phase Changing Materials (PCM), for the accumulation and release of thermal energy. The presentation will focus on the economic perspective, that is the socio-economic valuation of consumers' preferences and willingness to pay for heating/cooling devices using the module developed during the project. The goal is to provide guidelines for a trade-off between performances and costs.

Citizens, Society and a Future Technology for Solar Fuels and Chemicals: Challenges and Potentials

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Uppsala University Sustainability Initiatives (UUSI) is a unit with the task to identify and build up new university-wide research constellations with the cross- and trans-disciplinary competences required to efficiently address the complex questions that emerge within sustainable development. One sub-initiative within the UUSI initiative on Urban Sustainability is directed toward social and political challenges of technologies and innovations for the sustainable city, where technologies for renewable energy, both existing and future ones, are core. Many of the technologies under development have strong chemistry and materials science components. In a first project we explore if and how existing energy communities in Sweden (primarily utilizing solar panels) contribute to social inclusion or exclusion. Can one speak of "*energy segregation*" where some technologies are utilized by certain citizen groups? A second stream of work, which will be the focus of this talk, centers on an emerging research constellation where we will explore stakeholders' perceptions of technologies for solar fuels and chemicals, especially technologies based on genetically modified photosynthetic microorganisms that use CO_2 as carbon source and solar light as energy source to form organic compounds. In this constellation, bioengineers, chemists, human geographers, ethicists and lawyers will jointly explore stakeholders' perceptions of technologies for solar fuels and chemicals. These technologies have the potential to deliver significant societal benefits, but may also be controversial. Our aim is twofold: (*i*) to identify the conditions for social acceptance, including ethical and legal dimensions, of these emerging technologies, and (*ii*) to develop strategies for feeding back these insights into the research process, so that current and future research ensures that the future deployment of this renewable energy technology meets both ecological and social priorities.

Environmental Product Optimisation by Design

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Abstract

The 'human system' puts a break on imbedding new energy systems more than once. Regarding social acceptance, we read about NIMBY protests and psychological complaints, especially when locals are not included in making decisions or sharing profits. We read about 'energy poverty', and how governments debate whether to focus on alleviating the energy bill or subsidizing renovation.

Energy bound product service systems (PSS) that do get a hold, demonstrate unforeseen or neglected side effects. For example, a steep increase in electric cars increases the need for batteries' rare earth materials and charging stations, as well as (renewable) energy at the start and end of working days. Experiences, like charged cars occupying charging stations, lengthy cues at 'gas' stations, and limited mileage in winter, make adopters renounce and laggers postpone.

These few examples from a myriad of energy related societal issues illustrate how valuable understanding the human system is for successful implementation of new product systems. Also between stakeholders of proposed energy systems understandings are crucial for success. This includes governance, for both discouraging unsustainable practices and stimulating sustainable developments.

Since drastic and swift diminishment is required for quite some impact aspects that are on the brink of pushing the natural system over a tipping point, we rapidly need drastic changes in how human wellbeing and activity is facilitated. Provided the intent is to maintain or improve the human system, radical systemic changes are needed in the product- and product bound systems, among which energy supply that fit people's perception of progress.

During the workshop, a holistic product aspect systemization will support participants acknowledge the 'human side' of energy transition interventions. Hopefully mapping potential social, political, and socio-technical bounds, barriers, and opportunities, will illustrate the need for expertise from the 'soft' sciences to assure acceptance of technical achievements.

Development and socio-technical-economic-environmental assessment of innovative materials for exploiting renewable energy sources

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Abstract

The sustainable energy transition will come with an increasing demand for raw materials. For some renewable energy technologies, the supply of raw materials is already insecure and unsustainable. Moreover, the availability of raw materials might be insufficient to address future demand. The identification and development of innovative and circular materials for renewable energies is becoming urgent. In this regard, the project MAMER funded by Italian Ministry of Research aims to integrate the technical and socio-economic-environmental assessment for supporting the development process of a new device based on innovative and sustainable materials for wind and wave power. In particular, the presentation will show the analytical framework developed for supporting the prototyping and scale-up of new device. The framework assumes a life-cycle approach for assessing environmental and socio-economic dimension though Life Cycle Assessment (LCA), Life Cycle Cost Analysis (LCC) and supply chain mapping. The results will support the design of effective strategies and actions for fostering a new or reconverted supply chain.

Raw materials for the energy transition: circular approach and sustainability.

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Abstract

European policies promoting the adoption of electric mobility to reduce pollutant and to improve urban air quality, are fostering automotive fleets shifting from internal combustion to hybrid and electric engines. Currently most of the analyses carried out focus on the comparison of the emissions related to the different categories of cars in particular on carbon dioxide (CO_2) emission cut generated by the consumption of electricity produced from renewable sources in the use phase of the cars.

In this presentation, a new approach to investigate the need of raw materials in future scenarios of electric technology penetration in the urban vehicle fleet is proposed. Focusing on the Italian urban vehicle situation and considering the current technology employed for the electric batteries and the recharging systems, the analysis accounts for the raw materials needed for different penetration scenarios of the electric mobility adopting a Life Cycle Thinking perspective. The objective of this work is to evaluate if the substitution of combustion engines to an electric system is affordable considering the raw materials availability. This work allows evaluating the need in raw materials of considered technologies; the market analysis gives information about the price and the availability of the material analysed considering different hypothesis. Once defined different scenarios, an estimation of the effective availability of defined substances allows to evaluate different recycling technologies considering both the quantity and the price of the recovered material.

H2020 project openENTRANCE (Transition Scenarios to a Low Carbon Future)

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Abstract

Coordinator for the openENTRANCE project is SINTEF Energy Research with PhD Ingeborg Gråbak and the text above is collected and adapted from the proposal and the scenario report openENTRANCE D3.1 developed by TU Wien and lead by Hans Auer. The project was initiated under the e3s umbrella.

The presentation will give a introduction to the objectives of the HEU openENTRANCE which is to provide an open accessible framework to facilitate a collaborative environment for research within the modelling field. This is broken down in the following sub-targets that are relevant to work in e3s and AMPEA.

• A suite of open integrated modelling tools able to tackle most of the recent and future aspects of the European energy system in transition, including decentralization, variability and flexibility.

• Open scenario input data and two open source models for conducting scenario generation exercises to provide insight about the future system, analyse the transition to low-carbon futures and enable validation and comparison exercises.

• Open input data and two open source Computable General Equilibrium models to enable macro-economic analyses aimed at providing insight about economic effects of the energy transition pathways

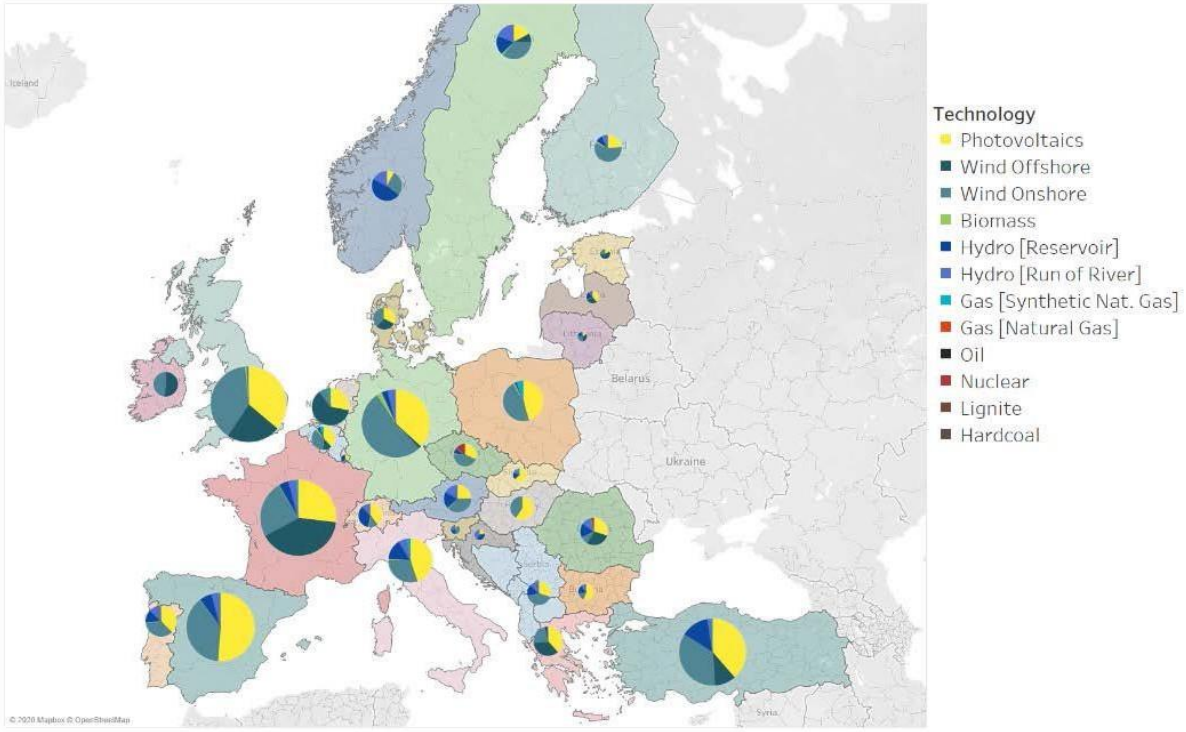
• Unique data from EU wide behavioural experiments and real-life multi-national field-tests of households' response to flexible electricity tariffs. The data are based on the implementation of an unprecedented approach

In the openENTRANCE project there have been a strong focus to support policy and decision making to succeed in decarbonizing the European economy. However, since future developments in the energy and transport system can't be foreseen exactly, four different storylines have been developed (i.e. narrative descriptions of equally possible energy futures) in the openENTRANCE project. This presentation will show some results from the corresponding quantitative scenario analysis. The openENTRANCE storyline descriptions are founded on a thorough analysis of already existing global and European pathway and scenario studies as well as a comprehensive review of the existing policy documents at European Commission level complying to the global climate challenges according to the Paris agreement. The scenarios therefore represent possible pathways to the low carbon futures.

The major development lines in the scenarios were analysed with an extended version of GENeSYS-Mod and the connection to AMPEA and material science is expressed in the following statement from the scenario report:

- Looking at the different installed electricity generation capacities, a general similarity among the scenarios exists when it comes to major dominating renewable technologies (the driving forces, however, are significantly different in the different scenarios): there is a slight increase of hydro-power generation and a significant increase of wind (onshore and offshore) as well as PV generation up to 2050. However, the shares of onshore and offshore wind as well as PV are quite different in the different scenarios

Each pathway will therefore represent different pathways also for material use and it will be necessary to include this aspect initiation collaboration between e3s and AMPEA-



Ex. **Electricity Generation until 2050 (Societal Commitment scenario)**

Environmental assessment of metal hydride technology for hydrogen storage and compression

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Abstract

Among several technologies for hydrogen compression and storage, an interesting approach is the use of metal hydrides (MH). These solid phases (elemental metal, alloy or intermetallic compound) are able to absorb large quantities of hydrogen and subsequently, simply through the use of heat, can release the gas. This release can take place at the same absorption pressure or at higher pressure, depending on the solid phase used.

The Life Cycle Assessment (LCA) methodology has been used to evaluate the environmental impacts associated with the production and use of different solutions for hydrogen compression and storage.

A first study focused on analysing the technology of a MH compressor, including materials selection and production, and comparing it with more established technologies, such us a generic hydrogen compressor and an air booster. The results show that the MH compressor generates limited environmental impacts only when a source of waste heat is available for hydrogen desorption. In a second study, still in progress, the use of a different solid phase, for the storage of large quantities of hydrogen, is evaluated. The innovative aspect of the latter solution is given by the combination of hydrogen storage with the use of phase change materials (PCM), which should allow an optimization of the heat exchanges during the absorption/desorption process.