Introduction to Panel 2 Sustainable production towards a circular economy

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Introduction

Today, industry accounts for about 25 % of EU's final energy demand, mainly due to energy-intensive industries and specific energy-intensive products/processes (e.g. steel, cement, ethylene) making the sector and its products critical for the achievement of European climate targets. However, the panel's focus is beyond the EU alone, in particular since supply chains today are typically global.

Previous analyses have shown that today's available technologies with a reasonable economic performance are not sufficient for deep decarbonisation in the industry sector. Therefore, turning the EU economy and in particular the production and consumption of CO_2-intensive materials into a material-efficient circular economy could substantially contribute to a CO_2-neutral economy, as set out in the long-term vision proposed by the European Commission. As the concept of circular economy gains momentum in the political debate across all stakeholders, synergies exist between the decarbonisation and the circular economy policy agendas. Consequently, circular material uses and their connection to the energy system through resource, material, and energy flows have to be taken into account in integrated policymaking, integrated energy-material modelling and the analysis of ambitious GHG mitigation pathways. Moreover, sustainable production plays an essential role in promoting sustainable development, as emphasized by the UN's Sustainable Development Goal (SDG) number 12, since it plays an important role in in the way that our societies produce and consume goods and services.

Energy efficiency, within the broader field of resource efficiency, surely represents one effective means towards increased sustainable production, also by looking at a broader context in the long-term perspective. On this issue, there is the need to look for broader and efficient opportunities, extending the view from a single company to supply chains for better products and services, and aiming at cost and environmental impact reduction for assuring the sustainable development at a wider level. Thus, there is a clear need of a holistic perspective to take all relevant facts that are involved when supply chains are designed into account. That will enable sustainable location decisions to also encompass potential synergies for boosting energy and make resource efficiency attainable with other entities inside and outside the supply chain (e.g. companies, public facilities, etc.).

This panel aims at offering a contribution in the debate over the aforementioned issues through a blend of peer-reviewed papers and extended abstracts, with relevant contributions from industry, academia and other institutions, organized into four main sub-streams: *i) Circularity and decarbonisation of the cement & building sectors, ii) Geographical triggers for circularity and decarbonisation of industrial processes, iii) Paths for circularity and decarbonization of manufacturing processes, and iv) Energy and material efficiency along the value chain.*

Circularity and decarbonisation of the cement & building sectors

The first topical area of the panel is focused on the cement and building sectors that together are responsible for a large share of global CO_2 emissions. Currently, the most discussed decarbonisation alternatives in the cement industry include carbon capture and storage, the use renewable energy sources, and non-clinker based cementitious materials. While deep decarbonisation alternatives require redesign or new installations, other options as the use of renewable energy sources (e.g. biomass, RES-waste, clean gas) might be feasible with updating existing processes, but do not allow for near zero emissions. Thus, circularity measures in the cement and building industry could make an important contribution to reduce CO_2-emissions.

Gerres et al. (extended abstract 2-013-20) present the case of the Spanish cement industry, studying the impact of different policy options on the optimal investment decisions for cement plant operators, replacing their kilns over the next decades, given different sector targets. Preliminary results highlight the importance of strong regulatory support for investment costs and operational expenditures during the early phases of the transition period.

Singh & Arens (peer-reviewed paper 2-074-20) present the case of India that stands on second place as manufacturer of cement in the world, with a projected increase of 9 %–10 % annually. The paper discusses the utilization of various industrial and agricultural by-products as an alternative form of binder in cement. The contribution estimates the impact of these clinker substitutes on CO_2 reduction in the Indian cement industry up to 2050, considering that the adoption of such practice could offer significant reduction in CO_2 emissions.

Rehfeldt et al. (peer-reviewed paper 2-137-20) present the potential impacts of selected circular economy actions in the building sector on cement production and CO_2 emissions in the cement industry. The assessed measures include actions along the whole value chain. Some examples are the reduction of over specification, material substitution (e.g. new binders, wood use), extending buildings' lifetime, design for disassembly, etc. Results show that circularity measures could substantially contribute to the objective of a CO_2-neutral economy: the overall greenhouse gas reduction potential is calculated as 58 % compared to a 2015 base case.

Karlsson et al. (peer-reviewed paper 2-029-20) provide an analysis of different pathways of technological developments in the supply chains of the buildings and construction industry, including primary production of steel and cement. The analysis combines quantitative analysis methods, including scenarios and stylized models, with participatory processes involving relevant stakeholders in the assessment process. The roadmap outlines material and energy flows associated with different technical and strategical choices and explores interlinkages and interactions across sectors. The results show that it is possible to reduce CO_2 emissions associated with construction of buildings and transport infrastructure by 50 % until 2030 and reach close to zero emissions by 2045, while indicating that strategic choices with respect to process technologies, energy carriers and the availability of biofuels, CCS and zero CO_2 electricity may have different implications on energy use and CO_2 emissions over time.

Rasmussen (extended abstract 2-017-20) discusses the potential role of greenhouse gas (GHG) emission reduction of stone wool insulation. First of all, it should be considered that industrial processes for the production of stone wool through the melting stone and recycled material requires large amounts of energy. Thus, Rasmussen present the case of ROCKWOOL and its effort in reducing CO_2 intensity, reducing waste generation, expanding the circularity offering, and improving water efficiency. The contribution gives examples of concrete actions and developments, with the aim of reducing the environmental and climate footprint of the stone wool production, e.g. through the introduction of new melting technology in Norway, making energy inspections of factories and upgrading the insulation, and recycling of old/used stone wool.

Geographical triggers for circularity and decarbonisation of industrial processes

The second theme of the panel concerns the geographical triggers for circularity and decarbonisation of industrial processes. Here, regional and site-specific analyses are becoming increasingly relevant in the context of industrial symbiosis and collaboration, but also for the optimal planning and use of the needed infrastructure (e.g. for the provision of electricity, hydrogen or CO_2) in a near climate-neutral economy.

Schneider & Saurat (peer-reviewed paper 2-037-20) describe quantitative scenarios of a possible evolution of the EU petrochemical industry towards climate neutrality. The cost-optimization model used to develop the scenarios describes at which sites investments of industry in the production stock could take place in the future. The processes included cover the production chain from platform chemicals via intermediates to polymers. Pipelines allowing for efficient exchange of intermediates between sites are taken into account as well. The model draws on these data to simulate capacity change at individual plants as well as plant utilization. Thus, a future European production network for petrochemicals with flows between the different sites and steps of the value chain can be sketched. The scenarios described reveal how an electrification strategy could be implemented within a closed carbon economy with minimized societal costs. Moreover, implications for the chemical industry, the energy system and national or regional governments are discussed.

Vahidzadeh et al. (extended abstract 2-133-20) consider the topic of industrial symbiosis, i.e. when two or more dissimilar industrial processes exchange their non-product residues as resources (material and energy) in a collective approach for increasing the production efficiency and minimization of emissions and wastes in the whole system. This is regarded as an innovative solution in the movement from linear toward circular economy. The hypothesis of the research is that the geographical conditions can result in different categories of regional symbiotic networks, and these features should therefore be included in the process of planning or evaluation of possible scenarios prior to undertaking practical steps toward developing regional platforms or defining the networking programs. The study applies social network analysis (SNA) in combination with territorial analyses for European regions with different geographical features.

Williamsson et al. (peer-reviewed paper 2-115-20) examine the business logics for bioeconomy collaborations. The contribution identifies four distinct business logics (single product, multi product, secondary product, and bundled product) for bioeconomy collaborations that help incumbents and entrepreneurial ventures to overcome barriers to the commercialization of sustainable innovations. These logics were derived from case studies of successful value chain collaborations for the bioeconomy in a Nordic context. Results show that basing new bioeconomy ventures on existing well-developed processes, industrial infrastructure and distribution systems is beneficial. The potential to scale up these types of bioeconomy ventures appears good but is dependent on feedstock availability and market size.

Amon et al. (extended abstract 2-112-20) provide a practical understanding of the water energy nexus (WEN), in agricultural production and industrial food processing to identify energy efficiency and water conservation opportunities. It presents a case study to illustrate the methods and practices used to conduct a WEN assessment at a microbrewery facility in Davis, California.

Paths for circularity and decarbonization of manufacturing processes

The third thematic block underlines possible triggers for circularity and decarbonization of different manufacturing processes, with specific regards to automotive, industrial automation and batteries.

Di Leo et al. (peer-reviewed paper 2-125-20) present a multi-region representation of an automotive manufacturing plant with the TIMES energy model. The multi-region approach allowed modelling the two industrial units, the assembly unit and the plastic unit, as two different regions with independent production systems of electricity, heat and cooling, connected through unidirectional "trades" processes related to the components produced in the plastic unit and considering the polypropylene waste as additional material input. Five medium-term evolutionary scenarios addressed energy and materials recovery and evaluated the feasibility of innovative technological solutions: photovoltaic, energy recovery, from the molding process of polypropylene components, production of syngas from waste materials, recovery of polypropylene waste, and use of pigmented polypropylene for bumper molding.

Rakova et al. (peer-reviewed paper 2-027-20) present a novel business model to reduce energy consumption in industrial automation, in particular in the field of compressed air systems. The developed platform establishes a connection between suppliers of efficiency solutions and machine builders by support of a developed free online tool. It offers the determination of the most cost-effective drive solutions in the field of compressed air systems (CAS) and tackles some of the barriers for the implementation of energy saving measures in industrial automation.

Fallahi et al. (extended abstract 2-096-20) presents preliminary results from an ongoing project that aims to increase trust and transparency in a circular value chain of batteries by developing and validating a tool that uses blockchain to verify and track performance of individual battery cells. Through blockchain, information about the battery's health can be verified and shared amongst value chain partners in a secure and reliable manner. This solution is expected to increase the share of batteries being reused and recycled compared to today. In addition, this will enable increased recycling, partially by improving the traceability of critical materials from their origin through the value chain.

Ungerböck et al. (extended abstract 2-060-20) discusses the worth of an open market for second life e-mobility batteries, in particular for energy storage solutions. The study presents the results of the project "Second Life Batteries 4 Storage" and presents a pilot application in an industrial environment.

Energy and material efficiency along the value chain

The fourth block presents different contributions on energy and material efficiency considering the value chain instead of a single actor perspective. Effective management of resources typically allows companies to reduce costs while simultaneously wisely using scarce resources and reducing industrial energy-related emissions. However, the lack of a cross-sectorial single metric benchmark makes it hard for companies to assess and compare their performance.

Morgdo (extended abstract 2-050-20) presents a benchmarking tool for resource efficiency across industrial sectors, using exergy as a single metric, allowing industries to assess their performance against the best available techniques, as well as comparing resource efficiency with other environment indicators.

Fritz & Aydemir (peer-reviewed paper 2-023-20) present the energy of exergy analysis of different production processes of olefins by the steam cracking process. The analysis is based on the data of a virtual production plant according to the best available techniques (BAT) document of the JRC. Two possible future production processes are considered and compared with the current production process. The results show that the exergy efficiency cannot be increased with any of the possible future production processes investigated. However, one of the two investigated processes represents a carbon sink and thus offers great opportunities with regard to the decarbonisation of industry.

Neusel et al. (peer-reviewed paper 2-084-20) discuss the relevance of non-energy benefits and behavioural aspects of energy efficiency measures. The paper investigates both aspects along the cold supply chain of the food sector, thereby moving from the single company perspective to a full supply chain assessment. Semi-structured interviews with companies active in cold supply chains were carried out across various member states of the European Union. Findings from the interviews suggest that energy efficiency is presently considered more strongly in individual companies than along entire cold supply chains. While non-energy benefits appear to be relevant for both individual companies and the cold supply chain as a whole, awareness along the chain seems to be lower in comparison. Further complexity along the cold supply chain seem added by the prevalence of various behavioural aspects which may impede an easy implementation of energy efficiency measures.

Garvey et al. (extended abstract 2-051-20) examine technology and material efficiency scenarios for a net zero UK steel sector. The contribution modelled four key technology scenarios including retrofit, replacement to best practice, fuel shifts to greater EAF production, and implementation of breakthrough technologies, under different assumed ambition levels. The results of the study show that only complementary scenarios combining material efficiency and technology options would achieve a level of mitigation in line with net zero in the UK. Moreover, they conclude that it is possible to achieve net zero emissions in the UK steel sector without use of CCS, but that this would require greater and earlier levels of material efficiency.

Toro (extended abstract 2-147-20) presents the results of an ongoing project for the German Environmental Agency on the development of a database with specific parameters and determination of CO_2 cost components along the value chain. The analysis of the material and resource efficiency potentials in the aluminium industry along the aluminium value chain derives implications for this industry based on more ambitious recycling and a circular economy approach, linked to the new circular economy package from the EU and the interactions with an improved EU waste legislation.