Introduction to Panel 6 Deep decarbonisation of industry – technologies, strategies & implications for policy, industry and research

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Introduction

Deep decarbonization or climate neutrality of industry is an emerging and challenging topic since this sector emits around 30 % of total greenhouse gas emissions globally. In addition, prospects for deep decarbonization seem to be much more challenging than for the other sectors like transport, energy and households, in particular for basic materials processing industries. However, deep decarbonization of industry has so far received rather little attention.

To develop the necessary far reaching and maybe even radical innovations, it requires vast changes in policy, including industrial, research, innovation, trade, energy and climate policies. For the "European Green Deal" an integrated strategy in climate and industrial policy covering all mentioned fields would be important and need to be informed by research and examples from industry and policy.

The panel targets research, industry, policy and society representatives to discuss roadmaps & scenario concepts as well as technologies and challenges of deep decarbonization in industry. Company and regional innovation strategies that enable long-term changes in these industries are also addressed.

Energy-intensive industries face manifold challenging circumstances like strong international competition, volatility of energy and resource prices and global overcapacities. They also need to deal with long investment cycles since their plants and facilities are capital-intensive. In addition, their activities seem to be more and more dependent on national legislations, such as exceptions given for certain taxes and levies or climate policies like emission trading systems. Turning industrial processes into processes that emit close to no greenhouse-gas emissions requires substantial changes in production facilities, value chains and infrastructure. Options include energy efficiency, fuel-switching, electrification and hydrogen as well as carbon capture and storage/use. A demand for the products that are more climate friendly needs to be created as well.

Overcoming barriers to the industrial transition will require the co-evolution of new technologies and low carbon energy infrastructures as well as long-term transition strategies that go beyond incremental improvements. International collaboration might help as well as a targeted supportive climate and industrial policy framework. Ambitious and credible long-term targets could create leadership initiatives by industries and governments that could then be followed by more companies.

The impact on the energy system and the need for infrastructure

The decarbonization of industry will have a major impact on energy systems and their infrastructure. As in the first industrial revolution deep decarbonization of basic industries will need a co-evolution of industries and energy systems. Substituting fossil fuels with renewable energy or renewable electricity will create massive challenges to produce, transport and supply the needed amounts. On the other hand, also carbon capture and usage or storage need infrastructure for carbon transport.

Merten et al. (peer-reviewed paper 6-098-20) explore infrastructure needs in order to decarbonize the industrialized area of Belgium, the Netherlands and North-Rhine Westphalia in Germany as well as in Southern France and Poland. They discuss a set of strategies to reach industry decarbonization e.g. if electricity is generated closely to where it is consumed or whether it is imported. Hydrogen, another decarbonization option could be generated onsite or could be imported from other regions, like the Middle East or North Africa. They point out that industry clusters have emerged around fossil fuel sites, but that industrial sites could be relocated to regions that are more favourable for renewable energies.

Focusing on Austria's industry sector, Geyer et al. (peer-reviewed paper 6-024-20) find that the estimated renewable potential in Austria is sufficient to serve its industry sector, but not all Austrian sectors. The resulting difference in renewable electricity therefore has to be reduced through energy efficiency gains or has to be imported. They also point to the crucial role of electrifying primary steelmaking and that these sites are not close to regions with high renewable potentials.

Kjärstad et al. (extended abstract 6-095-20) present the ZEROC project which analyses possibilities and challenges for the industry in Sweden and Southern Norway to achieve deep reductions in CO_2-emissions by 2045. It explicitly covers all industries in the region that emit at least 100,000 tons fossil and/or biogenic CO_2 annually which comprises 96 sites in Sweden and 15 sites in Southern Norway. The largest of which are mainly Swedish pulp and paper plants which offer interesting potentials for biomass-CCS as option for negative emissions. Relevant process solutions including associated support infrastructure (transport and storage infrastructure for CO_2, biomass, hydrogen and electricity) are determined to calculate marginal abatement cost curves (MACC) and to develop a roadmap including timelines for a carbon neutral industry by 2045.

Barberousse et al. (peer-reviewed paper 6-063-20) analyze the impact of transitioning coal-based steelmaking in Europe to steelmaking based on the electrolysis of iron ore. They find that additional electricity in the amount of today's electricity consumption of France will be required just for the decarbonization of the European steel sector. Like Merten et al. (peer-reviewed paper 6-098-20), they also point the benefits of relocating industrial sites to regions with favourable renewable conditions.

Scenarios and pathways

Deep decarbonization of industries will need a suite of technical as well as infrastructural measures, which is already pretty much agreed upon as show the scenario studies presented for the German industry and for the German chemical industry in particular, but also for the Nigerian cement industry. However, looking at recent Global, European and German scenario studies Samadi and Barthel find that by far not all have reflected the full range of strategies for industry decarbonization.

Samadi & Barthel (peer-reviewed paper 6-065-20) compare and analyse industry decarbonization strategies as envisioned in recent German, European and global scenarios. They identify a set of strategies (e.g. energy efficiency, direct electrification, climate-neutral hydrogen, CCS). The selected scenarios use different combinations of these strategies in order to achieve carbon neutrality. As this may be an option for society to opt for certain strategies, it also unveils the current uncertainty. Interestingly, none of the strategies is pursued as key mitigation strategy in all selected scenarios. In addition, the analysis unveils that strategies that reduce the demand for energy intensive industrial products such as steel, cement or chemicals are only included as key mitigation strategies in half of the scenarios.

Fleiter et al. (peer-reviewed paper 6-141-20) present a quantitative scenario analysis covering two pathways for deep decarbonization of the German industry; one based on electricity and one on 'green' gas. Both scenarios reach a GHG reduction of about 93 % in 2050 without using carbon-capture and storage assuming market introduction and fast diffusion of low-carbon technologies as well as substantial improvements in energy efficiency and material efficiency and a strong shift to a circular economy. The electrification scenario experiences an increase of direct use of electricity of about 100 TWh or 50 % by 2050 compared to 2015 plus additional 146 TWh green hydrogen. In the gas focused scenario electricity demand remains stable, while a demand for 557 TWh of green gas emerges by 2050, mainly replacing natural gas use, but also coal in the steel industry and feedstocks in chemical products. Major challenges identified are high operating costs of CO_2-neutral processes, the expansion of infrastructure, the effective implementation of CO_2 price signals along the value chains and the reduction of uncertainties regarding large strategic investments in low-carbon processes.

Ausfelder et al. (extended abstract 6-022-20) analyze decarbonization pathways of the German chemical industry including CO_2 emissions from the feedstock. If this sector would decarbonize through electrification, its electricity demand would increase by more than ten times reaching levels similar to current German electricity consumption.

Yetano Roche (peer-reviewed paper 6-043-20) takes the Nigerian cement sector as an example. It foresees a production increase from currently 20 million tons to more than 50 million tons (lower scenario) or to over 70 million tons (higher scenario) by 2040. Decarbonization measures include energy efficiency, demand management, and decarbonization technologies like fuel switch. The study finds that depending on the measures taken, CO_2 emission from cement production in Nigeria by 2040 can be reduced by about 11 %.

Initiatives and dynamics

Decarbonization is not only relevant on a strategic and political level but has already massively made its way into strategic plans of industrial enterprises and clusters as examples from Sweden and Germany show. Broad scale implementation, however, needs much broader than conventional innovation strategies as well as the willingness to pay.

Andersson & Löfgren (extended abstract 6-086-20) present the example of Sweden's largest chemical industry cluster, which aims to lead a transition from an industrial region based on fossil raw materials towards the production of chemicals, materials and fuels based on renewable and recycled raw materials. Its goal is to reduce CO_2 emissions by 80 % by 2030. This transition requires not only novel technology but new competences, business models and policy instruments.

Tönjes et al. (peer-reviewed paper 6-094-20) analyze dynamics of cross-industry low-carbon innovations referring to four European case studies from the REINVENT project. Based on this analysis they identify five factors that determine the dynamics of low-carbon innovations in energy-intensive industries (mitigation of financial risk; political framework conditions; institutionalized cross-industry exchange; professional management and coordination; and regional integration).

Büttner et al. (peer-reviewed paper 6-149-20) analyze which measures German companies in the manufacturing sectors have taken or are planning to implement to reduce the footprint of their company, their products and their supply chain. For this the answers by approximately 900 companies participating in the Energy Efficiency Index of German Industry (EEI) are used, along with media research focusing on decarbonization plans announced and initiatives pledging climate action. While the overall targets the companies have set are impressive, they find that ownership structure and corporate culture seem to significantly impact the degree of decarbonization action underway.

Zhu (peer-reviewed paper 6-035-20) looks at the decarbonization of the steel sector using the perspective of global supply chains. She finds that the majority of steel is consumed by the domestic market and that resources for ironmaking are globally distributed unevenly. However, increasing production costs for environmentally friendly steel may be of concern to current major steel producing countries.

How to design policies and what the challenges are

Strong international competition, low margins, volatility of energy and resource prices and global overcapacities are important economic barriers which make clear the need for targeted policy to decarbonize energy intensive basic materials industries. Due to the complexity of the problem traditional CO_2 pricing instruments need to be amended by specific policies e.g. for large scale electrification and the introduction of hydrogen. These, however, probably need to be combined into a comprehensive and bold policy framework to enable long term industrial transition as proposed by Nilsson et al. (see below).

Nwachukwu et al. (extended abstract 6-045-20) takes the Swedish iron and steel industry as an example to illustrate the impact of CO_2 taxes, energy price and substitution targets on the substitution of coal with biomass. She finds that next to high CO_2 prices also policies that consider both forests and the steel industry are required. However, biomass without CCS can only reduce CO_2 emission in steelmaking by a maximum of 50 %.

Tholen et al. (extended abstract 6-077-20) aim to disentangle the current German debate on framework conditions for hydrogen, analyses challenges for the implementation of policy measures and proposes steps towards a refined policy framework. After briefly sketching the barriers, the paper discusses policy instruments for facilitating low-carbon hydrogen development.

Nilsson et al. (peer-reviewed paper 6-082-20) discuss the key elements of an EU industrial development policy consistent with the Paris Agreement and assess the current EU Industrial Strategy proposal against these elements. The developed framework recognizes the need for a set of functions among which are directionality, creating lead markets for green materials and reshaping existing markets or building capacity for governance and change. They find the announced EU Industrial Strategy to be strong on most elements, but weak on transition governance approaches, a need for capacity building as well as creating lead markets.

Based on experiences from two recent research project and a review of recent literature Rootzén et al. (peer-reviewed paper 6-040-20) outline and discuss five areas which will be critical to the potential for and outcome of a move towards increased electrification of industrial processes in the European Union. They discuss how high geographical concentration of industrial loads in particular regions, in combination with significant changes on both the supply side and demand side of the electricity system (i.e. transports and residential heating) post 2030 will pose significant challenges. But they also describe, how new options for process designs, production planning, optimization and automation may provide benefits beyond CO_2 emission reduction and how careful proactive planning provide opportunities for synergies.

The role of technologies and processes

Decarbonization of energy intensive industries will incur significant changes in industrial sectors and materialize at individual sites and particularly in the typical clusters of these industries.

Hoxha et al. (peer-reviewed paper 6-134-20) present detailed insights from modeling and an economic analysis for ammonia and steel production. The results show that it will be possible to design low-carbon emission processes for these industries in a near future.

A possible transformation pathway of the German chemical industry is presented by Neuwirth & Fleiter (peer-reviewed paper 6-110-20). Like Ausfelder et al. (see above), the paper takes into account the specific replacement and modernization cycles of the production plant stock and today's maturity of hydrogen-based technologies to develop a possible transformation pathway. The model based analysis (using the same model as Fleiter et al.), includes a plant-specific database and sets a particular focus on the intermediate targets for 2030.

Durusut (extended abstract 6-120-20) provides an update of the UK industrial clusters project. Industrial clusters are seen as a key area for decarbonization in the UK which will play a pivotal role in initiating hydrogen and CCUS infrastructure. Next to a technology overview the presentation expands on the key role CCS is expected to play, discusses conversion towards hydrogen and key business models to kick-start investment.