# Introduction to Panel 4
# Technology, products and systems

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## Introduction

Improved technologies can play a major role in achieving the energy saving targets set by international efforts to tackle climate change. Energy efficiency improvements in crosscutting technologies have the potential to unlock large energy savings due to their wide application base, and both policy and innovative business models can contribute to accelerating the market uptake of energy efficient technologies.

Of the utmost importance is the way these technologies interact with each other. The largest potential savings can often be found by taking a step back and looking at the optimisation of the entire systems and processes, and beyond its individual components. This approach leads to the minimisation of waste, energy savings, raised productivity and to an overall resource efficiency improvement.

Panel 4 has received contributions highlighting the impacts of improved technologies, processes and systems and their presentation has been organized in five themes: i) energy efficient technologies, ii) decarbonization pathways – scenarios and electrification options I, iii) decarbonization pathways – scenarios and electrification options II, iv) energy efficiency and GHG emission reduction, v) industrial processing improvement.

## Energy efficient technologies

The first theme deals with energy efficient technologies, its industrial applications and contribution to the reduction of industrial energy demand. Michalakakis et al. (peer-reviewed paper 4-115-18) present a methodology for the exergy efficiency analysis of ammonia production. Exergy provides a representative value of the useful energy carried by any material or energy flow by combining these into a single resource stream, while taking into account the resource quality. The analysis was performed on simulated data for an ammonia production site based on Steam Methane Reforming (SMR) to produce syngas from natural gas.

Malkamäki & Mäkinen (extended abstract 4-032-18) present a case study of energy savings achieved through a high efficiency small-scale gas turbine 'A400' installed at a small-scale industrial site in Finland. Small-sized gas turbines have gained increased attention due to their multiple benefits compared to conventionally used reciprocating engines: lower emissions and lower operating and maintenance costs, and wider variety of allowed fuels, including biofuels.

The possibility of using a Reverse Electrodialysis Heat-Engine (RED HE) as an option for recovering low temperature industrial waste heat and converting it to electricity is presented by Papapetrou & Kosmadakis (peer-reviewed paper 4-054-18). The most promising sectors for applications of the RED HE are identified, based on the rejected amounts of heat at around the low temperatures that are suitable for the heat to power technology under development. Additionally, case studies are presented.

Egizabal Luzuriaga et al. (extended abstract 4-046-18) present the design and development of a new generation of the Organic Rankine Cycle (ORC technology) to generate electricity based on the application of direct heat exchange solution. The developed technology is suitable for cross sectorial applications and should allow reducing the overall costs while increasing efficiency, considered as the key factors to cut existing barriers for a significant penetration of the ORC technology in the industrial energy efficiency market.

## Decarbonization pathways – scenarios and electrification options I

Currently, there is a growth in global energy related $CO_2$-emissions. In 2017, energy-related carbon dioxide emissions increased by 1.4 % whereas global energy demand grew by 2.1 % [IEA, 2018]. International climate change targets therefore impose an urge for reducing the rise of emissions while maintaining the competitiveness and forthcoming increase of industrial production. The second theme deals with the presentation of methodologies for decarbonising industrial processes. Electrification as a decarbonisation pathway is also tackled under this session.

Samadi et al. (peer-reviewed paper 4-022-18) discuss all possible scenarios for the evolution of the industrial cluster of the Port of Rotterdam and provide the opportunities and challenges for its decarbonisation until the mid of the century while maintaining its strong industrial position. Two basic decarbonisation scenarios are compared as to their technological choices and infrastructural changes, i.e., "Biomass and CCS" and the "Closed Carbon Cycle" scenario which assumes that renewables-based electricity will be used at the port.

Schneider & Lechtenböhmer (peer-reviewed paper 4-065-18) elaborate on the concepts and pathways towards a carbon-neutral heavy industry by 2050 in the German federal state of North Rhine-Westphalia which is home to important clusters of energy-intensive basic materials. Three scenarios are analysed including carbon capture storage and use, electrification of industrial processes and transport and the import of low carbon energies. Geographical aspects of the three scenarios are discussed i.e. possible interconnections with neighbouring countries.

Herbst et al. (peer-reviewed paper 4-105-18) present two scenarios for the transition to an EU28 economy where GHG emissions will be reduced by at least 85 % in comparison to the 1990 levels. The scenarios have been simulated on a high level of technological detail while considering policy instruments. The discussion includes a potential policy mix based on the implementation of particular mitigation options such as fuel switch to RES and changes in production structure, compared to current policies in place.

Finally, the paper of Wiertzema et al. (peer-reviewed paper 4-021-18) deals with the presentation of a methodology for the bottom-up assessment of electrification options for deep decarbonisation of industrial processes, demonstrated by a case study for the steam system of an oil refinery plant. The paper concludes with an assessment of the methodology, results from the case study and suggestions on future work.

## Decarbonization pathways – scenarios and electrification options II

The third theme continues with the analysis of scenarios for the low carbon transition by 2050 and also addresses energy flexibility in the industrial sector which can lead towards renewable energy sources (RES) integration and can confront grid extension requirements.

Flatau et al. (extended abstract 4-080-18) present an analysis of different decarbonisation pathways of selected main energy intensive industrial processes from a holistic perspective for on the basis of exergy analysis. The methodology is applied on the German industry and the German policy targets and in particular the case study of the German paper industry. In this frame, system boundaries are explained and the evolution of the primary energy consumption, exergetic efficiency and GHG emissions is discussed.

Braeuer et al. (extended abstract 4-086-18) analyse energy flexibility in industry, which is nowadays a promising path towards decarbonisation since prices for battery storage systems have dropped. The discussion addresses conditions for a profitable utilisation of battery storage systems through specific load indicators and sample companies and draws conclusions as to the factors influencing potential relevant investment.

Schüwer & Schneider (peer-reviewed paper 4-051-18) have identified the potential of electrification as an option for decarbonising the industrial process heat sector through modelling, expert interviews and literature research. Specific energy intensive sectors are analysed as to their state of the art and the observed obstacles and risks to the development of power-to-heat paths. Long-term applications, potentials impacts and supportive measures for an overall concerted strategy are mentioned. The methodology is particularly applied for the case of the German power-to-heat market.

Finally, the presentation of van Harmelen et al. (extended abstract 4-124-18) focuses on the position of the Dutch heavy industry in 2050 in relation to the different electrification pathways for basic materials and transportation fuels. The $CO_2$ emissions during the life cycle of the production process are compared to the total Dutch GHG emissions and basic decarbonisation scenarios are analysed.

## Energy efficiency and GHG emission reduction

Energy conservation is strongly linked to GHG emission reduction, which raises a crucial issue in the industrial sector namely that of maintenance of the industry's competitiveness. Supplementary to energy conservation means such as carbon management and intelligent production can lead to safeguarding of the industrial sectors sustainability.

Hatzilau et al. (extended abstract 4-090-18) describe how the glass industry may proceed to carbon management activities and improve its position in the frame of the European Emissions Trading Scheme (EU-ETS) once having improved the energy efficiency of the container glass production process through waste heat recovery.

Carvalho et al. (peer-reviewed paper 4-114-18) outline the significance of efficient and intelligent industrial production. The paper presents a pilot implementation of a machine learning based application for the automatic extraction of useful insights from machine level energy data sets. The energy data analysis tool developed has been validated in a controlled lab experiment planned to simulate a real shift of work in a factory. Two case studies on small and medium enterprises (SMEs) are analysed namely that of a precision engineering company and that of an injection moulding company.

Bhadbhade et al. (extended abstract 4-042-18) conduct a bottom-up analysis of energy efficiency improvement and carbon dioxide emission reduction potentials in the Swiss basic metals and fabricated metal manufacturing sector. Energy efficiency cost curves for electricity and fuel are derived considering the specific costs for various sub processes of the addressed industries and scenarios are presented within a sensitivity analysis that takes into consideration among other factors prices in combination with the payback period and the overall cost effectiveness.

Maggiore et al. (peer-reviewed paper 4-099-18) present the Energy Efficiency Good Practices in industry: the EIEEP platform, consisting of a web database of energy efficiency projects implemented in industry under the existing schemes is available. The database is searchable by country, sector, supporting scheme, implementation year, and company size and is, at present moment, the largest publicly available database of energy efficiency projects in Europe.

## Industrial processing improvement

Advances in industrial energy efficiency can be achieved, not only by improving individual technologies, but also by improving the performance of the entire manufacturing process and the interaction between actors within a product's supply chain.

Johansson et al. (peer-reviewed paper 4-012-18) presents a study on the production of a product in the Swedish aluminium industry in terms of implemented energy efficiency measures and potentials for further improvements. Most previous studies have focused on energy efficiency measures in individual companies (value chains). However, this paper presents and analyses energy efficiency measures in each individual company as well as measures when considering the whole supply chain of the product.

Bonilla Campos et al. (peer-reviewed paper 4-056-18) present energy efficiency and line productivity improvements for a continuous heat treatment process of an aluminium die-casting plant by means of an integral modelling methodology which includes a sensitivity analysis. Simulated theoretical phenomena were compared and validated with real data measurements.

The availability of data to support energy efficiency improvements in the dairy industry is analysed by Challis et al. (peer-reviewed paper 4-013-18). The main results from a survey with eight major dairy processing sites on energy monitoring practices are presented and the benefits from having energy data from processes visible and accessible to operators and engineers are shown.

Turek et al. (extended abstract 4-074-18) present efficiency optimisation strategies for small scale data centres where often these measures are considered not to be economical feasible or the technical staff is not aware of these saving potentials. The findings are weighted with respect to the limited budget and technical capabilities commonly attributed to SMEs.

## Conclusions – key messages

The panel covers all aspects of industrial efficiency improvements within technologies, products and systems as well as in their combination. Key messages deriving from the contributions to the panel are:

- There is a great interest in the analysis of decarbonisation pathways of the industrial sector with 2050 as a milestone date, while electrification options are recognised as decarbonisation routes. Energy flexibility in industry becomes also an option due to the potential for sustainable storage solutions.
- The energy efficiency of industrial technologies and systems has continued to improve, reflecting the raised awareness towards its benefits, and along with it strategies to improve industrial processes as a whole. Some of this process improvement strategies are now well proven and have high replication potential.
- The availability of data, and the way it is managed and used, can play an important role in the reduction of the energy demand and GHG emissions in industry.
- Additionally, to energy efficiency improvement measures, means such as carbon management and intelligent production can lead to safeguarding of the industrial sectors sustainability.