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1-004-20: Peer-reviewed paper

Shaping a sustainable industry: conclusions from round table meetings

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Panel
1. Policies and Programmes to drive transformation

Keywords
decarbonisation, EU climate strategy

At the 2018 European Sustainable Energy Week, the European Commission announced the launch of a series of round table meetings with the industry. Their purpose was to identify barriers to energy efficiency and renewable technology uptake in the EU in terms of policy, finance, sector coupling and awareness, and the solutions needed at the local, national and EU level.

The food and beverage sector was targeted due to its relevance for all EU Member States, diversity in size and composition, and share of SMEs that are less often targeted by energy efficiency and renewable energy policies.

A series of four meetings were organised in 2018–2019 and discussed 1) barriers to energy efficiency and renewable energy investments experienced by companies; 2) key success factors of national policies to overcome these barriers; 3) the motivation of some corporate companies to commit to sustainable and climate action, and 4) how their work relates to the EU strategic long-term vision for a prosperous, modern, competitive and climate neutral economy by 2050.

These discussions revealed that a common denominator: the commitment of the top management to climate action is a key driver to overcome the various barriers within the company. Policies and measures are effective to stimulate less committed companies to action and create the necessary context. Companies see themselves as a step in a broader value chain for de- 1. Disclaimer: All views in this article reflect the views of the author(s) and do not represent the views of the European Commission. carbonisation where energy efficiency and renewable energy must be a part of product and process redesign. Hence, policy makers must consider supportive, prescriptive and economic measures when designing policies stimulating the decarbonisation of the industry. The paper concludes with policy recommendations at EU level.

1-015-20: Extended abstract

Ennshafen case study – Insights into real-life industrial energy cooperation development

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Panel
1. Policies and Programmes to drive transformation

Keywords
cooperation, corporate strategy, sustainable development, overcoming barriers, local and regional energy planning, case studies, multiple benefits

A promising way to enhance sustainability and primary energy efficiency is industrial energy cooperation. Additionally, economic and innovation benefits for the companies as well as sustainable long-term regional development are aimed for. The Austrian industrial business park "Ennshafen" was chosen to put theoretical solutions to the test and to draw generalizable conclusions for other parks. After theoretical evaluation of energy cooperation possibilities, barriers and drivers via literature research, company interviews were conducted to verify and adapt the theoretic results. Important barriers are missing knowledge and communication on energy cooperation possibilities followed by economic, technical and framework barriers, especially if a cooperation opportunity shall be implemented. Identified viable opportunities among others are:

- Enforce and exchange information on cooperation potentials and technical opportunities at the total site (not limited to the company level)
- Trigger joint energy purchase & renewable energy communities
- Support inter-company waste heat utilization
- Evaluate joint strategies on optimizing heavy transport

The applicability of cooperation solutions is highly case-specific and results suggest that solutions are more likely to be implemented given continuous information exchange, eventually initiated by a dominant and integrative company or central institution.

1-021-20: Peer-reviewed paper

Review of regional energy efficiency policies towards industrial SMEs from within Europe

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Mihai Marian, South-West Oltenia Regional Development Agency, Romania
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Panel
1. Policies and Programmes to drive transformation

Keywords
industrial SME, energy efficiency policy, regional policies

Industrial SMEs represent 99 % or more of the total number of companies in most countries, and one-third of the total industrial energy use. Despite this, industrial SMEs have not received much attention both in terms of research and policies. The scientific papers published in the field covers national energy efficiency policy programs and evaluations of these, while scientific studies of regional policy programs are few. SMEs in general have a low capacity to work on improved energy efficiency, and the term SME is generally too vague to provide any guidance on how to design public policy programs. Administrative policies might be a sound approach for mediumsized enterprises but for small-sized enterprises the administrative policies could be less effective. For medium-sized and energy-intensive industrial SMEs, economic and/or regulatory incentives are important, while for small-sized and non-energy intensive industrial SMEs there is a need for a more supportive approach.

The aim of this paper is to provide an overview of existing regional energy efficiency policies targeting industrial SMEs in seven selected EU member states. This overview also provides an insight of the type of policy approach (informative, economic or administrative) that is most commonly used in regional policy activities.

1-025-20: Extended abstract

Voluntary energy efficiency agreements in Europe and the United States: Insights and best practices

Andre de Fontaine, Tractebel Impact, Belgium
Erwin Cornelis, Tractebel Impact, Belgium

Panel
1. Policies and Programmes to drive transformation

Keywords
industrial energy saving, voluntary agreements, decarbonisation, energy efficiency agreements, public private partnerships

Voluntary agreements have been utilized for decades to stimulate energy efficiency improvements in industry and other sectors of the economy. The practice has spread globally, with policymakers in different countries tailoring voluntary frameworks to meet the unique needs of their energy systems and end users. As a result, many different types of voluntary energy efficiency agreements have emerged over the years, all with varying goals, participants, design elements, and outcomes.

The authors will present insights from voluntary energy efficiency agreements in the two regions where this programmatic mechanism has been used most prominently: Europe and the United States. The history of voluntary agreements in both regions will be summarized briefly, with program design and goals analyzed and compared. Different models of voluntary agreements will be presented and assessed on the basis of their ability to elevate the importance of energy efficiency to senior management, engage industry in the development and design of the programs, clarify the business case for energy efficiency, and enhance coordination and information sharing among companies and especially within sectors. The presentation will conclude with a set of best practices pulled from each region that policymakers could draw from to improve program design in their respective locations.

Additionally, the presentation will include a brief discussion on how the European and American programs compare with similar efforts In China and Japan. The presentation will close with general conclusions on how voluntary agreements can complement other policies to drive the deep decarbonization called for through the Paris climate change agreement. A brief analysis of the application of voluntary agreements to broader sustainability goals beyond energy (such as water and waste) will also be presented.

1-049-20: Extended abstract

Development of the voluntary agreements system in Ukraine

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Panel
1. Policies and Programmes to drive transformation

Keywords
voluntary agreements, subsidies, financial incentives, energy-intensive industry, energy policy

The energy intensity of Ukraine’s economy is three to four times higher than the EU average. The industry and trade sectors account for over 40 per cent of energy consumption in Ukraine due to outdated, environmentally unfriendly and inefficient energy and resource-intensive technologies. As a result, many companies in Ukraine have potential to reduce their energy consumption by 30 to 50 percent.

Many countries worldwide including Denmark have introduced various support programs in order to reimburse part of the costs of implementing energy efficiency measures and to incentivize enterprises to modernize their energy consumption. The experience stemming from these support programmes are valuable and useful in the development of new socio-economic beneficial support schemes.

This study investigates whether a Voluntary Agreement Scheme should be implemented to underpin a transition towards a more energy efficient industry in Ukraine. More specifically, the study focuses on the incentive mechanisms, the necessary finance sources and the regulatory framework that is required to reduce energy consumption in the Ukraininan industry.

As part of the study, modelling calculations and guidelines have been developed in a collaboration between Ukraininan and Danish government officials and consultants. This has revealed and identified the need to adapt a Voluntary Agreement Scheme to local and country specific conditions.

1-058-20: Extended abstract

DOW Low Carbon Utilities

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Panel
1. Policies and Programmes to drive transformation

Keywords
decarbonisation, utilities, power, industrial steam systems

Manufacturing processes can be very energy intensive, and the CO2 emissions associated with the required power and steam can be significant. Regulations to address climate change, which increasingly include a price on carbon, are requiring manufacturers to achieve aggressive CO2 reduction targets. As a large, global manufacturer that also produces and consumes large amounts of power and steam, the regulatory changes and emissions cost structure have significant implications for Dow. To focus efforts and accelerate solutions, Dow conducted and will share results from its initial review of available options to provide lower carbon power and steam.

The presentation will focus on the regulatory landscape in the areas where Dow operates and the most attractive technological and commercial options for lowering CO2 emissions.

Criteria for evaluation included the technology readiness level, impact of the technology on energy efficiency and other environmental aspects, public acceptance, competitiveness, and infrastructure needs. Although no single technology scored favorable on all aspects, several possible options were identified, including opportunities to collaborate with government stakeholders to enable the development of low carbon solutions. The risks associated with target-setting policies that are focused solely on Scope 1 emissions were assessed, and the results will be shared. The assessment examined the possible effects on sustainability, cost competitiveness, and the resulting energy transition cost burden placed upon society.

1-072-20: Extended abstract

IMPAWATT – Actions to improve the energy culture

Konstantin Kulterer, Austrian Energy Agency, Austria
Yannick Riesen, Planair SA, Switzerland

Panel
1. Policies and Programmes to drive transformation

Keywords
industrial energy saving, energy management, behavioural change

Two main levers to improve industrial energy efficiency are awareness and motivation. However, which concrete instruments in this respect are available for companies? The European project IMPAWATT developed an online platform to address these issues.

To increase awareness for energy efficiency in companies the following capacity building and staff training material was elaborated: 25 open PowerPoint presentations, 70 measure descriptions, 40 best cases, numerous data collection sheets, and checklists for on-site checks. Furthermore, around 20 measurement and verification plans for evaluation of saving measures are provided. This material was executed for 13 technological areas and energy management. It can be used by energy managers for internal workshops with employees. In addition, energy managers can probe the knowledge of the attendees afterwards through email quizzes.

Another objective of the platform is to evaluate and promote the energy culture within a company. Therefore, an online test was designed to be distributed in-house. The answers of participants are used for developing a maturity matrix based on the five columns of energy culture (awareness, motivation, current practices, external factors, and effect on barriers). Depending on the maturity level, a set of recommendations to advance the energy culture of the company in question are then suggested.

Other topics covered by the project are identification and reporting of saving measures on the platform and useful information on life cycle management.

The entire material will be tested by 150 companies in the six participating countries (Switzerland, France, Germany, Italy, Austria, Finland) during the first half of 2020, assisted by the partners of the project. This will be done through support on-site (energy audits, workshops) and emails. Furthermore, the material will be presented in around 60 webinars. At the end, detailed interviews on the effect of the platform will be conducted.

1-089-20: Peer-reviewed paper

Energy efficiency networks: latest developments in Germany and in the world

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Antoine Durand, Fraunhofer Institute for Systems and Innovation Research ISI, Germany
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Panel
1. Policies and Programmes to drive transformation

Keywords
energy efficiency network, energy management system, energy efficiency action plans, energy efficiency policy

Energy efficiency networks (EEN) have established themselves as a firm fixture in the global energy efficiency landscape. At least 21 countries and all continents except Australia have had experience with energy efficiency networks to this point. The authors count 1,333 EEN worldwide, with Germany and China far ahead of other countries in terms of absolute numbers. Next, this paper offers insights from the monitoring of the German Initiative Energy Efficiency Networks (IEEN), set up as a voluntary measure within the framework of the National Action Plan for Energy Efficiency (NAPE) in 2014. To date, 272 EEN have registered under this programme.

The results of the accompanying monitoring are represented separately for different levels: that of networks, that of participating companies and that of individual energy efficiency measures implemented. Across these different levels, a large heterogeneity in terms of the main parameters such as energy and CO2 savings can be observed, highlighting the diversity of participating companies and the contexts they operate in. Also presented are the factors which seem to contribute to the successful or less successful operation of the networks.

Finally, the paper offers a short discussion on the operational and political choices faced by the potential future initiators of an energy efficiency networks initiative.

1-114-20: Extended abstract

Leaders in the industrial energy transition

Christiane Egger, OÖ Energiesparverband, Austria
Christine Öhlinger, OÖ Energisparverband, Austria

Panel
1. Policies and Programmes to drive transformation

Keywords
energy efficiency investments, climate neutral economy, decarbonisation of industry, energy efficiency programmes

Understanding how to achieve climate neutrality in practice and concretely plan the process for a specific company is a path not yet travelled by many. Independence from fossil energy is becoming a key factor for industrial competitiveness. Following automation and digitisation, "Industry 5.0 decarbonisation" will characterise the next big step in the industrial transformation.

The novel initiative "Industrial Leaders in the Energy Transition" developed by the OÖ Energiesparverband (ESV) brings together 16 industrial and service companies interested in carbon neutrality. Together, these manufacturing companies and large-scale retailers employ over 25,000 and have a turnover of over 7 billion Euro/a.

The initiative adopts a unique approach developed by the ESV. This consists of company internal processes and dedicated collaboration activities that lead to finding ways for companies to achieve their energy transition. Key elements include:

- developing action plans for companies and implementing concrete steps to phase out fossil fuels while simultaneously increasing competitiveness
- showcasing real-life examples of pioneer companies
- supporting the development of products and services needed for the industrial energy transition

- creating an innovation ecosystem for the industrial energy transition by bringing together companies, public organisations and researchers around a vision of "climate-neutral economy".

Upper Austria has made significant progress in the energy transition: Since 2005, industrial GHG emissions were kept stable despite a 55% BIP increase. Building GHG emissions were reduced by 38% in the same period by significant increases in energy efficiency and renewable energy. 58% of all space heating in Upper Austria is supplied by renewables. Over 2 billion Euro are invested annually in the energy transition, of which 30% are invested in energy efficiency measures in industry and CHP installations.

1-116-20: Peer-reviewed paper

Low-carbon transition in steel industry: A compative study between Iran and Sweden

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Panel
1. Policies and Programmes to drive transformation

Keywords
technological innovation system, sustainability, low carbon technologies

The challenges of the new era about being more sustainable have been increasing in recent decades. Most of the studies have focused on investigating the sustainability transition in clean-tech industries of emerging economies. Meanwhile, the role of scale-based industries like the steel industry in the transition to sustainability has been neglected, specifically in emerging economies and developing countries. The iron and steel industry has a share of one-third of global industrial emissions all over the world, which can make a stronger argument to get more attention.

The pressure on the industry shift to more sustainable ways of production is currently undergoing in the Swedish steel industry within the HYBRID project that aims to transition towards a hydrogen-based steel making. Hydrogen Direct Reduction (H-DR) is taken as a case study in order to compare with the steel of Iran in terms of sustainability transition.

Considering the advantages of Iran like the availability of renewable energy (solar), of iron ore, a growing steel industry, and well-skilled people, the main question is how Iran as a latecomer, can make a collaboration with Sweden in order to develop the sustainability transition in this industry. Here, the experiences of Sweden shall be taken into account to identify the features and conditions in Iran. We apply a Multi-Level Perspective (MLP) in this study.

1-124-20: Extended abstract

No time to waste reinventing the wheel – introducing the concept of a pan-European interactive knowledge transfer platform for radical energy savings

Cédric Jeanneret, Services Industriels de Genève - SIG, Switzerland
Imane Fouiteh, University of Geneva, Switzerland
Susan Mühlemeier, VSE - AES, Switzerland
Helena Lindquist, Lightswitch, Sweden
Jose Daniel Cabrera, University of Geneva, Switzerland

Panel
1. Policies and Programmes to drive transformation

Keywords
Energy utilities, best practice, cooperation, action plan, academic

The urgency of the climate crisis calls for radical measures by stakeholders across all societal sectors in Europe and globally to curb energy consumption.

Most known drivers supporting energy savings are technological innovations and policy instruments. Nevertheless, many studies show that stakeholder collaboration initiatives can be an effective way to enhance energy efficiency and inspire concrete actions.
However, for such collaboration to be truly effective, more attention needs to be placed on the structure and mechanisms of knowledge exchange processes. During the course of our research, this need has been confirmed in stakeholder interviews. Inspired by the work of various organizations promoting cooperation and networking among energy stakeholders, this extended abstract proposes an idea to create a collaboration platform consisting of a complementary set of tools, strategies and support for facilitating structured and efficient knowledge transfer (henceforth KT) among European energy stakeholders.

METHODOLOGY AND RESULTS
The proposed platform structure has been developed based on the results of literature studies and interviews with nine organizations in the energy sector in Germany, France, Sweden and Switzerland, offering KT opportunities for their respective members. The interviews focused on challenges and success factors in regard to realising impactful collaboration amongst network members. In addition, the platform ideas build upon the co-authors' own experiences from participating in and organising KT activities.

Key conclusions include (interview quotes between quotation marks):
– All interviewees express that peer-to-peer exchanges with the objective of learning from one another is seen as very important for network members.
– With a few exceptions most KT activities consist of conferences, seminars and network meetings focused on topics of common interest. It was clear that no explicit strategy for KT was developed.
–'I noticed that the real knowledge sharing actually happens in the coffee breaks, so I started to organize longer ones', but no further measures were taken.
– Receiving information about cases and approaches by peers is generally appreciated by members but rarely have a direct impact on concrete energy efficiency practices in their respective organisations. 'implicit feedback is generally carried out but is hardly ever usable by other members' because 'when projects are presented, the concerns encountered and errors made are rarely expressed'.
– Although some offer capacity building activities to members (e.g. training courses), more structured KT activities aiming to capitalise more concretely (i.e. leading to real action in the participating organisations) on the explicit and tacit knowledge in peer-to-peer networks are very rare.
– Activities in which participants are truly engaged and which have a concrete goal, e.g. working together to solve a shared problem, are regarded as more impactful in terms of learning compared to more passive approaches like seminars. Such activities also bring added benefits such as strengthening peer-to-peer fabrics and providing informal fora for sector dialogue. 'when they present their achievements or help another company struggling with a problem that they have already solved, it gives them enthusiasm and confidence'

PROPOSING A PAN-EUROPEAN KNOWLEDGE PLATFORM
Based on our analysis, we propose to form a platform aiming to accelerate energy savings through facilitating concrete deep-dive and challenge-driven KT. We present how such a platform could be structured and managed as well as give suggestions on content and activities. Examples include a "knowledge needs matrix", living labs, collaboration mechanisms for involving researchers in concrete "how-to" KT projects and a library of both real cases and supporting research. The proposed platform will combine both IT tools and human resources to facilitate sector KT collaboration both, online and live.

1-129-20: Extended abstract

White certificates in industry: M&V, additionality and global outcomes in the Italian scheme

Dario Di Santo, FIRE, Italy
Livio De Chicchis, FIRE, Italy

Panel
1. Policies and Programmes to drive transformation

Keywords
tradable white certicates, white certificates, energy efficiency obligation, Energy Efficiency Directive (EED), EU 2020 target, incentive mechanisms

In Italy the white certificate scheme has been mainly promoting over time energy efficiency projects implemented in the industrial sector. There has been a period of time in which such projects amounted to almost 80% of the total accounted energy savings. Recently the ration between industrial projects and energy efficiency measures implemented among other sectors in terms of accounted savings is around 60% and it is raising again since from 2017 on only metered savings are used (deemed savings methods are eligible no more).

The fact that around 60% of the project have been metered, with an approach analogous to IPMVP option B, carried many benefits: real savings are accounted for, a lot of valuable data on processes transformation has been collected (see for example the EU-MERCI good-practices platform), energy managers' and ESCOs' skills on M&V have been improved, higher performance are stimulated (since certificates are issued over a given amount of years according to the effective results), no need of evaluation programmes. The presentation will illustrate how M&V worked in the Italian scheme and what the main outcomes have been.

The presentation also aims to investigate the topic of additionality, a complex one when dealing with the industrial sector, especially with the improvement of manufacturing processes. Additionality has been evaluated in different ways over time, with different impacts on the eligibility of projects and deep effects on the capability to present new energy efficiency projects under the scheme.

Finally, the presentation will provide an update on the main outcome of the Italian scheme and on the recent modification introduced in 2018 and 2019 to overcome the serious problems in terms of market shortage that has been affecting the scheme since 2016.

1-138-20: Peer-reviewed paper

What the industry needs from energy efficiency: Reflections on energy efficiency programs in food & beverage sector

Adam Pawelas, SA Evian, France

Panel
1. Policies and Programmes to drive transformation

Keywords
energy efficiency action plans, food and drink, incentive mechanisms, efficiency standards, education

Energy efficiency is an important building block of industry decarbonisation journey. Business case is compelling: improving bottom line, making company more resilient to energy price volatility, funding the decarbonisation projects, and other non-financial benefits (broader sustainability credit). Yet there are also factors or conditions when energy efficiency does not work this way. These conditions are: focus on quick one-off savings and not investing into energy efficiency culture, capability gap to deliver and sustain efficiency improvements, wrong efficiency metrics not delivering meaningful information on performance, rebound effect eating out efficiency gains.

In order not to let the energy efficiency fail or plateau out the industry needs to stay aware of the pitfalls as above. The success factors for sustained benefits in energy efficiency are: (1) understand the nature of energy efficiency and its metrics, (2) make energy efficiency a program encompassing wider purpose, transformation and cross-functional collaboration, (3) take advantage of both generic techniques as well as scout new solutions, (4) trim the program to resources available internally and externally, (5) create barriers against rebound effects, (6) look out for education, standards, services, technologies, financial incentives, and other resources. Examples will be discussed.

From the market and policy making perspective the industry has the following needs supporting efficiency agenda (addressing factor 6 from the list above): education, communication and industry collaboration, incentive schemes for financing and technology adoption, direct knowledge transfer to smaller companies and support to less mature markets, coordinated standards of equipment and energy efficiency techniques to streamline efficiency features in projects. Examples of concrete needs will be discussed.

1-140-20: Extended abstract

Evaluating the Polish white certificate scheme

Tadeusz Skoczkowski, Warsaw University of Technology, Poland
Jan Rosenow, The Regulatory Assistance Project (RAP), Belgium

Panel
1. Policies and Programmes to drive transformation

Keywords
tradable white certicates, white certificates, energy efficiency obligation

Poland, as the EU Member State, introduced an Energy Efficiency Obligation (EEO) in 2012 to deliver its energy efficiency targets under Article 7 of the Energy Efficiency Directive. The Polish EEO includes White Certificate trading as a key element making it one of the few EEOs in the world that include this feature. For the first time since its inception, this research provides a systematic evaluation and review of the Polish EEO.

The study has been based on a database of the 4,620 projects submitted to the EEO and statistically processed during the research. It compares the two periods of the EEO (end 2012-mid 2016 and mid 2016-present); critically reviews the principal rules of operation during the two periods; assesses the types of measures delivered in different sectors; and estimates the triggered energy savings and the costs of the EEO.

It has been found that the transition from the first to the second period of the EEO was poorly managed and happened abruptly, although several improvements have been made to the EEO that, at least to some extent, resolved some of the teething problems observed during the first period.

Several areas of concern that need to be addressed to improve the functioning of the system have been identified. Firstly, projects supported by the Polish EEO do not have to be additional to market activity that would have happened anyway even in the absence of the EEO. There is clearly a risk that the savings reported are inflated because at least some of the activity would have happened anyway. The measurement and verification regime appears to rely on self-declared energy savings by companies obtaining white certificates. There is no official specification of lifetimes. Finally, there is a lack of independent evidence-based evaluations of the EEO.

We observe several improvements through the redesign that can be expected to lead to greater energy savings going forward:

a) Reducing the complexity for market actors involved in delivering the programme makes it easier for companies to obtain white certificates and for obligated parties to deliver on their targets.
b) Disallowing projects already carried out from being funded through the EEO lowers the risk of non-additional savings and free-ridership.

c) Switching to the metric of final energy savings significantly reduces the opportunities for using renewable energy technologies for the purpose of delivering energy savings.

A positive requirement is that projects must not be doubly financed from public sources, EU or national.

The analysis shows that present levels of energy savings delivered by the EEO are insufficient to achieve the new EU energy efficiency targets for 2014–2020 and post-2020. Given the uncertainties around the savings reported and recorded by ERO the actual shortfall could be much below the 2020 saving target. This could potentially compromise the EU's ability to meet its 2020 energy efficiency target: Poland is a major economy in the EU and has a share of over 6% of the EU's final energy consumption. If Poland misses its Article 7 target, the implications for the EU 2020 energy efficiency target may be serious and need to be considered as a common EU threat.

Several policy recommendations for improving the EEO have been derived from an assessment of the current programme architecture. One issue currently unaddressed is energy poverty. An increasing number of EU countries now have sub-targets in their EEOs for energy poverty. Including a sub-target for energy poverty in the EEO could result in additional savings whilst also ensuring that the poorest households benefit from the EEO.

The paper has also identified a few lessons learned that are particularly applicable to countries considering the introduction or redesign of an EEO. An overall recommendation is also to increase the transparency of the EEO, making data easily accessible, and involving a wide range of stakeholders in the evaluation and delivery of the EEO.

1-150-20: Extended abstract

Valuing and communicating the multiple benefits of energy-efficiency projects

Catherine Cooremans, Université de Lausanne, Groupe Ecologie Industrielle, FGSE / IDYST, Switzerland
Clemens Rohde, Fraunhofer Institute for System and Innovation Research ISI, Germany

Panel
1. Policies and Programmes to drive transformation

Keywords
non-energy benefits (NEBs), multiple benefits, corporate investment decisions, business case, case studies

Many benefits other than mere energy savings accrue in energy-efficiency projects. Commonly referred to as "non-energy benefits" (NEBs), they include important core business benefits for industrial companies, such as improved product quality or reduced risks. A reduction in GHG emissions is another frequently observed benefit of energy-efficiency projects. Similar to energy benefits, NEBs translate into financial benefits for the investor.

In order to increase the chances of energy-efficiency investments, NEBs should be included in investment appraisal. Unfortunately, this is often not the case due to a lack of method, expertise and evidence base. As described in the report Capturing the multiple benefits of energy efficiency (IEA, 2014:137) "Because so few studies have been undertaken in this area, methodologies for quantifying wider benefits from energy efficiency measures in industry are still at the inception stage".

Within this context, the H2020 project M-Benefits (2018-2021) has developed a Toolkit to "Valuing and Communicating the Multiple Benefits of Energy-Efficiency Projects", with the goal of increasing the capacities for actual implementation of energy-efficiency measures in industry and services. The Toolkit includes an analytical and communication method (originally described in Cooremans, 2015), a user-friendly software, and training tools to facilitate the use of the method by energy-efficiency engineers.

M-Benefits implementing partners started applying the Toolkit to several pilot projects. It is the first time in the field of energy efficiency, that a common method is applied ex-ante to various industrial energy-efficiency projects to identify NEBs and value them. The goal of this paper is to describe the case studies carried out in the framework of M-Benefits and to compare and analyse their results, which confirm the existence of non-energy benefits and their importance for raising the business case of energy-efficiency projects.

1-151-20: Extended abstract

Five steps to decarbonisation

Stefan M. Büttner, University of Stuttgart, EEP – Institute for Energy Efficiency in Production, Germany
Hannes Mac Nulty, MacNulty Consulting, France
Rod Janssen, Energy in Demand, United Kingdom
Werner Koenig, REZ - Reutlingen Energy Center for Distributed Energy Systems and Energy Efficiency, Reutlingen University, Germany
Diana Wang, University of Stuttgart, EEP Institute for Energy Efficiency in Production, Germany

Panel
1. Policies and Programmes to drive transformation

Keywords
decarbonisation, decision-making process, political targets, investment decision-making, implementation, communication gap, environmental awareness, enabling stakeholders

Public attention towards climate change was limited in the past. Only over the past year, with Greta Thunberg & Fridays for Future, the attention rose and politicians appeared to give the topic a higher priority. It was at the European Parliament election only where voters awarded climate conscious parties a staggering increase in votes. At the UN climate summit in September, only countries that had significant news were allowed to speak. These, however, still have been labelled as insufficient by youth and scientists. One may get the impression that everything depends on politics only, 'someone else'.

Politics is only the actor who sets the framework, however – everyone is responsible for implementation action, in the words of a Dutch saying 'a better world starts with yourself', therefore the challenge ahead is to...

1. create awareness for the need to decarbonize, for energy efficiency
2. create an understanding that each type of stakeholder (each one of us) is able to make a difference
3. enable stakeholders to know & implement what this is (individually)
4. trigger their decision for it
5. bring about implementation

In this paper, we show how experiences, examples & empirical demand-side data gathered over the past years lead us to these five steps and provide insights on how to succeed in each of them, why they are needed and need to be ticked-off in that order.

This is of particular relevance in the industrial sector, as there (1) are misperceptions on the real barriers due to communication gaps between different stakeholder types and functions within companies, (2) is a much higher complexity of decarbonisation projects, (3) is a much shorter

period within which results need to be visible & pay-off, and (4) as the sector, besides its own, significantly impacts on the footprint of all other economic sectors that use their products for buildings, vehicles, farming, etc. through the product design, performance and sourcing choices industry leaders take.

2-013-20: Extended abstract

Overcoming the carbon lock-in: A techno-economic analysis of the Spanish cement sector

Timo Gerres, Comillas Pontifical University (IIT), Spain
José Pablo Chaves Ávila, Comillas Pontifical University of Madrid (IIT), Spain
Pedro Linares Llamas, Comillas Pontifical University of Madrid (IIT), Spain
Tomás Gómez San Román, Comillas Pontifical University of Madrid (IIT), Spain

Panel
2. Sustainable production towards a circular economy

Keywords
energy policy, decarbonisation, EU 2050 targets, cement, industrial transition

Cement clinker production is one of the most emission intensive industrial processes. Emissions originate from both the combustion of fossil fuels and the chemical reaction of limestone to calcium oxide within the kiln. Decarbonisation alternatives include carbon capture and storage, renewable energy sources and non-clinker based cementitious materials. Since drastically reducing the carbon footprint of cement is an absolute necessity for a near-carbon neutral society, as aimed for by the European Union, alternatives to today´s processes need to become commercially available and fully replace existing installations until 2050. This marks a huge challenge for the industry and installations in operation, today.

Cement kilns have an economic lifetime of 25 years and its replacement is highly capital intensive. While deep decarbonisation alternatives require a redesign or new installations, other options as the use of renewable energy sources (biomass, hydrogen and partial electrification) might be feasible with updating existing processes, but do not allow for near zero emissions. Cement plant operators, replacing their kilns over the next decades, will base their investment decision on the expected profitability of the available technologies.

Policy makers therefore need to design incentives, which ensure that re-investment decisions by plant operators are in line with long-term decarbonisation targets. Else, a carbon lock-in with technologies not able to deliver the required emission reduction is likely.

The objective of our research is to evaluate the potential of different policies to avoid such carbon lock-in. For the case of the Spanish cement industry, we study the impact of different policy options on the optimal investment decisions given different sector targets for the year 2050. Preliminary results highlight the importance of a strong regulatory support for investment costs and operational expenditures during the early phases of the transition period.

2-017-20: Extended abstract

Working with sustainability in the insulation industry

Soeren Nyborg Rasmussen, ROCKWOOL Technical Insulation, Denmark

Panel
2. Sustainable production towards a circular economy

Keywords
thermal insulation, energy saving potential, circular economy, industry, recycling, carbon emissions

Insulation in general and specifically stone wool insulation have a truly significant potential on reducing emission of Green House Gasses, thereby playing an important role in our attempts to curb the drastic changes in our climate that we are experiencing. However, industrial processes such as the production of stone wool through the melting stone and recycled material requires large amounts of energy.

Also other resources like water are used in the process. What about waste and where it goes?

ROCKWOOL was one of the first companies to embrace the 17 UN SDGs and has operationalised these into several tangible targets linked to our production footprint: reducing CO2 intensity, reducing waste generation, expanding the circularity offering, improving water efficiency among others.

The company already has a lot of experience working with circularity – using waste products from own processes and other industries to produce new insulation materials. But also here ambitious goals will drive the development and processes much further, as ultimately ROCKWOOL will expand its circularity offering to more and more markets taking back old ROCKWOOL insulation and process this into new materials.

This paper will elaborate on the above and give examples on concrete actions and developments such as:
1) Introducing new melting technology in Norway
Stone wool production is energy intensive, and with the energy traditionally coming from coke, coal and natural gas also a significant emitter of CO2. With new technology the stones can be melted in electrically powered furnaces – this leads to direct CO2 reductions of 80 %, but also additional benefits such as reduction of waste and better possibilities for rework of old/used stonewool. Electrically powered furnaces are relevant where low-carbon power is available, like e.g. in Norway.

2) Taking own medicine, making energy inspections of factories and upgrading the insulation. There are big potentials for energy saving in the industry – via improved insulation. This is an opportunity for both cost and CO2 saving that is often ignored during the construction and

maintenance of equipment in the industry – even on factories manufacturing insulation! Via simple energy audits that identifies and measures heat loss, it is possible to track areas/surfaces where upgrades can be made to the benefit for the owner and the environment.

3) Recycling of old/used stone wool - expansion of circularity offering
Insulation take up a lot of volume and the waste traditionally go to landfill. Now there is an alternative to land fill; stone wool can be recycled, whether it is cut-off waste from an installation or the old used insulation from a storage tank. In more an more countries ROCKWOOL is upgrading its recycling facilities and making agreements with local waste management companies to facilitate the logistics in returning the old insulation.

All of the above initiatives/investments, with the aim of reducing the environmental and climate footprint of the stone wool production.

2-023-20: Peer-reviewed paper

The energy of exergy – analysis of different production processes of olefins

Markus Fritz, Fraunhofer Institute for Systems and Innovation Research, Germany
Ali Aydemir, Fraunhofer ISI, Germany

Panel
2. Sustainable production towards a circular economy

Keywords
exergy analysis, CO2 reduction, chemical industry, olefin production

In order to achieve the greenhouse gas emissions reduction targets, there must be a significant reduction in all sectors. The chemical and petrochemical sector was responsible for 7 % of worldwide CO2 emissions and 10 % of worldwide industrial final energy demand in 2010. For this reason, efficiency potentials must be used or new production processes introduced.

In the context of decarbonisation, the focus is often exclusively on the energy perspective, since this provides the relevant information for investment decisions in the field of energy or greenhouse gas efficiency. However, for industries in which energy carriers are used both energetically and materially, a purely energetic analysis can only have limited informative value with regard to the efficiency of the entire production process.

An alternative to purely energetic analysis is exergy analysis, in which all relevant material flows for an analyzed process are included. In this context, an indicator for the efficiency of the overall process can be defined that combines energy and material flows. We therefore conduct such an analysis for the production of olefins by the steam cracking process. The required data is based on a virtual production plant according to the Best Available Techniques (BAT) document of the JRC. In addition, we analyze two possible future production processes and compare them with the current production process.

The future production processes consider the production of Olefins either from waste or from hydrogen and CO2. The exergy efficiency of the steam cracking process is around 56 %. The results show that the exergy efficiency cannot be increased with any of the possible future production processes
we have investigated.

2-027-20: Peer-reviewed paper

A novel business model to reduce energy consumption in industrial automation

Elvira Rakova, Direktin, Italy
Martinelli Matteo, Italia
Luca Pagni, Italia

Panel
2. Sustainable production towards a circular economy

Keywords
industrial energy saving, business models

In a world ever more pressed by natural and societal challenges, increased industrial energy efficiency offers a unique opportunity to reconcile economic competitiveness with sustainable development. The World Economic Forum (WEF) lists a set of barriers to implement energy efficiency measures, including lack of expertise and information, low priority of energy efficiency projects, and access to capital[1]. In this context, online platforms and marketplaces of B2C and C2C services opens new horizons for the development of new business models that promote increased industrial energy efficiency.

This paper presents a novel business model named “assisted market place and extended service” for the field of compressed air systems. The novel business model is supported by the development of an online platform that establishes the direct connection between suppliers and machine builders, further allowing for the determination of the most cost-effective drive solutions in the field of compressed air systems (CAS). This novel business model aspired to solve some of the main barriers for the implementation of energy saving measures in industrial automation.

2-029-20: Peer-reviewed paper

Roadmap for climate transition in the building and construction industry – a supply chain analysis including primary production of steel and cement

Ida Karlsson, Department of Space, Earth and Environment, Chalmers University of Technology, Sweden
Johan Rootzén, University of Gothenburg, Sweden
Alla Toktarova, Department of Space, Earth and Environment, Chalmers University of Technology, Sweden
Mikael Odenberger, Department of Space, Earth and Environment, Chalmers University of Technology, Sweden
Filip Johnsson, Chalmers University of Technology, Sweden

Panel
2. Sustainable production towards a circular economy

Keywords
steel, cement, construction industry, climate change mitigation, decarbonisation, carbon capture and storage, electrification, biomass, bio fuel

Sweden has, in line with the Paris agreement, committed to reducing greenhouse gas emissions to net-zero by 2045. Emissions arising from manufacturing, transporting and processing of construction materials to buildings and infrastructure account for approximately one fifth of Sweden's annual CO2 emissions. This work provides a roadmap with 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. By matching shortterm and long-term goals with specific technology solutions, these pathways make it possible to identify key decision points and potential synergies, competing goals and lock-in effects. The analysis combines quantitative analysis methods, including scenarios and stylized models, with participatory processes involving relevant stakeholders in the assessment process.

The roadmap outline 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 CO2 emissions associated with construction of buildings and transport infrastructure by 50 % to 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 CO2 electricity may have different implications on energy use and CO2 emissions over time. The results also illustrate the importance of intensifying efforts to identify and manage both soft (organisation, knowledge sharing, competence) and hard (technology and

costs) barriers and the importance of both acting now by implementing available measures (e.g. material efficiency and material/fuel substitution measures) and actively planning for long-term measures (low-CO2 steel or cement).

Unlocking the full potential of the range of emission abatement measures will require not only technological innovation but also innovations in the policy arena and efforts to develop new ways of cooperating, coordinating and sharing information between actors.

2-037-20: Peer-reviewed paper

Simulating geographically distributed production networks of a climate neutral European petrochemical industry

Clemens Schneider, Wuppertal Institute for Climate, Environment, Energy, Germany
Mathieu Saurat, Wuppertal Institute, Germany

Panel
2. Sustainable production towards a circular economy

Keywords
closed carbon cycles

The paper describes quantitative scenarios on a possible evolution of the EU petrochemical industry towards climate neutrality. This industry will be one of the remaining sectors in a climate neutral economy still handling hydrocarbon material to manufacture polymers. Concepts of a climate neutral chemical industry stress the need to consider the potential end-of-life emissions of polymers produced from fossil feedstock and draft the vision of using renewable electricity to produce hydrogen and to use renewable (hydro)carbon feedstock. The latter could be biomass, CO2 from the air or recycled feedstock from plastic waste streams.

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. Around 50 types of products, the related production processes and the respective sites have been collected in a database. The processes included cover the production chain from platform chemicals via intermediates to polymers. Pipelines allowing for efficient exchange of feedstock and platform chemicals between sites are taken into account as well. The model draws on this 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 in this paper reveal how an electrification strategy could be implemented by European industry over time with minimized societal costs. Today's existing assets as well as geographical variance of energy supply and the development of demand for different plastic sorts are the major model drivers.

Finally, implications for the chemical industry, the energy system and national or regional governments are discussed.

2-050-20: Extended abstract

BAT benchmarking tools for industry

Ana Morgado, University of Cambridge, United Kingdom

Panel
2. Sustainable production towards a circular economy

Keywords
exergy analysis, resource efficiency, industrial emissions, best available technologies (BATs)

According to the International Energy Agency, industry is responsible for over a third of the total greenhouse emissions. Despite current debate's primary focus on efficiency improvements in buildings and transportation, the scale of emission reduction potential from the industry sector is considerably bigger, and thus, crucial for achieving carbon neutrality.

In 2017, industrial energy-related emissions increased 14%, surpassing 3.5 GtCO2eq. Hence, the preferential treatment that has been given to energy efficiency, EE, options for curbing industrial emissions comes as no surprise. Nonetheless, and in spite of the remarkable decreased in process energy intensity observed in the past 50 years, the importance of EE improvements in reducing the impacts of rising economic activity on final energy use have been steady since 2000. While other decarbonisation strategies, such as Carbon Capture and Storage, are still being developed, it is important to assess how Material Efficiency, aimed at delivering the same level of goods and services by reducing the materials consumed in their production, and Resource Efficiency, RE – the combined effect of energy and material efficiency –, improvements contribute to achieve the imposed emissions reductions targets in the industrial sector.

It seems intuitive that an effective management of resources allows companies to reduce costs, namely by avoiding waste, ensuring bigger flexibility to adapt to future regulation, while simultaneously responding to the need to wisely use scarce resources and to reduce 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. This works aims at benchmarking RE across industrial sectors, using exergy as a single metric, allowing industries to assess their performance against the Best Available Techniques, as well as comparing RE with other environment indicators.

2-051-20: Extended abstract

Technology and material efficiency scenarios for a net zero UK steel sector

Alice Garvey, University of Leeds, United Kingdom
Jonathan Norman, University of Leeds, United Kingdom
John Barrett, University of Leeds, United Kingdom

Panel
2. Sustainable production towards a circular economy

Keywords
steel, material efficiency, energy efficient technologies, net zero, mitigation options

With the UK's legislation of a 2050 net zero emissions target, there is urgent need for radical industrial decarbonisation. The steel sector represented 15% of UK industrial emissions in 2017 and is therefore a critical target for mitigation. Mainstream scenario analyses variously assume use of unproven CCS or reductions to steel demand in order to reach a 1.5°C compatible budget by 2050. Our analysis considered whether technology options excluding CCS can achieve a scale of mitigation in the sector in line with a cumulative budget aligned to net zero, and what level of material efficiency would be required to close remaining mitigation gaps. We 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. We found that the most effective interventions were through established technologies, such as retrofit, replacement and EAF production, but implemented at a faster rate than previously observed.

Given the commercialisation constraints of breakthrough technologies, structural shifts such as material efficiency and EAF production were considered highly important. However, structural changes are necessarily more complex to influence via policy, and there is little precedent for structural change by design in the UK. Our results 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.

We 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, and is highly contingent upon future domestic and international demand for steel.

2-060-20: Extended abstract

How to create an open market for second life e-mobility batteries in stationary energy storages

Reinhard Ungerböck, Graz Energy Agency, Austria
Andreas Nickl, AVL DiTEST, Austria
Marion Werinos, AVL List, Austria
Valentin Stein, Saubermacher Dienstleistungs AG, Austria
Astrid Arnberger, Saubermacher Dienstleistungs AG, Austria
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Panel
2. Sustainable production towards a circular economy

Keywords
batteries, re-use, peak load

Energy storage systems are increasingly essential for the efficient integration of renewable energy sources in energy grids or to reduce individual energy costs, especially in industrial environments. Apart from conventional storage media, used battery systems from e-mobility applications are interesting for energy storage solutions: When they have reached approx. 80% of their maximum capacity, they are no longer suitable for e-mobility applications, but still show a sufficient state of health (SoH) for storage applications.

Second life battery storage solutions are sporadically integrated in energy grids for supplying energy to balance the grid frequency. Several pilot projects have been installed - mainly in Germany and in close cooperation with vehicle manufacturers (i.e. original equipment manufacturers – OEMs). A strong commitment by the OEMs to incorporate this market can be observed.

What would be necessary to open this market for other players? A system for rapid and low priced analysis of the SoH of a used battery system, independently from data access provided by the OEM. There is no adequate tool yet for a reliable calculation of the remaining value of those second life batteries, which comprehensively pictures all process steps including the recycling of the battery after it's second life. Moreover there are new use cases for battery storage systems: peak shaving and energy recovery applications in industrial environments have not been piloted yet. These use cases require publicly available tools to dimension and design storages for any given plant.

By using these technologies and tools, any potential market player is able to make value out of second life battery systems for energy storage solutions and to implement their economical and ecological advantages.

We will present results of the project "Second Life Batteries 4 Storage" that aims at developing those required components and culminates in a pilot application in an industrial environment

2-074-20: Peer-reviewed paper

Utilization of industrial and agricultural by-products in blended cement mortars – creating an effort of circular economy in Indian cement industry

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Marlene Arens, Environmental and Energy Systems Studies, Sweden

Panel
2. Sustainable production towards a circular economy

Keywords
cement, circular economy, CO2 reduction, new binders, industrial by-products

India stands in second place as a manufacturer of cement in the world, accounting for over 8 % of the worldwide mounted capacity until the end of the year 2018. It is estimated that the production of the cement will touch 550 Mt by the year 2020 and will reach more than 600 Mt by 2025. Up to the year 2015, the total emissions of CO2 from cement sector in India have touched the level of around 150 Mt in comparison to an amount of 52 Mt emitted in the year 2013. This amount of generation has been projected to increase by 9 %–10 % annually up to the year 2025.

The boosting demand for construction activities results in incessant growth of the sector along with alarming environmental consequences and non-sustainability in the cement industry. Utilization of the various industrial and agricultural by-products as an alternative form of binder in the cement can reduce the perilous environmental impacts and their practice will further offer an auxiliary solution in fetching the concept of circular economy in the surging cement industry. Blended types of cement made up of industrial and agricultural by-products can successfully replace the limestone-based clinkers. The adoption of such practice could offer a significant reduction in CO2 emissions approximately by 20 %.

On the other hand, the abundant generation and the efficient utilization of industrial and agricultural wastes primarily having binder qualities similar to that of cement has set up a new challenge in the construction industry. Next to a review of industrial and agricultural clinker substitutes, this contribution estimates the impact of these clinker substitutes on CO2 reduction in the Indian cement industry up to 2050.

2-084-20: Peer-reviewed paper

Energy efficiency from farm-to-fork? On the relevance of non-energy benefits and behavioural aspects along the cold supply chain

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Simon Hirzel, Fraunhofer ISI, Germany
Simone Zanoni, Università degli Studi di Brescia, Italy
Beatrice Marchi, Università degli Studi di Brescia, Italy

Panel
2. Sustainable production towards a circular economy

Keywords
cold supply, supply chains, food and drink, refrigerators, non-energy benefits (NEBs), behaviour, energy efficiency

Though cooling is an ancient concept to preserve food, only modern artificial cooling and freezing made it possible to offer high quality food worldwide and independently of the season. This makes cooling and freezing important energy end-uses in the food industry: they are responsible for about 30 % of electricity consumption. Energy efficiency could thus be of remarkable importance for companies operating in this field. Energy efficiency measures can entail, additionally to the evident energy savings, non-energy related benefits, e.g. enhanced competitiveness, reduced maintenance requirements or an improved working environment. Such factors have been identified as important for affecting the assessment of energy efficiency measures.

When it comes to whole cold supply chains, behavioural and organizational aspects seem to be important for decision making about energy efficiency as well, because factors affecting decisions in individual organizations may also occur as cross-organizational issues. Existing analyses on both nonenergy benefits and behavioural aspects related to energy efficiency mainly focus on individual companies and hardly touch whole supply chains, in particular from food industry.

To contribute to closing this research gap, this paper investigates both aspects more in-depth along the cold supply chain of the food sector, thereby moving from the single company perspective to a full supply chain assessment. For this purpose, 61 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.

2-096-20: Extended abstract

Adding transparency to the circular flow of batteries

Sara Fallahi, RISE Research Institutes of Sweden, Sweden
Derek Diener, RISE Research Institutes of Sweden, Sweden
Pavel Calderon, EVLedger AB, Sweden
Karolina Kazmierczak, Chalmers Industriteknik, Sweden
Moheb Nayyeri, Chalmers Industriteknik, Sweden

Panel
2. Sustainable production towards a circular economy

Keywords
circular economy, batteries, blockchain, business models

With the ever-growing number of Li-ion batteries used in diverse applications in the transport and energy sectors, establishing a sustainable and circular battery flow is becoming a necessity. Previous research highlights that for batteries to be used in a more circular value chain, there is a need to increase collaboration and trust between actors. Ideally, before being sent for recycling, a used battery cell from a high-demanding environment like EV should change application after electric performance degradation into an application that is less demanding. Only then, can the full potential from the batteries be utilised, and a more sustainable solution be assured. For example, a battery could be used in an electric scooter as a second life application after it has been used in a car or another vehicle in its first use. Subsequently, when the battery cannot perform sufficiently for an electric scooter, it can be installed in a domestic energy storage solution, where the battery requirements are less demanding. Unfortunately, a value chain like the one described above is not common today.

This paper shares 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. By facilitating the trade of batteries and exchange of knowledge, it is expected that this solution will contribute to increasing the share of batteries being reused and recycled compared to what is reached today. In addition, this will enable increased recycling, partially by improving the traceability of critical materials from their origin through the value chain. This will in turn make it easier to trace recovery levels for valuable materials such as cobalt and lithium.

2-112-20: Extended abstract

Methods and practice to conduct agro-industrial WaterEnergyNexus assessments

Ricardo Amon, university of california davis, USA
Christopher Simmons, UC Davis, USA
Scott Peterson, UC Davis, USA
Edward Spang, UC Davis, USA

Panel
2. Sustainable production towards a circular economy

Keywords
water energy nexus, resource conservation

Our research provides a practical understanding of the water energy nexus (WEN), in agricultural production and industrial food processing; to identify energy efficiency and water conservation opportunities. We present a case study to illustrate the methods and practices used to conduct a WEN assessment at a microbrewery facility in Davis, California. Collecting and analyzing static and dynamic data to account for the operational efficiency of thermal and electric energy assets powering water. Water and energy flow calculations provide the quantitative foundation to estimate water energy intensity (WEi) metrics, by unit operation; providing performance indicators to establish resource use efficiency baseline conditions. Energy efficiency and water conservation opportunities are identified, calculating energy cost savings and estimating greenhouse gas (GHG) emission reductions. Published research papers (JIE, vol 22, issue 4), document WEN assessments conducted in 2013, at the Campbell Soup, Dixon California, tomato processing facility.

In 2014 and 2015, the company adopted multiple recommendations to address thermal and electric energy inefficiencies, generating cost savings, GHG emission reductions and water conservation. A whole-systems approach reveals synergistic conditions to identify innovative resource conservation opportunities. Like, capturing waste heat from evaporators to replace natural gas-powered steam and recover condensate water at industrial tomato processing facilities (ATE, vol 78). Leading to additional electric load and demand savings from cooling tower pumps and fan systems. The brewery WEN assessment provided granular-level information to establish WEi metrics, calculating the amount of energy that is embedded in the water that is packaged in Lager beer.

The WEN methods provide replicable metrics to measure and validate (M&V) incentives; to optimize the performance of energy assets and identify water conservation projects with embedded energy. Water conservation projects are very relevant in California, to support the implementation of the 2014, Sustainable Groundwater Management Act (SGMA); requiring all water end-users to develop long-term groundwater-basin conservation plans. The WEN methods are available to engineers and managers, working to optimize water and energy use in agricultural production and food processing facilities; contributing to circular economy sustainability principles.

2-115-20: Peer-reviewed paper

Business logics for bioeconomy collaborations

Jon Williamsson, School of Business, Economics and Law, Sweden
Gabriela Schaad, University of Gothenburg, School of Business, Economics and Law, Sweden
Anders Sandoff, University of Gothenburg, School of Business, Economics and Law, Sweden

Panel
2. Sustainable production towards a circular economy

Keywords
sustainability, business models, biomass

Fossil fuels constitute the core of the linear socio-technological order on which our modern society is built. Through a combination of ambitious goals to foster the bioeconomy, Sweden wants to achieve zero net greenhouse gas emissions by 2045. The move towards a bio-based economy represents a transformative force for economic development which builds on the access to, and use of, forest-based resources. The commercialization of sustainable innovations that utilize renewable feedstock is a central challenge when managing the transition to a bioeconomy. Collaboration between actors from diverse industries is seen as a solution to tackle the systemic challenges that this transition entails.

This paper reports on novel cross-industry value chain collaborations in a Nordic context that have the purpose to bring new sustainable innovations to the market. Data was collected by way of four case studies of collaborations along diverse newly formed industrial value chains with varying scope and at different stages in their development. From these case studies, four distinct business logics (secondary product, bundled product, mixed product, and multi product) for bioeconomy collaboration were derived that enable the commercialization of sustainable innovations. While all four logics hinge on substituting environmentally less favorable products, different collaborative mechanisms are at play.

Results show that basing new bioeconomy ventures on existing well-developed processes, industrial infrastructure and distribution systems is beneficial. Additionally, processes of market building need attention, especially in terms of product legitimacy and policy support. The potential to scale up these types of bioeconomy ventures appears to be dependent on feedstock availability and market size.

2-125-20: Peer-reviewed paper

A multi-region representation of an automotive manufacturing plant with the TIMES energy model

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Filomena Pietrapertosa, National Research Council of Italy - Institute of Methodologies for Environmental Analysis, Italy
Monica Salvia, National Research Council of Italy - Institute of Methodologies for Environmental Analysis, Italy
Carmelina Cosmi, National Research Council of Italy - Institute of Methodologies for Environmental Analysis, Italy

Panel
2. Sustainable production towards a circular economy

Keywords
circular economy, TIMES energy model, energy saving assessment, energy scenario, waste recycling

Circular economy requires a material-specific and systemic approach in the design and management of production processes, as indicated in the European Commission Action Plan adopted in 2015 to promote global competitiveness, sustainable economic growth and create new jobs. This new approach implicates a more efficient use of resources within the entire production chain that aims to “close the loop” of the product life cycle. It promotes a self-regeneration that turns waste into resources. In this way, the recycling and reuse of recycled materials is constantly increasing and the demand for raw materials is decreasing, allowing waste to be contained.

The concepts of the circular economy were applied to develop a two-region partial equilibrium model of an automotive manufacturing plant based on the ETSAP MARKAL-EFOM (TIMES) generator, aimed at identifying more efficient and sustainable configurations of the production system through a scenario analysis, taking into account energy recovery and recycling of plastic waste material from production processes as well as reducing CO2 pollutant emissions.

The multi-region approach allowed modelling two industrial units, the Assembly Unit and the Plastic Unit, as two different modelling “regions” with independent production of electricity, heat and cooling. Such “regions” are connected through unidirectional “trades” processes, i.e. the components produced in the Plastic Unit and he polypropylene waste, which represent a secondary input material. The model was calibrated based on real consumption data for the years 2015, 2016 and 2017 and optimized over a time horizon of ten years. 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, use of pigmented polypropylene for bumper molding.

2-133-20: Extended abstract

Assessing the geographical aspects of regional industrial symbiosis for European regions

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Giorgio Bertanza, Università degli studi di Brescia, Italy
Mentore Vaccari, Università degli studi di Brescia, Italy
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Panel
2. Sustainable production towards a circular economy

Keywords
efficiency, circular economy, waste heat recovery, avoided emissions, networks, local and regional energy planning, territories, sustainability, sustainable production

In industrial symbiosis (IS), 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. Various models for industrial symbiosis has been introduced to the industrial ecology discussions, based on different degrees of centralization in the collaboration networks. Industrial symbiosis at regional scale is usually considered as a planned (or facilitated) approach which relies on the central role of an organization for connecting the network members (nodes) by regulation, providing information and incentives. While geographical proximity and system boundaries were considered as crucial factors in formation of industrial symbiosis in the earlier studies, more recent definitions pay less attention to such features.

The hypothesis of this research is that the geographical (contextual) conditions can result in different categories of regional symbiotic networks. These features should 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.

This study applies social network analysis (SNA) in combination with territorial analyses for European regions with different geographical features. Published documents about 47 regional industrial symbiosis projects were analysed this way. While the comparative studies between pairs of regions were common in IS literature, the impacts of geographical dependencies on such comparisons have been rarely considered. Based on this mapping activity 3 different arrangements were identified for regional symbiosis networks with energy exchanges, i.e. Centralized Closed Systems, Decentralized Closed Systems, and Semi-centralized open systems.

2-137-20: Peer-reviewed paper

Modelling circular economy action impacts in the building sector on the EU cement industry

Matthias Rehfeldt, Fraunhofer Institute for Systems and Innovation Research, Germany
Andrea Herbst, Fraunhofer ISI, Germany
Samy Porteron, Ramboll Group A/S, Denmark

Panel
2. Sustainable production towards a circular economy

Keywords
circular economy, cement, decarbonisation, modelling

The 2015 Paris Agreement aims to strengthen the global response to the threat of climate change by keeping global temperature rise in this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. The industrial sector in particular will need a bundle of technologies and measures that go beyond energy efficiency and fuel switching.

In this context, circular economy is an important pillar in reducing the demand for energy-intensive raw materials and gains momentum in the political debate. This contribution to the eceee Industrial Efficiency 2020 presents the potential impacts of selected circular economy actions in the building sector on cement production and CO2-emissions in the cement industry.

The analysis is based on a bottom-up material flow modelling approach. 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 CO2-neutral economy (not taking into account rebound effects). The overall greenhouse gas reduction potential is calculated as 58% compared to a 2015 base case. In addition, the individual actions' contribution is presented. We conclude that effort along the entire value chain is necessary to enable the construction sector to contribute to European climate policy.

2-147-20: Extended abstract

Material and resource efficiency potentials in the aluminum industry – Prospects for increased circular economy and decarbonisation

Felipe Andrés Toro Ch., IREES, Institute for Resource Efficiency and Energy Strategies, Germany

Panel
2. Sustainable production towards a circular economy

Keywords
material efficiency, Aluminum Production

The Aluminium value chain is very complete including the primary sector where aluminum ingots are obtained from refined alumina from bauxite. Primary aluminum in the form of ingots has a high purity and amounts over 64 Million ton per year worldwide by 2018, out of which the EU-28 accounts for 3.4% of it. The value chain includes also the production of semi-finished (e.g. extrusions, sheets, plates, rolls, bars) and end products for final consumers such as automotive, aviation, electric cables and beverage cans. In Europe more than 600 plants in EU covering raw materials (e.g. bauxite & alumina), primary metal production, semi-fabrication (e.g. rolling & extrusion) and recycling. Smelters and rolling mills are multi-national companies while extrusion and recycling are usually SMEs. Further downstream plants include building systems houses, aluminium casting manufacturers and foil manufacturing plants.

The following abstract presents the results of an ongoing project for the German Environmental Agency on the development of a database with specific parameters and determination of CO2 cost components along the value chain for selected case studies, among them the Aluminum industry. The author has researched and developed the case study for Aluminum Industry and in this paper it will present the ongoing results on that project as well as extend the analysis towards the material and resource efficiency potentials in the Aluminum industry along the aluminum value chain and derive implications for this industry due to more ambitious recycling and circular economy from the new circular economy package from the EU and the interactions with an improved EU waste legislation.

Strategic circular economy priorities of the Industry include more efficient sorting and treatment technologies and re-melting processes increasing the added value of the recycling steps or measurable recycling targets for EU Member States with the aim to reduce scrap exports (leakage) among others.

3-007-20: Peer-reviewed paper

How do companies decide on non-strategic energy efficiency issues? An in-depth study of the decision making process.

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Elisabeth Dütschke, Fraunhofer ISI, Germany

Panel
3. Energy management

Keywords
decision-making process, corporate investment decisions, non-residential buildings, non-strategic issues, actors

Reducing energy demand is crucial to achieve climate goals. For energy-intensive industries, energy is obviously a very relevant cost factor and therefore an integral part of strategic decision-making. However, ambitious emission goals also require companies to improve their energy efficiency in other areas that are not part of their core business and therefore nonstrategic. In this contribution, we report findings from a detailed survey of such non-strategic decision processes in German companies. The survey addressed investments in thermal conditioning (i.e. related to windows, facades, etc.) of office and retail buildings as an example to gain a more comprehensive understanding of non-strategic decision processes, which have not been sufficiently addressed in the literature so far. To identify relevant themes and topics, we drew on an earlier interview study.

This study indicated the relevance of a variety of different triggers (e.g. need for repairs, shortage of space due to business growth or new regulations on fire protection and accessibility). For these triggers, we surveyed factors that might promote or inhibit the actual implementation of (ambitious) energy refurbishments on such occasions. Ambitious energy refurbishments are characterised by the implementation of an energy efficiency standard that exceeds the minimum legal requirements.

This analysis includes the potentially significant multiple benefits of refurbishments, such as increased employee motivation and productivity or an improved image. We examined decision-makers' individual perceptions of these potential benefits and the possible downsides of ambitious energy efficiency (EE) measures, and analysed their influence of these perceptions on the willingness to champion EE measures. In addition, we analysed the role of different departments within a company and the potential influence of intermediaries e.g. like energy consultants, carpenters, plasterers, installers, architects, etc. on decisions about EE measures.

We therefore chose a multi- actor approach and aimed at identifying innovative leverage points for policies and programmes to support companies in reducing their energy demand in areas outside their core business activities.

3-009-20: Peer-reviewed paper

Non-routine adjustments – towards standardizing M&V approach for quantifying the effects of static factors

Shankar Earni, Lawrence Berkeley National Laboratory, USA
Peter Therkelsen, Lawrence Berkeley National Laboratory, USA

Panel
3. Energy management

Keywords
measurement and verification, evaluation, energy performance, ISO 50001

The success of an energy management program relies on ensuring that the energy savings can be verified with an adequate level of certainty. Energy savings cannot be directly measured and hence have to be deduced by comparing the pre-retrofit energy consumption with post-retrofit energy consumption data adjusted to account for differences in conditions. These adjustments are needed, since conditions that influence energy consumption may not stay the same between pre- and postinstallation phase of the project.

These adjustments can often be routine when accounting for factors like production volume and weather that are expected to change and are included in the energy consumption adjustment model. Existing measurement and verification (M&V) resources and guidance mostly concentrate on developing models for routine adjustment of one or more factors that normally change. On the other hand, there are factors (static) like product mix, operating hours, gross square area, etc. that are assumed to stay constant during normal conditions. However, in order to adapt to dynamic market conditions, the industries are forced to react thereby leading to changes to these static factors. Identifying these static factors that warrant adjustment, called non-routine event, along with quantifying their effect on energy consumption can be complex and lack of proper guidance can exacerbate this issue.

This paper reviews some of the current work in terms of how non-routine events are defined, characterized, detected and quantified based on a review of existing M&V guidelines, protocols and other relevant literature. This work also reviewed some of the existing non-routine events and adjustment practices to understand how these different aspects are addressed along with a discussion on some of the key challenges and gaps in the current guidance.

3-011-20: Extended abstract

Integrating energy efficiency in investment process - Experience from Scania CV Green Field Foundry Project

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Thomas Lindstedt, Scania CV AB, Sweden
Mikael Lindén, Scania CV AB, Sweden

Panel
3. Energy management

Keywords
energy efficiency investments, energy saving methodology

Scania CV AB invests SEK >1.5 billion in a green field foundry. E-mobility and electrification of heavy trucks is in the origin and the development is moving fast. However, the combustion engine, running on biofuel, will play an important role in the shift to a sustainable transport system. Therefore, producing high quality castings for combustion engines will be crucial over the next decade.

The energy intensity in a foundry is higher than in any of Scania's manufacturing processes. A foundry consists of a complex composition of sub-processes with several energy intensive steps of heating, cooling and forming. The foundry is expected to start the ramp up procedure during late 2020 and produce at full capacity in the end of 2023.

The project has set up ambitious targets regarding sustainability. The new foundry should:
– Operate on 100 % renewable energy
– Install 100% heat recovery capacity compared to heat demand
– Increase the energy efficiency by 50% per produced castings, compared to existing foundry (Base line 2016)
– Pollute 0 % CO_2 emissions

To realise this targets and untapped potential, a new working process have been developed to integrate energy efficiency in the ordinary investment and engineering process. This extended abstract introduces the reader to an overview of an novel method to realise energy saving and decarbonisation potential in green field manufacturing processes. The audience will get inspiring and practical examples from each working step in the project, from pre-study – purchasing machines – to verifying the results of integrating energy requirements in the working process.

3-048-20: Peer-reviewed paper

Human factors for energy management: features, fit and field study

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Maureen Hassall, The University of Queensland, Australia

Panel
3. Energy management

Keywords
human factors, energy management, frontline workers

Effective energy management reduces company expenditure and carbon emissions. It can also improve energy security, enable energy flexibility and delay capital investment in new generation capacity. Thus effective energy management is a source of competitive advantage for all companies, regardless of size or energy intensity. Despite these benefits, research has shown, energy management endeavours are hampered by a number of challenges and barriers, causing it to fall short of expectations. Additionally, there is a sparsity of literature about the support required at the frontline to effectively manage energy. Energy management presents a sociotechnical challenge spanning all organisational levels, from frontline workers to senior management and government policy makers.

Human factors with its user-centred, sociotechnical, system focus and proven track record for improving the performance of industrial systems has the potential to improve energy management outcomes. The fit between human factors solutions and energy management challenges lies not only in the success of human factors in sociotechnical systems, but in the specific challenges that appear to be stopping energy management from reaching its potential. These challenges include the need for proper organisational support, a systematic approach and informed decision making.

This work presents an analysis of the challenges associated with energy management, the status of human factors approaches in the energy management field and the results from a human factors based assessment at an energy intensive industrial site. At the industrial site human factors' techniques were used to investigate heat recovery in heat exchanger trains. The investigation found human factors approaches could offer insights into barriers, decision making and information requirements.

The investigation also revealed producing quality outcomes using human factors approaches, takes time and expertise, but they should reduce the effort required to effectively manage energy in the long run.

3-070-20: Peer-reviewed paper

Establishing energy efficiency in SMEs – energy management to enhance energy efficiency in everyday work life

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Sabine Löbbe, Reutlingen University, Reutlingen Energy Center for Distributed Energy Systems and Energy Efficiency, Germany
Stefan M. Büttner, University of Stuttgart, EEP – Institute for Energy Efficiency in Production, Germany
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Panel
3. Energy management

Keywords
energy management, energy efficiency gap, energy efficiency practices, energy efficiency culture

Despite strong political efforts across Europe, small and medium- sized enterprises (SMEs) seem to neglect adopting effective measures for energy efficiency. Adopting a cultural perspective and based on a study among industrial SMEs in Southern Germany, we investigate what drives decisions for energy efficiency in SMEs and how energy management contributes to closing the energy efficiency gap. The study follows a mixed-methods approach and combines eleven ethnographic case studies and a quantitative survey among 500 manufacturing SMEs in Southern Germany.

The main contribution of the paper is to offer a perspective on energy efficiency in SMEs beyond the diffusion of energyefficient technology. By contrast, our results strongly suggest that the diffusion of energy efficiency in industrial companies should not be solely reduced to decisions for technical measures. We shed light on how energy efficiency is established and the importance of energy management in SMEs.

Our study shows that energy efficiency is well established in the investigated SMEs. At the same time, establishment cannot be explained by company size or energy demand. By contrast, the contextual environment of the company and the individual leadership of the company appear to have a more substantial influence. The embedding of energy efficiency in corporate strategy, a broad spectrum of different practices, the involvement of the employees, actions for raising awareness in everyday work life, and distributing attention by organizational measures constitute the driving forces in establishing energy efficiency, and these drivers can be subsumed under the label of energy management.

3-079-20: Peer-reviewed paper

Understanding the impacts on the industrial operations from the adoption of energy efficiency measures: lessons learnt from Italian case studies

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Enrico Cagno, Politecnico di Milano, Italy
Andrea Trianni, University of Technology Sydney, Australia
Nicolò Ferrari, Politecnico di Milano, Italy
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Panel
3. Energy management

Keywords
energy efficiency measures, adoption, characteristics, performance, manufacturing

Energy efficiency is a key driver to decarbonize industry, improving its sustainability and competitiveness. Nevertheless, the adoption of well-known energy efficiency measures (EEMs) is in many cases hindered by the lack of information about them. Unfortunately, EEMs are usually assessed with a simplistic energy and cost effectiveness analysis, neglecting however other characteristics that should be carefully encompassed, since they can deeply affect the EEMs performance during their implementation and service phases. Among others, the impact EEMs could have on surrounding production activities plays a critical role, especially when embedded in the core business of a company. So far, too little literature has highlighted such impacts, mainly referring to the existence of the so-called non-energy benefits, while research linking the impacts to the key performance indicators of industrial operations is still scarce.

Therefore, the present study is intended as a preliminary exploration giving contribution to this discussion, trying to highlight intrinsic features of the EEMs and connect them with their potential impacts in terms of performance indicators once implemented.

Results show the need to create a framework linking, e.g., pure production and operationsrelated information to raw material consumptions and emissions, in order to provide an extensive and integrated vision of the impacts of EEMs adoption. The conceptual framework, to be further developed as an assessment tool in support of decision-makers and energy managers, could represent a valuable support for policymakers and technology suppliers in highlighting the real implications of adopting EEMs.

3-080-20: Extended abstract

Identification of optimal measurement points for energy monitoring of industrial processes: the case of milk power production

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Lorenzo Bellemo, GEA Process Engineering A/S, Denmark
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Panel
3. Energy management

Keywords
data collection, energy monitoring, industrial processes, pinch analysis, retrofit

Key to deep decarbonisation of industry is to increase the energy efficiency of industrial processes. Meaningful energy analyses are paramount in this context, ranging from the more generic energy audits [1] to the more detailed Process Integration (PI) studies [2]. A key role of such analyses is played by the quality and availability of energy-related process data [3]. High-quality data is required for getting reliable results, while availability is essential for decreasing the time and costs of the analysis. For this reason, the European Energy Efficiency Directive [1] urges industrial manufacturers in installing energy monitoring systems as a first step towards the energy efficiency goals. However, a lack of systematic methods for identifying the required measurement points, joint to scarce information on the related benefits, results in reluctance from companies in investing in such systems.

A recently published method, named Required Data Reduction Analysis (RDRA) [4], could fill this gap. It was originally developed for reducing the time consumption in PI retrofit studies, by identifying a limited number of parameters whose detailed measurement is paramount to meaningfully characterise the plant from an energy perspective. It combines Pinch Analysis with uncertainty analysis (Monte Carlo simulations), global sensitivity analysis (standardised regression coefficients) and optimisation procedures to solve the “Factor Fixing” and “Variance Cutting” problems [5]. This feature can be further exploited for the identification of optimal measurement points for energy monitoring purposes while also indicating a clear use for the monitored data, i.e. to perform advanced energy analysis employing PI techniques.

The capabilities of the RDRA method for identifying necessary measurement points in industrial processes are presented. It was applied to four milk powder production plants, identifying the process parameters to be monitored in order to estimate the plant energy consumption and potential for energy savings with given maximum confidence, ensuring the quality of the results. Comparing the results obtained from the four case studies it was possible to infer some general traits of milk powder production processes. In particular, 15 out of 60 to 66 parameters were identified as generally important in all the facilities, their position in the plant was highlighted and the minimum accuracy level required for their measurement was estimated. Such information could subsequently be used for designing an energy monitoring system and giving proof of its benefits to the involved company, by quantifying them in terms of uncertainty reduction in the outcome of the energy analysis.

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3-081-20: Peer-reviewed paper

Quantifying non-energy benefits for energy-intensive industry – A case study of heat recovery measures in a Swedish oil refinery

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Elin Svensson, CIT Industriell Energi, Sweden
Simon Harvey, Chalmers, Sweden

Panel
3. Energy management

Keywords
non-energy benefits (NEBs), heat integration, energy-intensive industry, retrofit, case studies

Energy efficiency is of great importance to reduce fuel usage and related emissions in energy-intensive industry. Since heat is used extensively in energy-intensive industry, one major option to reduce energy consumption is increased heat integration. Many energy efficiency measures are profitable based on energy cost savings alone. Furthermore, non-energy benefits may substantially strengthen the attractiveness of an energy efficiency measure and increase its priority in the decision-making process of new investment projects. Although many studies in a variety of industrial sectors have identified the importance of non-energy benefits, few have quantified their monetary value in energy-intensive industries.

This paper aims to quantify the economic value of selected non-energy benefits for a few examples of heat recovery measures in an oil refinery and compare this to the energy cost reduction of the energy efficiency measures. In a previous study, heat integration retrofits were designed and discussed in an interview study with refinery engineers. In the interview study, several non-energy benefits were identified for the designed retrofit measures, which are now investigated in further detail in this paper.

The non-energy benefits quantified are production increase and greenhouse gas emission reduction. Other non-energy benefits are discussed. The results show that non-energy benefits can contribute more to the cost benefits of the energy efficiency measures than the fuel cost savings. This highlights the importance of considering non-energy benefits at an early design stage when designing energy efficiency measures.

3-144-20: Extended abstract

Coaching – an effective model for energy efficiency in small and mediumsized industries

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Gustaf Länn, Swedish Energy Agency, Sweden
Annika Mattsson, Aktea Energy, Sweden

Panel
3. Energy management

Keywords
SME, energy efficiency networks, energy management, audit, coaching, Sweden

SMEs represent 13% of global energy consumption (IEA, 2015), but few apply a systematic approach when investing time and other resources in improved energy efficiency. Instead, focus has been on selective actions with limited long-term effect. Findings from the Swedish project "EENet – Energy Efficiency Networks" suggests Coaching as an effective model for integrating energy efficiency in the company structures, enabling both short and long-term results.

Overcoming the obstacles towards increased energy efficiency in small and medium-sized industries is the main aim of "EENet – Energy Efficiency Networks", a project lead by the Swedish Energy Agency. During 2016-2020, 300 SME´s with an energy use above 1 GWh/year (organized into 35 regional networks) will work together to reduce their energy use. Each company also receives 150 hours of support from an energy efficiency expert.

With support from the network and energy expert, the goal is that the companies should become on average 15% more energy efficient and implement a systematic energy management system. Instead of supporting the implementation of selective actions (often limited to investments in new technology), the experts take on a coaching role, reflecting the company's overall energy policy and goals in an energy audit which in turn is translated into a concrete action plan. Prioritized measures are implemented, results are followed up and the plan is updated. Throughout this process, support is given according to each company's individual needs and prerequisites.

Findings show that the companies participating in the Energy Efficiency Networks have begun their journey towards increased energy efficiency. Preliminary measurements so far indicate savings of more than 5%, with a prognosis for the full project of almost 15%. More importantly, energy is becoming an integrated part of the company operations. These are both strong indicators that Coaching is an effective model energy efficiency in for SME's.

3-157-20: Peer-reviewed paper

Energy management in the Norwegian sawmill industry

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Panel
3. Energy management

Keywords
energy management system, sawmills, data monitoring, visualisation, energy efficiency action plans, energy use

In recent years, Norwegian sawmills have introduced simplified energy management systems. The current paper is based on seven of these energy management implementations. The sawmills covered in the paper produce wood products from timber using electricity and heat in the production process, the heat being produced from internal by-products. Historically, the price for electricity has been low in Norway and there has been a low demand for the by-products outside of the sawmill. Hence, the energy costs have been a small part of the production cost and energy management has not been a top priority. However, in the coming years, it is anticipated that the electricity price and the demand for by-products will rise, increasing the importance of energy management.

The primary goal of an energy management system is to reduce the energy use of the production process. In the sawmills studied, the energy savings achieved are in most cases results of structured and persistent energy management, gradually eliminating unnecessary energy use. Big investments in new and more energy efficient equipment also contribute to energy savings but are not as important as an organic evolution of an energy efficiency culture in the company. The resulting energy savings vary between the sawmills, but the typical sawmill achieves 5–10 % energy savings (kWh/m3 sawn products) in the first 1–2 years. In the following years, the sawmills set an energy saving goal of typically 2 % per year; a goal that is normally reached. The sawmills that have successfully implemented energy management have (1) a dedicated energy team with an appropriate amount of resources, (2) an energy management approach incorporated in the daily routines, and (3) a top management that enquires energy efficiency results. These sawmills also use strategic partners in different specialised fields to support the energy team.

4-001-20: Peer-reviewed paper

Environmental impact of high temperature industrial heat pumps – from a global warming potential (GWP) perspective

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Ron Zevenhoven, Åbo Akademi University, Finland
Umara Khan, Åbo Akademi University, Finland

Panel
4. Technology, products and systems

Keywords
heat pump, CO2 emissions, VHTHP, thermodynamic analysis

Several factors drive the increased utilisation of heat pumps in industry. Two important factors are the drive to reduce the negative environmental impact of industrial processes and the general trend of electrification ("de-fuelling") of energy systems. Much of the heat demand in the process industry is at temperature levels above 100 ÅãC, which is above the temperature achievable with conventional heat pumps. Heat pump manufacturers are developing new heat pump technologies that can meet the demand of high sink temperatures and high temperature lifts. These heat pumps are often referred to as High Temperature Heat Pumps (HTHP) or Very High Temperature Heat pumps (VHTHP). The new heat pump technologies operate under conditions different from conventional heat pumps used for domestic heating, and it is not obvious how to evaluate the environmental impact of the installations.

It depends very much on the technology being replaced what the various efficiencies of the heat pump system are (e.g. Coefficient of Performance (COP), system efficiency or exergy efficiency), and what the emissions are from generating the electricity used to drive the heat pump.

In this paper we are investigating ways of evaluating the conditions where a heat pump installation will be an improvement and under which conditions it will not, where the focus will be on reducing global warming. We will look at basic thermodynamic considerations and modern thermodynamics tools, e.g. exergy and pinch analysis using data from the European energy systems as practical examples. To give a fuller picture of the impact, a life cycle impact assessment (LCA) is given, comparing a Stirling engine- type VHTHP with more conventional heaters. The paper is also using a current VHTHP installation as an example throughout the paper.

4-003-20: Extended abstract

Opportunities for applying high temperature heat pumps in industry

Jonathan Jutsen, RACE for 2030 Cooperative Research Centre, Australia
Jarrod Leak, Australian Alliance for Energy Productivity, Australia

Panel
4. Technology, products and systems

Keywords
heat pump, electrification, process heating, decarbonisation, industry

Process heating is the largest consumer of fossil fuels in manufacturing industry. So, to decarbonise this sector of industry it will be necessary to eliminate fossil fuel usage by one of the following approaches:

1. Replace process heating with a non-thermal process supplied with renewable electricity
2. Provide the process heat with high temperature heat pumps supplied with renewable electricity
3. Replace the fossil fuel with biogas or biomass (or green hydrogen).

The Australian Alliance for Energy Productivity (A2EP) conducted analysis of the first 2 options for Australia to identify the most effective option for a range of industries, aiming to achieve lower fossil carbon emissions in a cost-effective way. We were also looking to implement technologies which would be compatible with an Industry 4.0 manufacturing environment - flexible, modular and responsive. Replacing central boilers and steam systems with distributed heat pumps achieves all these outcomes. So, we conducted a feasibility study for applying high temperature heat pumps in the manufacturing industry and identified a number of opportunities for cost-effective implementation of this technology. This was based on typical electricity and gas prices in Australia for medium-large industry at the time of 15-17.5c/kWh for power and $10-12/GJ of gas.

The Alliance is currently conducting a renewable process heating program with funding support from the Australian renewable agency ARENA, with a focus on high temperature heat pumps. Under the program, 10 pre-feasibility studies have been completed for heat pump applications in a range of manufacturing plants for process heating up to 95°C, of which 4 have been the object of complete feasibility studies. Several of these companies will apply for ARENA capital funding for up to 50% of the project cost. ARENA has recently extended the project to include 20 pre-feasibility studies and temperatures up to 120°C, as well as up to 10 feasibility studies. Of the 4 initial feasibility studies, 3 looked promising pre-COVID 19, and the largest one was likely to approach ARENA for capital funding support.
We will present the results of this work and show how this supports our desk-top analysis of the opportunity to decarbonise process heating using high-temperature heat pump technologies.

4-008-20: Peer-reviewed paper

Effects of process decarbonisation on future targets for excess heat delivery from an industrial process plant

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Elin Svensson, CIT Industriell Energi AB, Sweden
Simon Harvey, Chalmers University of Technology, Sweden

Panel
4. Technology, products and systems

Keywords
decarbonisation, industrial excess heat, energy targeting

The use of industrial excess heat for purposes such as district heating has the potential to contribute to societal targets for energy efficiency and greenhouse gas emissions reduction. However, to meet the ambitious national and international climate targets set for 2050, a breadth of different decarbonisation pathways are required, not least in the industrial sector. These include a transition to bio-based and recycled feedstock and fuels, carbon capture and storage, and electrification. Such profound changes of industrial processes and energy systems are likely to affect the availability of excess heat from these plants, and a better understanding of how the excess heat potentials might change is needed in order to utilise excess heat in ways that can be resource-efficient also in the long-term.

In this paper, we present a systematic approach which can be used to analyse how different decarbonisation options may affect the potential future availability of excess heat at a specific plant site.

The approach is based on the use of consistent, energy targeting methods based on pinch analysis tools, and therefore relies on comprehensive data about process heating and cooling demands. To illustrate the approach, we demonstrate results from two industrial case studies in which different decarbonisation measures are assumed to be implemented. The case studies were selected from a case study portfolio, which includes relevant and site-specific process and energy data for a large share of Swedish industrial process sites. The results show that deep decarbonisation can have significant impact on the availability and temperature profile of industrial excess heat, illustrating the importance of accounting for future process development when estimating excess heat potentials.

4-014-20: Extended abstract

Digital technologies driving efficiency in electric motor driven systems

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Konstantin Kulterer, Austrian Energy Agency, Austria
Jazaer Dawody, Swedish Energy Agency, Sweden
Glenn Widerstrom, Swedish Energy Agency, Sweden
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Panel
4. Technology, products and systems

Keywords
digital, energy systems, electric motors, energy efficiency policy, electric motor driven systems, digitalization

Digitalization brings smart applications to all kinds of industrial energy systems, of which electric motor driven systems take the largest part of the industrial electricity use. Electric motor driven systems (EMDS) are currently responsible for some 53% of global electricity consumption (IEA 2017), and approximately 70% of the industrial electricity use.

An optimal motor system includes optimal aligned system components (motor control, motor, mechanical equipment and application) engineered and operated for the right process demands in a specific timeframe. The application of digital technologies to electric motor driven systems can enlarge the scope and accessibility of optimization, leading to efficiencies in operations (operational cost, flexibility, procurement, footprint), energy, materials (circularity) and emissions.

IEA 4E EMSA works on the assessment of specific developments in the field of industrial digitalization. The target is to identify the relevant different technology fields (areas), its potential impact (on efficiency and transitions), and the potential need for extra policy measures. Focus is on the speed of development and implementation of digital technologies for motor systems, and the type of measures needed: enabling the actual implementation and/or managing the risks of extra energy use driven by the use of those new digital technologies.

Some examples of related digital technologies and products are sensors and big data analysis, decision tools and new testing tools. The application of digital twins, artificial intelligence and similar developments will enhance energy and motor management and maintenance and systems efficiency strategies. First assessments indicate a significant contribution, e.g. an improvement of energy efficiency of up to 25% and an increase of operational efficiency of up to 25%. The effects towards related policy areas as with regard to capacity building, pilots and regulatory issues are to be investigated as well.

4-018-20: Peer-reviewed paper

Evaluation of hybrid electric/gas steam generation for a chemical plant under future energy market scenarios

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Simon Harvey, Chalmers University of Technology, Sweden
Elin Svensson, CIT Industriell Energi AB, Sweden

Panel
4. Technology, products and systems

Keywords
electrification, decarbonisation, hybrid steam generation, industrial processes, steam system

Hybrid electric/gas steam generation is a suitable concept to reduce CO2 emissions from existing industrial plants while at the same time being able to benefit from shifting between different varying energy carrier markets. In this study, hybrid steam generation was assessed in terms of total annualised cost for a case study chemical plant under current and future energy market conditions using a linear optimisation model. The methodology accounts for hourly steam demand fluctuations as well as hourly variations of energy carrier prices. Consistent future energy market scenarios (energy carrier prices and CO2 charges) were used to assess the long-term benefits of different investment options.

The optimal capacities in terms of total annualised cost of steam production for different energy market conditions were calculated by the model and used as base for three investment decisions that were further assessed in terms of running cost. The assessment considers the impact of on-site CO2 and electric grid capacity limitations.

The results show that flexible hybrid steam generation is an economically robust option compared to investment in a stand-alone gas boiler. This characteristic makes hybrid steam generation a promising technology for the transition from current natural gas-based steam production to steam production from electricity and biomethane.

4-036-20: Peer-reviewed paper

White certificate on electrical motor driven systems

Marc Berthou, EDF R&D, Département TREE, France
Abdessalim Arras, EDF R&D, France
François Saliou, Leroy-Somer SAS, France

Panel
4. Technology, products and systems

Keywords
motor driven system, motor consumption, white certificates, energy efficiency action plans

The major part of the electrical consumption in the industrial sectors is due to electrical motors. The motorised machines will therefore play an important role in the implementation of energy efficiency and decarbonisation technologies.

The European Energy Efficiency Directive sets new targets in order to increase the efficiency in the EU different Member States. In France, the principal instrument to achieve these savings is the introduction of an energy efficiency obligation, frequently applied as White Certificates, “WC”. Since 2006, the French white certificate regulation has promoted new efficient motor technologies. These innovative technologies have quickly penetrated the market thanks to financial aids associated with the energy savings generated. In the existing framework each part of the motor device is considered separately resulting in overall inefficiencies. Furthermore the motor performance is reaching an asymptote.

This paper aims to explain how France tackles these limits with a specific approach of the problem and a regulation incentive. First, expertise has shown that it was possible to save more energy with a new global system approach compared to a unitary approach. The global system approach called “Motor Driven System” for pumps, fans or compressors is widely addressed in scientific publications and standardization groups. Second, an overview of the electrical motor consumption is given with a segmentation of the consumption by industrial sectors and usages to point out the issue. The age distribution shows that the existing motors in France are globally old. Third, a study of the white certificate standardized operations eligible for the industrial sector shows that between 2006 and 2017, 20 % of the certificates validated by the French Ministry came from the standardized operations concerning electrical motors.
The analysis conducted on the three aspects above was considered by the French government who published recently a decree which integrates into the white certificate scheme a new standardized operation entitled “motor driven system”. Two practical examples of applications of the standard WC motor driven system approach are detailed. They both show that the system approach approach can reduce both energy consumption and CO_2 emissions far beyond what the mere replacement of the electrical motor can achieve.

4-053-20: Extended abstract

Efficient utilization of industrial excess heat for carbon capture and district heating

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Johanna Beiron, Energy Technology, Chalmers University of Technology, Sweden
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Panel
4. Technology, products and systems

Keywords
district heating, energy integration, cost impact, carbon capture and storage, partial capture, seasonal variations

Carbon capture and storage (CCS) from fossil and biogenic (BECCS) emission sources is necessary to limit global warming to well below 2°C. The EU as well as Swedish national agencies emphasize the importance of CCS for emission intensive industries. However, the cost of implementing CCS is currently still higher than the cost of emitting CO2 via the EU ETS, for example. To incentivize rapid deployment of CCS, the concept of partial capture has been suggested, i.e. capturing only a fraction of the site emissions to reduce capture cost. Several studies have found that the utilization of excess heat from industrial processes could significantly reduce the capture cost as the heat required (~120°C) may be available in significant quantities. However, available excess heat will not be sufficient to power full capture at most industrial sites. In Sweden, many industries utilize all or part of their excess heat in heat recovery units or in combined heat and power (CHP) plants to produce electricity and deliver heat to municipal district heating (MDH) systems. A broad implementation of CCS will, thus, effect the availability of excess heat for industrial heat and power generation. The future product portfolio of industrial processes with excess heat export and CHP plants can therefore be expected to include not only heat and power production, but also climate services (CCS/BECCS) and grid services (frequency regulation due to intermittent renewables).

The aim of this work is to assess partial capture at sites that have access to low-value excess heat to power the capture process, whilst considering competition from using the excess heat for MDH delivery. The work is based on process modelling and cost estimation of CO2 capture processes using amine absorption for two illustrative case studies, a refinery and a steel mill, which both currently use excess heat for MDH. The main focus is on investigating how seasonal variations in the availability of excess heat as well as the demand of district heating impact cost-efficient design and operation of partial capture at industrial sites. A challenge when utilizing excess heat in connection to a process connected to a district heating system is that the heat source which can be used to power part of the capture process will exhibit seasonal availability, and thus may inflict extra cost for the CCS plant not running at full load, and therefore may counteract the economic motivation for partial capture. To prevent this, heat integration between CCS and municipal district heating is investigated, for example by utilizing heat from the CO2 compression so that low-pressure steam is released from MDH to provide heat to capture CO2 whilst maintaining MDH supply.

The design of the amine absorption capture process will have to handle significant load changes and still maintain high separation efficiency within hydrodynamic boundaries of the absorber and stripper columns. The cost of such operation will depend on the solvent circulation flows, the number of absorber columns (including packing and liquid collectors/distributors) and capacity of solvent buffer tanks for storing unused solvent during the winter season. Assuming that a constant amount of CO2 is avoided, the avoidance cost of CCS based on excess heat with seasonal heat load variations is compared to the avoidance cost of CCS based on the use of external fuel to achieve a constant heat load to the reboiler.

4-056-20: Peer-reviewed paper

Ultra-low charge ammonia chillers for energy efficiency in industrial applications

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Panel
4. Technology, products and systems

Keywords
domestic energy efficiency, demand response, industrial energy saving

Ultra-low charge air-cooled ammonia (R-717) chillers offer versatility for industrial applications with both energy efficiency and water saving capabilities. Field evaluation of this new innovative product demonstrated its energy and water saving potential with the safe usage of zero GWP natural refrigerant based, air-cooled packaged chiller at a food processing industrial host site in the USA. Two key energy efficiency advances of the technology enable the significant reduction of ammonia refrigerant charge by an order of magnitude, specifically by a factor of 20 compared to conventional ammonia-based chillers. The two innovations are: (a) Advanced microchannel heat exchangers, which have improved heat transfer effectiveness due to the increased surface area; and (b) A new, pre commercial, semi hermetic compressor with no mechanical seal between the compressor and the compressor motor.

The advanced microchannel heat exchanger has integrally brazed airside fins, which gives higher heat transfer effectiveness. The heat exchanger is all aluminium; efficiency in heat transfer allows for the same capacity to be delivered with much lower refrigerant charge. A mechanical seal is one of the most vulnerable point of refrigerant leak in a refrigeration system, and this is the first type of compressor compatible for ammonia refrigerant that is available globally.

The new semi-hermetic compressor has aluminium windings since typically the motor windings are made of copper, which are incompatible with ammonia. Accordingly, the combination of these two innovations enabled the development of a packaged, air-cooled, ultra-low charge ammonia-based chiller, which eliminates and reduces the many burdensome regulations that otherwise govern the use of ammonia in industrial plants. The evaluated chiller uses less than 1.5 pounds (0.68 kg) of ammonia refrigerant per ton refrigeration (TR) capacity of the chiller, which corresponds to less than 75 pounds (35 kg) for the 50 TR chiller at the field demonstration site. While the field evaluation project is on-going, the aircooled ammonia (R-717) system has been

evaluated against an existing conventional water-cooled chiller with R-507A as a baseline at the food processing site. Field performance results show up to 40 % improvement in energy efficiency and water savings of 2.35 gallons of water per kWh of electricity used by the air-cooled ammonia chiller.

4-057-20: Peer-reviewed paper

Requirements engineering and morphological analysis of adaptive control strategies for flywheel energy storage. systems in industrial applications

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Yijun Lu, University of Stuttgart, Germany
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Panel
4. Technology, products and systems

Keywords
storage, requirements, adaptive control, industrial energy saving

Industrial applications including lifts, milling and lathing centers are characterized by dynamic short-term loads and recuperative braking. The integration of flywheel energy storage systems (FESS) reduces the installed power of new machines and buildings and can increase energy efficiency. Benefits and drawbacks as well as plug and play requirements for the integration and control of FESS are presented in this paper.

The requirements are weighted by six stakeholders and then analyzed in order to identify crucial system parameters. Based on this prioritization, a morphological analysis is conducted that leads to generic solutions for three industrial applications.

The analysis shall facilitate the implementation in real applications, saving the company time and money by avoiding costly controller tuning. Therefore, adaptive control strategies aiming for smoothed load profiles and an ameliorated energy efficiency using FESS are thoroughly investigated. The proposed analysis enables further research in terms of system modelling as well as control strategies and stability.

4-073-20: Peer-reviewed paper

Industrial excess heat and district heating: potentials and costs for the EU-28 on the basis of network analysis

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Tobias Fleiter, Fraunhofer ISI, Germany
Mostafa Fallahnejad, TU Wien, Energy Economics Group, Austria

Panel
4. Technology, products and systems

Keywords
waste heat, district heating, industry

Many studies see district heating as an important measure to reduce greenhouse gas emissions in the building sector. In this context, industrial excess heat can contribute to the provision of cost-effective heat for district heating networks with a low CO2-footprint. The potential of excess heat to be used for district heating depends, among other things, on the amount of energy available from the supplying factories, the seasonal profiles and the distances to possible district heating areas, which in turn determine possible transport costs for the heat. Here, we present a new method to estimate the costs of supplying industrial excess heat to potential district heating areas by calculating potential pipeline connections based on network analysis.

As a first step, we map areas with district heating potential. In the second step, we calculate how much industrial excess heat can be provided to supply these areas. To do this, we use a database of georeferenced industrial sites containing information on the amount of excess heat (1,058 sites with a total of 94 TWh). In addition, we use a heuristic model to design networks for heat transport between excess heat sources and district heating areas. On this basis, the investments for the necessary infrastructure are estimated. We take into account investments and operating costs for pipelines and heat exchangers as well as heat losses. This results in costs for transporting the excess heat to the district heating areas.

For our analysis, we vary the parameters in our model and thus generate cost-potential curves to show how much excess heat can be transported to the district heating areas at which costs. For the EU-28, our calculation shows that about 34 TWh of excess heat could be provided for transport costs of up to 0.75 ct./kWh. This corresponds to about 36 % of the excess heat in the data set. A further 13 % can be provided at costs of up to 1.5 ct/kWh. In total, about 54 % of the excess heat can be provided for costs of up to 2 ct./kWh.

4-092-20: Peer-reviewed paper

Double transmission double expansion technology as a method for reducing energy losses associated with. oversizing of industrial compressed air systems

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Panel
4. Technology, products and systems

Keywords
efficiency, industrial energy saving, compressed air, alternative energy systems (AES)

Compressed Air Systems (CAS) are successfully used in industrial processes and production lines in almost all sectors due to low investment costs, durable construction, high power density, etc. The biggest disadvantages of these systems are high operational costs due to the very low energy efficiency (10–20 %). Such large energy losses in these systems significantly affect the economic aspects of the industrial sectors and the natural environment. Energy losses in compressed air systems can be differentiated by their place of occurrence, i.e. in the compressor, in pneumatic lines and in pneumatic machines. Compressed air energy losses in pneumatic machines account for approximately 20–30 % of all losses in CAS. They result from oversizing of those machines and process parameters. Such losses lead to significantly higher energy consumption in CAS compared to the actual energy demand for a given production task.

There are several solutions to improve efficiency in final pneumatic machines, but neither have been implemented on an industrial scale. In this work we would like to introduce the Double Transmission Double Expansion (DTDE) technology. This technology is based on the accumulation of air exhausted from the pneumatic machine.

Then accumulated exhaust air is used in another pneumatic machine and, for example, converted into electricity. We present results from a lab-scale demonstration unit consisting of a 1 kW prototype of this technology connected to a pneumatic machine. The paper also presents achievable energy benefits from the usage of this technology.

4-102-20: Extended abstract

Analysis of energy efficiency improvement and carbon dioxide abatement potentials for Swiss Food and Beverage sector

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Martin K. Patel, University of Geneva, Switzerland

Panel
4. Technology, products and systems

Keywords
cost effectiveness, energy efficiency improvements, food and drink, CO2 abatement

The food and beverage (F&B) production is the second most energy intensive industry subsector, consuming up to 14% (22 PJ) of the Swiss industry's TFE and emitting 14% (0.6 million tonnes) of the industry's total CO2. In the period from 2004 to 2017, the sector's energy consumption has been increasing at a faster rate than production, which implies deterioration of energy efficiency. On the other hand, growing share of electricity in the fuel mix has resulted in a drop in CO2 emissions intensity of the Swiss F&B sector during the same period.

Against the background of a technical energy savings target of 26% between 2017 and 2050 under the assumption of constant future production, this study investigates the options of realizing the energy efficiency target and its possible impact on CO2 abatement. The process-related (i.e. excluding building envelope) technical energy efficiency potential of the Swiss F&B sector is estimated at 25% whereas the currently commercially available energy-efficient technologies can potentially reduce 24% of the sector's current CO2 emissions. The cost-effective potential estimated by means of a bottom-up approach (cost curves) ranges from 14% to 16% for energy efficiency and 18% to 21% for CO2.

Results of sensitivity analysis indicate that low energy prices may act as a barrier for the adoption of cross cutting technologies. A qualitative analysis of emerging technologies presented along with the detailed cost-effectiveness analysis of commercially available energy-efficient technologies can help to overcome the techno-economic barriers and achieve the CO2 abatement targets through the energy savings for the Swiss F&B sector.

4-108-20: Peer-reviewed paper

Decarbonizing Swiss industrial sectors by process integration, electrification and traditional energy efficiency measures

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Martin K. Patel, University of Geneva, Switzerland
Anna Sophia Wallerand, EPFL, Switzerland
Francois Marechal, EPFL, Switzerland
Cordin Arpagaus, NTB University of Applied Sciences of Technology, Buchs, Institute for Energy Systems, Switzerland
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Panel
4. Technology, products and systems

Keywords
economic assessment, heat recovery, Switzerland

The Paris Agreement 2015 is a historic initiative taken by the global community to fight against climate change and steer the world towards clean energy transition and deep decarbonization. Switzerland has developed the Energy Strategy 2050 which is a strategic policy package for realizing the transition towards a low-carbon economy. Energy efficiency (EE) is one of the strategy's major pillars.

Although several steps to incentivize EE improvement in the industry have been taken in Switzerland, the size of the EE gap that currently exists in its high-value-added manufacturing sector is largely unknown majorly due to the complexity of the sectors and lack of data. Moreover, since industrial technologies are advancing rapidly, it is essential to evaluate the potential wide-scale application of emerging technologies and best practices in the industry. To this end, this study explores the techno-economic final energy and CO2 saving potentials in the Swiss industry in the short-tomedium term at the level of individual sectors and for crosscutting technologies.

In total, the studied EE measures correspond to an economic final energy savings potential of 23 PJ per year (19 % of the final energy demand in the Swiss industry; potential dominated by process heat integration measures) if total investments are considered. If additionality is accounted for, then the total economic potential increases from 19 % to 21 %. The estimated thermal energy savings, in addition to the savings from measures exclusively related to CO2

mitigation, are equivalent to a potential CO_2 abatement of 1.3 Mt CO_2 p.a. (34 % of the fossil-based CO_2 inventory in Swiss industry). This work is a contribution to the so far limited international literature on economic EE measures applicable to high value-added and heterogeneous manufacturing sectors and is meant to inform decision-makers.

4-109-20: Peer-reviewed paper

Assessing emerging energy-efficient technologies for industry – application of the EDUAR&D methodology for the case of high temperature electrolysers

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Gregor Zesch, IREES, Germany
Ulrich Schmoch, Fraunhofer Institute for Systems and Innovation Research (ISI), Germany

Panel
4. Technology, products and systems

Keywords
energy efficient technologies, hydrogen, steel, electrolyzer technology, R&D assessment

Research and Development (R&D) for energy efficient solutions is not an objective for itself, but it must serve society by reducing energy costs and avoiding GHG emissions. Public R&D funds should be efficiently allocated as far as possible by addressing substantial energy efficiency potentials, by identifying bottlenecks and detectable risks, and by supporting the stakeholder dialogue with comprehensive information.

These objectives can be supported by applying a methodology that has been developed by an interdisciplinary group of energy technologists, economists, and innovation researchers, called the Energy Data and Analysis of Research & Development – EDUAR&D; (Jochem et al. 2009). The methodology has been successfully applied to several energy technologies, such as passive houses, industrial furnaces, the PEM fuel cell, and carbon capture and storage. The paper at hand gives summarised results from an analysis of solid oxide high temperature electrolysers as an innovative and energy efficient means to produce green hydrogen, e.g. for utilization in future primary steelmaking. Where applicable, e.g. for the innovation system, regional specifics for the case of Germany were assessed.

The analysis presented shows a promising energy efficient electrolyser technology for basic industries, in a low-to-medium stage of its technological development, with a considerable increase of R&D and patent activities (but still on a rather low absolute level), low market activities and a very clear need for policies supporting further R&D as well as market entry through industrial scale demonstration plants.

4-126-20: Extended abstract

Opportunities to significantly expand & scale electrification of industrial processes

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William Morrow, Lawrence Berkeley National Laboratory, USA
Joe Cresko, Department of Energy, USA
Neal Elliott, ACEEE, USA

Panel
4. Technology, products and systems

Keywords
electrification, beneficial, decarbonisation, barriers

Several transformative pathways have been proposed for industrial decarbonization including beneficial electrification. The prospects for accelerated electrification vary by industry, but there are several large, cross-cutting opportunities (e.g. motor drives; industrial heat-pumps; convective process heating & drying) and more process specific opportunities (e.g. surface treatments; materials preparation; resistive/inductive/dielectric thermal operations). Multiple hurdles have impeded broad adoption of these electrified industrial operations, such as low stock turnover, energy cost gaps, process integration, risk aversion, and unique/proprietary process designs. However, electrotechnologies have established footholds in multiple niches and provide advantages over incumbent (non-electrified) processes. These successful cases represent islands of opportunity, from which an extended opportunity space may be assessed. By highlighting co-benefits, pursuing unique advantages, enhancing growth within industrial clusters, integrating energy efficiency, and thoroughly capturing the complete value of the technology, electrotechnologies can be expanded from these niche opportunities to benefit a broader range of manufacturers.

Across all opportunities, a durable, supportive, and agile policy environment that addresses issues across RD&D, scale-up, process integration, and infrastructure is needed to accelerate electrification and the targeted GHG emissions reductions, and realize extended systems benefits.

This talk will describe opportunities and challenges for significantly increased industrial electrification, routes to address hurdles, pathways to accelerate growth niche applications, and policy approaches to enable more rapid adoption of current, emerging, and future electrotechnologies.

4-132-20: Peer-reviewed paper

High temperature heat pumps for industrial processes – application and potential

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Franz Helminger, AIT Austrian Institute of Technology GmbH, Austria
Michael Lauermann, AIT Austrian Institute of Technology GmbH, Austria

Panel
4. Technology, products and systems

Keywords
heat pump, dryers, decarbonisation

Industrial heat pumps convert unused waste heat into valuable process heat and therefore, they increase process efficiency and the share of electrified processes. With a total of 25 % of the energy demand in the European Union, industry is a key player to achieve the climate goals of the European Union. The share of heat pumps in Austrian industry is steadily increasing.

Typically, heat pumps are applied in the food industry with heat supply temperatures of up to 80 °C or for district heating applications. High temperature heat pumps that deliver process heat up to 160 °C offer a larger range of applications in industrial processes and are currently being developed. DryFiciency is an H2020 demonstration project, where two high temperature heat pump demonstrators are developed and operated in drying processes in a real industrial environment.

This work presents the techno-economic assessment of the first operation period of the DryFiciency heat pump. It is integrated at a production site of Wienerberger in Austria und supplies hot air for brick drying.

The DryFiciency heat pump allows for significant reductions of end energy consumption (from 66 % at a heat supply temperature of 160 °C to 81 % at 120 °C) and CO2 emissions (67–82 %) compared to a natural gas burner. Due to the recovery of waste heat and the prospect of increasing shares of renewable electricity production and increasing CO2 costs, the heat pump is a future-proof process heat supply system. Based on average Austrian energy prices, cost reductions in the range of 12–50 % can be achieved. With higher CO2 prices, up to 28– 59 % of energy cost reductions are possible.

4-155-20: Peer-reviewed paper

Value chain-wide energy efficiency potentials of additive manufacturing with metals – some preliminary hypotheses

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Georg Kobiela, Wuppertal Institute, Germany

Panel
4. Technology, products and systems

Keywords
value chain, additive manufacturing

For some time, 3D printing has been a major buzzword of innovation in industrial production. It was considered a game changer concerning the way industrial goods are produced. There were early expectations that it might reduce the material, energy and transport intensity of value chains. However for quite a while, the main real world applications of additive manufacturing (AM) have been some rapid prototyping and the home-based production of toys made from plastics. On this limited basis, any hypotheses regarding likely impacts on industrial energy efficiency appeared to be premature. Notwithstanding the stark contrast between early hype and practical use, the diffusion of AM has evolved to an extent that at least for some applications allows for a preliminary assessment of its likely implications for energy efficiency.

Unlike many cross-cutting energy efficiency technologies, energy use of AM may vary substantially depending on industry considered and material used for processing. Moreover, AM may have much greater repercussions on other stages of value chains than conventional cross-cutting energy efficiency technologies. In case of AM with metals the following potential determinants of energy efficiency come to mind:

• A reduction of material required per unit of product and used during processing;
• Changes in the total number and spatial allocation of certain stages of the value chain; and • End-use energy efficiency of final products.

At the same time, these various streams of impact on energy efficiency may be important drivers for the diffusion of AM with metals. This contribution takes stock of AM with metals concerning applications and processes used as well as early evidence on impacts on energy efficiency and combine this into a systematic overview. It builds on relevant literature and a case study on Wire Arc Additive Manufacturing performed within the REINVENT project.

4-156-20: Peer-reviewed paper

Analysis of heat pump integration into drying process for decarbonization in industry

Takenobu Kaida, CRIEPI, Japan
Yannick Beucher, EDF, France
Florence de Carlan, EDF, France
Jean-Marie Fourmigué, EDF, France

Panel
4. Technology, products and systems

Keywords
waste heat recovery, heat pump, dryers, case studies, CO2 reduction

Heat pump is one of the key technologies for decarbonization in industry. A large part of the final energy used for industrial thermal purposes is wasted through heat losses. Heat pump can recover the waste heat and convert it into useful heat by adding relatively small amounts of electric power. When the power derives from low carbon electricity, heat pump has two positive coupled effects: energy saving and CO2 emissions reduction. Among various industrial heating processes, drying is a highly energy-intensive process. Some estimations have reported that drying process accounts for 10–25 % of total industrial energy consumption in most developed countries. Currently, however, waste heat recovery from drying process is still limited to air preheating by heat exchangers. Heat pump can valorize more waste heat and lift up the decreased temperature to the temperature required by the drying process. The recent availability on the market of high temperature heat pumps (>100 °C) allows to consider heat pumping technology for a wide range of dryer applications.

This paper focuses on drying process as a typical example of decarbonization in industry by waste heat recovery with heat pumps. As the heat pump supply temperature increases, the applicable process range expands, but the coefficient of performance (COP) decreases because of larger temperature lift. Hence it is necessary to design the heat pump integration at an appropriate heat pump supply temperature. Using a simple thermodynamic modelling of heat pump integration into drying process, the optimum heat pump supply temperature is identified, and the heat pump contribution to decarbonization is estimated as well as the contribution to energy saving and energy cost reduction for three different assumed cases for the surrounding energy system: EU average conditions, France and Japan. As a result, it is found that the energy cost reduction effect is maximized when the heat pump supply temperature is set around 130 °C in EU and in Japan, and the optimum temperature is around 170 °C in France. In this case, the CO2 emissions reduction is estimated to be 50 % in Japan, 60 % in EU and 95 % in France compared to existing natural gas fired steam boiler system.

5-012-20: Peer-reviewed paper

De-carbonisation, guaranteed: Realising affordable, equitable and long-term financing for industrial SME projects

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Jason Erwin, Borg & Co AB, Sweden

Panel
5. Business models, finance and investment

Keywords
public guarantees, energy efficiency financing, financing, industrial SME, decarbonisation, climate policy

Using an investment simulation model, the authors compare the financial viability of three renewable energy technologies with natural gas based industrial process heat generation under different scenarios. The main burden of long-term decarbonisation investments to replace natural gas with renewable technologies has to be shouldered by private companies.

For debt financing, the inherent long-term credit risk has a decisive impact on the availability and on the risk premium included in the cost of debt. Therefore, public guarantees designed to address long-term credit risk can be highly impactful when compared with e.g., subsidies for CAPEX or high carbon prices/ taxes. The authors find that the use of long-term public guarantees will be necessary to support small and medium sized companies' (SMEs) access to bank loans. Further, such guarantees render renewable technologies with high initial investment requirements financially viable by reducing risk premiums and thus financing cost.

In conclusion, the authors suggest linking support for decarbonisation initiatives to the amount of CO2 reduced or substituted (the concept of "climate guarantees").

5-032-20: Extended abstract

Bridging the gap: A platform to connect small industrial efficiency projects with the capital markets

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Jason Erwin, Borg & Co AB, Sweden
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Panel
5. Business models, finance and investment

Keywords
investment, decarbonisation, renewable energy, business models, special purpose vehicle, forfaiting

Smaller suppliers of renewable energy (RE) and energy efficiency (EE) projects face business constraints. Smaller projects are not bankable due to a lack of standardised procedures for technical assessment, due diligence, and risk assessment in line with standard financing practice. This situation prevents project-based financing.

Smaller suppliers cannot make projects more attractive to customers by offering special payment conditions (i.e. energy performance contracts/savings arrangements), as the suppliers' working capital would be locked into existing/delivered projects and unavailable for developing new projects. These factors dampen EE and RE project deployment in particular for SMEs.

To accelerate implementation of SME-generated projects, TrustEE (initially an EU-funded project) developed and commercialized a platform. The key features include: streamlined and standardised technical and economic assessment; risk and credit assessment procedures coupled with insurance offerings complying with standard banking practice; multi-year repayment plans for industrial end-users; and standardised preparation of the project portfolio for securitisation (a later phase).

In short: TrustEE is a new service combining project development with standardised assessment to improve the liquidity of all parties involved and deliver bankable projects to the capital markets.

Registered suppliers initiate the process by applying for project financing via the platform. If positive, TrustEE purchases the open receivables upon project commissioning. This step ensures that the supplier retains the technical risk during the operational phase, which is critical for investors. Suppliers can thus offer their industrial customers a re-payment plan over several years.

Today standardised assessment for thermal EE, solar process heat, biomass, biogas and heat pump projects are implemented into the platform. PV, optimised control systems and other technologies will be added in short-term.

5-042-20: Extended abstract

Designing and implementing a capacity building program dedicated to the financial community aiming to boosting energy efficiency investment in the industry

Apolline Abauzit, GreenFlex, France
Sebastien Delpont, GreenFlex, France

Panel
5. Business models, finance and investment

Keywords
training, multiple benefits, overcoming barriers, energy efficiency investments, investment decision-making, third party financing, operational tools, skills management, capacity building

According to the IEA, the industrial sector could improve its energy intensity up to 44% between now and 2040, by investing in cost-effective and proven solutions.

Yet today, investments in such solutions remain insufficient compared with the energy saving potential. Existing financial tools and contractual schemes for investing in energy-efficient projects are not known and not used enough by industrials to be efficient and financiers of industry were weakly mobilized on this issue offering solutions not always aligned with the needs of industrial decision-makers.

To overcome these barriers and activate this potential, the capacity building program INVEEST has been designed to specifically target investment decision-makers in industrial companies (CFOs, industrial directors, etc.) and their financial stakeholders (bank advisors, accounting experts, etc.). INVEEST is willing to mobilize this public and to foster an acceleration in EE projects investment through the implementation of the 3 following actions:
– Training and supporting 1,000 actors by the end of 2020 on financing strategic energy efficiency projects, with a three-step program (e-learning preparation, 2-days training and individual tutoring)
– Providing these actors with operational tools for implementing concrete, profitable and risk-free projects
– Creating a broad and collaborative community of decision-makers around financing the low-carbon industry

INVEEST is carried out by GreenFlex, in collaboration with the French Environment and Energy Agency and under the supervision of the French Ministry of Ecological and Inclusive Transition. It is co-funded by the French White Certificates scheme and the European Commission through the LIFE program.

Launched in September 2019, the program has already been adopted by four major French banking institutions. Hundreds of decision-makers are now involved in the INVEEST energy efficiency financing practitioner community.

5-044-20: Extended abstract

EFFORCE: how blockchain tecnology can revolutionize energy efficiency investments

Jacopo Visetti, Efforce, Italy

Panel
5. Business models, finance and investment

Keywords
Blockchain, Securitization, energy performance contracting (EPC), third party financing, industrial energy saving

EFFORCE is a blockchain-based energy saving platform. EFFORCE platform solves the three main problems of the energy efficiency market: the difficulty of putting Investors and Savers in contact, the size of the investments required and the type of financial return.Through EFFORCE, energy saving financed by the investor (Contributor) is tokenized and used or sold to energy-intensive consumers.

The role of the blockchain is paramount, since it guarantees the integrity and uniqueness of the energy saving data obtained. The data that each smart meter will transmit will be validated and certified by the blockchain, in order to unequivocally guarantee the savings obtained at a certain point in time and, therefore, the quantity of KWh saved which will be loaded on the user profile of the investor (the "Contributor").

The energy savings of each Investor will be tokenized and can be used both to offset energy consumption and to be traded. Through EFFORCE, energy end Consumers can participate in tokenized energy savings. Thanks to the control system and data certification guaranteed by the blockchain, EFFORCE has created the first Energy Performance Smart Contract.

Each EFFORCE token holder will be granted with the access with priority to the energy savings projects that will be listed in the platform, contributing to the spreading of energy efficiency on a global scale. Each project will have a wallet in which the amount of KWh saved from that project will be accrued. In this way each token will accumulate the KWh of energy saving achieved. These savings derive from the efficiency improvement projects with high financial returns carried out by reliable industrial and commercial partners.

Efforce securitizes energy savings. This is the innovation that can revolutionize the energy efficiency market. Each token represents an Energy Performance Smart Contract, which guarantees the savings obtained over a certain period of time, thanks to a specific energy efficiency project.

5-059-20: Extended abstract

Innovative approach to use standards in new business models blockchain ready

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Ettore Piantoni, CEN/CENELEC JTC 14 Chairman, Italy
Bernard Gindroz, CEN/CENELEC Sector Forum Energy Management Chairman, Italy

Panel
5. Business models, finance and investment

Keywords
energy management, energy efficiency financing, De-Risking, Blockchain, efficiency standards

EU's energy and climate framework to 2030, as any business strategy execution, requires ex-ante assessment of the projected effects of the policies and ex post evaluation of the implemented actions with a materiality approach. The updated Guidelines for companies and financial institutions on reporting climate related information to investors and Non-Financial Reporting Directive, integrate the framework, striving to provide investors with material information on the effects of climate change on corporations as well as the impact of their activities on climate. The aim is to engage investors and shareholders (financial materiality) with Sustainable Finance and stakeholders, companies, consumers to adopt sustainable energy measures towards decarbonization, by providing de-risking tools and platform to track and monitor progresses and effectiveness of the measures.

It is business and standards activism to shape and support the framework that stimulates innovation addressing challenges directly. This requires the development and adoption of emerging and new technologies such as NZEB distributed RES production, real-time coordination of electricity supply and demand, energy storage, e-mobility, hydrogen as well as impact finance. Standardization, quality of data, transparency, traceability for disclosure and reporting are essential requirements of this integrated framework.

Extending the positive application of Distributed Ledger and Blockchain to energy we can substantially contribute to define a coherent set of trusted rules supporting policy measures and regulatory initiatives. This will enable the technical and financial value chains to share common business platform to mitigate risks and value the multiple benefits of the implemented actions.

In the presentation we will cover the "relevance" standardized framework for a business model blockchain ready. The desired outcome is to develop a collaborative use case with all relevant shareholders and stakeholders.

5-062-20: Extended abstract

Components of chemical company Paris climate alignment

Nate Aden, World Resources Institute, USA

Panel
5. Business models, finance and investment

Keywords
chemical industry, science-based targets (SBTs), greenhouse gas emission reduction, corporate investment decisions, greenhouse gas mitigation, greenhouse gas emissions intensity, corporate strategy

The chemicals sector plays a central but complex role in the transition to a low-carbon economy, not least because of the current ubiquity and increased demand for chemicals in low-carbon and energy-saving technologies. IEA Energy Technology Perspectives data indicate that current CO2 emissions from the chemical and petrochemical sectors are the third largest industrial sector source of emissions behind cement and steel. While chemical products are expected to contribute to the well-below 2°C outcome described in the 2015 Paris Agreement, greenhouse gas (GHG) emissions related to chemicals production will need to be reduced to maintain global emissions budgets consistent with climate stabilization this century. Energy efficiency improvements, fuel switching, technical innovation, and new business models offer cost-effective opportunities for chemical company emissions reductions. Leading chemical companies are setting science-based emissions reduction targets (SBTs), but the sector has yet to turn the corner on its total GHG emissions growth. This paper identifies barriers to broader chemicals sector climate action and resources for supporting increased mitigation ambition.

SBTs are a keystone metric for companies to integrate energy efficiency and other GHG mitigation options into aggregated public targets for low-carbon transformation. As of December 2019, seventeen chemicals companies have committed to setting SBTs via the Science Based Targets initiative, and seven of these companies have publicly-approved SBTs.[1] These targets are a starting point for developing sector resources.

[1] Note that this list does not include pharmaceutical manufacturers or oil and gas companies. Chemicals companies with approved targets include: Borregaard AS, International Flavors & Fragrances Inc, Novozymes A/S, Royal DSM, Sekisui Chemical Co Ltd, Sumitomo Chemical Co Ltd, and Syngenta.

5-069-20: Extended abstract

Guaranteed and insured energy saving to boost EE investment by SMEs

Livia Miethke Morais, BASE - Basel Agency for sustainable Energy, Switzerland
Daniel Magallón, BASE, Switzerland
Daniele Forni, FIRE, Italy

Panel
5. Business models, finance and investment

Keywords
energy savings, SME, energy efficiency investments, investment decision-making, energy savings insurance, guaranteed savings

The EU 2030 and 2050 targets require to enhance the private investment in energy efficiency (EE) across all sectors. Innovative financing schemes can help to create the conditions needed to ensure an adequate supply of private finance for EE investments.

Enterprises employing fewer than 250 persons represented 99% of all enterprises in the EU and are a substantial market opportunity for EE improvements. However, this remains largely untapped.

The barriers inhibiting SMEs investments in EE include lack of trust between the different actors and perceived high risks. Decision-makers are price sensitive, especially in SMEs, which are faced with competing investment needs and opportunities, combined with limited financial resources or limited access to credit. The barriers exist despite the benefits of EE investments, such as the recovery of their - usually higher - upfront costs in a short period of time from cash flows generated through savings, while also improving productivity, efficiency and reducing emissions.

The energy savings insurance (ESI) model consists of different mechanisms that aim to drive demand and motivate SMEs to invest in EE, by reducing the perceived risks and creating trust between key actors (technology providers, enterprises, financial institutions). The main components of the ESI model are: 1) standardised turnkey contract including guaranteed savings clause, 2) insurance covering the contractual guaranteed savings, 3) procedure involving a third party to validate the project, the installation and the measurement and verification of savings, 4) financing structure linking existing financing instruments for SMEs and EE.

A pipeline of EE projects in Italy, Portugal and Spain is underway to operationalise the ESI model under the Horizon2020 funded project ESI Europe. To further built trust, the ESI implementation also counts on a management information system developed in Blockchian, guaranteeing traceability and reliability of EE projects.

5-100-20: Extended abstract

The Energy Efficiency Financial Institutions Group (EEFIG) as a catalyst for deep decarbonization

Carsten Glenting, Viegand Maagoe, Denmark

Panel
5. Business models, finance and investment

Keywords
energy efficiency financing, market barriers, overcoming barriers, financing, economic analysis, business models, institutions

The European Commission President Ursula von der Leyen, indicated in the political guidelines for the new Commission that the European Green Deal will be a key political priority, and that a clear proposal on this to be presented within the first 100 days will include more ambitious CO2 targets for 2030. This will likely translate into an even larger investment gap for energy efficiency. In this context, the Energy Efficiency Financial Institutions Group (EEFIG) and its support to up-scaling energy efficiency investments is a very important and relevant player.

The abstract will give an overview of recent and ongoing work of EEFIG within a broad range of subjects with a focus on contributions to industrial energy efficiency, including: the emerging EU sustainable finance taxonomy and tagging of energy efficiency loans; improvement of the De-risking Energy Efficiency Platform (DEEP); monitoring of the evolution of financing practices in buildings and industry; the risk profile of energy efficiency financing; the multiple benefits of energy efficiency; industrial practices dealing with energy efficiency; and how energy efficiency financing will work of the next EU Multiannual Financial Framework (MFF) 2021–2027.

5-106-20: Peer-reviewed paper

EU Taxonomy on sustainable economic activities – preliminary assessment of the implications for corporate energy efficiency investments

Bettina Dorendorf, KfW Bankengruppe, Germany

Panel
5. Business models, finance and investment

Keywords
energy efficiency investments, business models, EU taxonomy, sustainable finance

Transforming the economy to achieve the goals of the Paris Agreement and for this purpose pursuing a carbon neutral economy in 2050 requires an additional yearly investment volume in the range of EUR 175 to 290 bn per year according to estimations of UNEP FI. (1)

The EU Action Plan on Financing Sustainable Growth, adopted in March 2018, pursues inter alia the increase of direct capital flows towards sustainable investments, of which corporate and industrial energy efficiency investments are a part of.

However, so far there is no clear and widely accepted definition what the term “sustainable” means in this context. An important step in this direction is a new regulation which establishes a framework to facilitate sustainable investments. The Taxonomy Regulation, part of the EU Action Plan, forms the basis for a classification system by determining clear criteria under which an economic activity can be considered “green” in the sense of ecologically sustainable (referred to as “taxonomy” or “EU taxonomy”). (2)

For this purpose, the EU taxonomy defines specific quantitative and qualitative criteria (metrics, thresholds and do no significant harm-criteria). Their application will be binding for those providers of investment products which claim their products are sustainable (creating transparency) as well as for large corporates in respect to their non-financial reporting.

A Technical Expert Group (TEG), created to assist the EU Commission in defining the technical criteria for the taxonomy, has distinguished 70 economic activities and has defined for each of them the specific conditions which have to be met in order to consider an economic activity ecologically sustainable.

This peer reviewed paper will describe the main elements of the EU taxonomy for sustainable economic activities and make a preliminary assessment of the impact on corporate energy efficiency investments based on the example of the renovation of a production facility

(non-residential building). It will point out the need for action for the corporate sector and discuss the main challenges for corporate energy efficiency investments to comply with the taxonomy requirements.

Disclaimer: at time of writing, the EU Taxonomy Regulation has not yet been fully adopted (expected 1st half 2020. Also, the Delegated Act with the final version of the technical screening criteria has not yet been published (expected for end of 2020). However, fundamental changes with regard to methodological approach and scope are not expected.

(1) United Nations Environment Program Finance Initiative.
(2) In this paper, the term “taxonomy” or “EU taxonomy” relates to the Regulation of the European Parliament and of the Council on the establishment of a framework to facilitate sustainable investment, and amending Regulation 2019/2088 on sustainability- related disclosures in the financial services sector(2018/0178(COD), as adopted by the European Council on 15.4.2020.

5-127-20: Peer-reviewed paper

Financial carbon footprint: calculating banks' scope 3 emissions of assets and loans

Jens Teubler, Wuppertal Institute for Climate, Environment and Energy, Germany
Markus Kühlert, Wuppertal Institute for Climate, Environment and Energy, Germany

Panel
5. Business models, finance and investment

Keywords
green investments, carbon footprint, sustainable finance, avoided emissions, carbon accounting

Financial institutions play a crucial role in achieving the 2015 Paris Climate Agreement. They can manage capital flows for financing the required transformation towards a decarbonized industry. Currently established policy programs and regulations at European and national level increasingly address financial institutions to make their climate warming impact measurable and transparent. However, required science-based assessment methods have not been sufficiently developed so far.

This paper discusses methodological opportunities and challenges for measuring carbon footprints of financial institutions. Based on a scientific case study undertaken with the German GLS Bank, the authors introduce an innovative method for quantifying greenhouse gas emissions from a bank's asset with a focus on loans. The authors apply an input/output database to calculate greenhouse gas (GHG) intensities and allocate them with bank's loans and investments.

Moreover, the paper provides insights of calculating avoided GHG emissions initiated by a bank's investment and loans. In conclusion, a high degree of consistent and standardized assessment methods and guidelines need to be developed and applied to promote comparability and transparency.

5-142-20: Extended abstract

Risk mitigation for industrial excess heat recovery projects

Elsa Chony – **Industry Department**, ADEME, France
Cyrielle Borde, ADEME - Industry Department, France

Panel
5. Business models, finance and investment

Keywords
energy efficiency financing, risk management, third party financing, operational tools, market barriers, investment decision-making, corporate investment decisions, district heating

Excess Heat Recovery represents a huge potential of reducing energy consumption as well as boosting competitiveness of the EU Industry. Despite a significant support from EU Policy maker in this field, number of barriers still exist. At least two main reasons characterize the specificity of these projects:
– The multiplicity of stakeholders (industry that produces the excess heat, industry that consumes the energy, financing organization, local authority)
– Energy production is a complementary activity from the industry viewpoint.

These two reasons lead to a risk-staking that is difficult to allocate to the different stakeholders. Some important risks are:
• Technical (Design failure, uncertainty about long-term availability of the excess heat, etc.)
• Organizational (Lack of agreement between stakeholders, lack of skills, etc.)
• Financial/Economical (Failure to achieve profitability : fluctuation in energy market prices ; fluctuation in excess heat supply or consumption ; failure to find appropriate business models, etc.)
• Legal (Lack of policy instrument ; Implementation constraints; etc)
• Operational (Failure to achieve targeted performance, etc.)

In order to tackle those barriers, especially from the financing institution viewpoint, ADEME conducted a study in order to obtain a comprehensive overview of standard risks that are encountered throughout the lifecycle of a heat recovery project. The objective was to define a list of standard risks, possible causes, existing mitigation measures and to propose new mitigation measures.

10 real and very different projects – success and failures – has been studied from this perspective. A tool is now operational and applied at project level as well as territorial level. The final aim is to improve projects bankability for investors by mitigating risks. The sudy/tool and its very first utilization at project level (by investor) as well as territorial level (Marseille/Fos Port) will be discussed.

5-143-20: Extended abstract

Industrial production to 2050: the PEPIT0 model

Sylvain Sourisseau, ADEME, France
Guillaume DAILL, ADEME, France
Cyrielle Borde, ADEME, France

Panel
5. Business models, finance and investment

Keywords
roadmaps, product policy, long-term scenarios, business strategy, energy-intensive industry, activities, competitiveness

In the industrial sector, the two main factors of the energy demand are: the production levels and the energy efficiency level. Until now, the industrial energy efficiency perspectives are quite well-documented, but the production level "predictions" for the French industry are more uncertain.

ADEME wanted to get equipped with a modelling tool for the industrial production levels through the demand for materials produced by the following 9 energy-consuming industries: steel, aluminum, clinker, glass, chlorine, ammonia, ethylene, papers and pulp, and sugar. The aim is to take into account the market changes of these sectors, particularly focusing on the ones that are impacted by a low carbon scenario.

The methodological contribution of these works comprises two key elements:
– Quantifying the production and consumption of 9 raw materials, as well as of consumer goods and capital goods (intermediate or end products) created from these materials. This quantification includes, among other elements, the import and export dimensions, as well as the recycling process. This quantification was made for the year 2014 from an analysis that crosschecked the main national or international data sources, and it is outlined in an “input-output table” type matrix representation.
– Modelling the production paths for the 9 materials studied, from this reference point and formulating assumptions related to the 6 markets. They are about the changing consumer demand, reuse and possible repair of some goods, technological improvements of material balance, incorporation rate of recycled material in manufacturing, but also trends in international trade.

Model description (assumptions and limits) and the consequences of the French Low Carbon Carbon Strategy on the French Industry production as well as policy impacts will be discussed.

5-146-20: Extended abstract

Cooling as a Service: unlocking demand for clean and efficient cooling.

Thomas Motmans, BASE - Basel Agency for sustainable Energy, Switzerland
Daniel Magallón, BASE - Basel Agency for Sustainable Energy, Switzerland
Carla Della Maggiora, BASE - Basel Agency for Sustainable Energy, Switzerland
Dimitris Karamitsos, BASE - Basel Agency for Sustainable Energy, Switzerland

Panel
5. Business models, finance and investment

Keywords
cooling, business models, energy efficiency financing, air conditioning, commercial buildings, public buildings, industrial energy saving, internet of things (IoT), as-a-Service, climate change, innovation, collaboration, energy efficiency investments, green investments, pilot projects, developing countries, market development, market barriers, initiatives and solutions, risk management, new paradigm, circular economy, servitisation

According to the IEA's future of Cooling report, the demand for air-conditioning is set to triple by 2050, consuming the equivalent of one third of the global electricity demand today, and corresponding to an opportunity of 6.9 USD trillion over the next 30 years. However, despite the clear economic benefits of energy efficiency for building and business owners, investments in clean and efficient cooling are not happening at the scale expected. The key barriers are the higher upfront cost of more efficient equipment, a lack of trust in the promised savings, and a preference of businesses to invest in their core business.

Together with the Kigali Cooling Efficiency Program, the Basel Agency for Sustainable Energy (BASE) is leading the Cooling as a Service Initiative to mainstream the adoption of the innovative business model Cooling as a Service (CaaS).

This model overcomes these key barriers through a servitisation strategy, where instead of investing in the equipment, the building owner only pays the cooling service for every unit of cooling consumed. The technology provider owns the cooling system, maintains it, and covers all operational costs including electricity and water. Since the fixed price per unit of cooling includes the running costs, it is in the provider's own interest to install the equipment with highest efficiency as well as to offer excellent preventive maintenance to reduce the cost to deliver the service.

Through the initiative, BASE is supporting, inter alia, the development of tools to enable the model (e.g. CaaS contracts, pricing tools, financial structures); the implementation of pilot projects in Latin America, Africa and Asia; the setting up of the Cooling as a Service Alliance; the organisation of matchmaking events between providers, clients and investors. BASE is also organising the Cooling as a Service Global E-Summit planned for the 1st of December 2020.

This year, BASE is also starting a project to scale up "Energy-Efficient Equipment as a Service" funded through the European Commission's H2020 Research and Innovation Programme. The project will be implemented in Spain (partner: ANESE), Belgium (partner: AGORIA) and the Netherlands (partner: Innoenergy) with the objective to develop and deploy the servitisation model and a financial structure accelerating the market adoption of energy-efficient equipment (beyond cooling).

We believe that CaaS and servitisation in general is a true game-changer, and we are keen to spread the word about this business model innovation opportunity and share our lessons learned.

5-158-20: Peer-reviewed paper

A new model for jointly purchased energy services in Turkish industrial parks

Gokhan Kirkil, Kadir Has University, Turkey

Panel
5. Business models, finance and investment

Keywords
industrial energy saving, joint purchase of energy

As a part of an EU-funded H2020 project called S-PARCS (new energy efficiency service models in industrial parks), we performed a survey for existing energy services in four biggest industrial parks in Turkey. Industrial Parks in Turkey are initially founded as public entities but later governed by a board formed by both public and private managers. In terms of electricity and natural gas services, industrial park management acts as a distribution company. In the past, industrial park management purchased electricity and natural gas through bilateral agreements and sold them to their companies after adding some transaction cost. With this model, they were able to foresee their profits.

Over last few years, as a result of establishment of electricity and natural gas markets in Turkey, industrial parks started purchasing electricity and natural gas from daily energy markets. This new model brings new challenges to park management as energy prices started to fluctuate all over the year. In addition, the government started to collect renewable energy feed-in-tariff payments from industrial customers proportional to their consumption.

In this paper we propose a new energy management model for industrial parks to better manage energy price fluctuations and tariffs.

5-159-20: Extended abstract

How can we best create a synergy between existing electricity-intensive industry, existing materials and energy systems and future establishments?

Anders Pousette, Swedish Energy Agency, Sweden
Thomas Fägerman, Boden Business Park, Sweden
Nils Lindh, Boden Business Agency, Sweden

Panel
5. Business models, finance and investment

Keywords
server halls, agriculture

In the municipality of Boden have, since the 1970s, considerable resources been invested in energy production – electricity production via hydropower/cogeneration, heat via waste incineration to district heating and biogas via digestion of food waste and sewage sludge. When the military operations in the municipality of Boden decreased, the municipality decided to invest in land in strategic areas and further develop these land areas through zoning and connection of infrastructure in the form of electricity, district heating and biogas. The investment has been made in collaboration between private and public actors.

A 50 hectare former military area is transforming into a modern sustainable industrial area with unique conditions. A hydropower station with a new substation delivers 200MW of green electricity to the area. A biogas plant produces 1200m3 of biogas which is currently used for cars and busses, but the intention is to also use the gas as part of the production of fuel cells/hydrogen. A number of data centers have been built for storing data, and for frequency control of electricity and local food production by using residual heat for greenhouses and land-based fish farms all year round. The area has also a district heating infrastructure with excess energy that can be used both to supply heat and cooling. The interest for the area is high from both local, national and international players.

Education is the key to attract new people to move to the region, but also to retain and develop those who already live in the area. Identifying and implementing the right type of education is key – a lot has been invested in world- and future reconnaissance. An interesting part of the local commitment is the local food cluster that includes everything from growers, suppliers and wholesalers.

The purpose of the investment is to create a synergy between existing electricity-intensive industry, existing materials and energy systems and future establishments.

6-022-20: Extended abstract

GHG neutral pathways for the German chemical industry

Florian Ausfelder, DECHEMA e.V., Germany
Alexis Bazzanella, DECHEMA e.V., Germany
Alexander Möller, DECHEMA e.V., Germany
Roland Geres, FutureCamp, Germany
Andreas Kohn, FutureCamp, Germany
Sebastian Lenz, FutureCamp, Germany

Panel
6. Deep decarbonisation of industry

Keywords
CO2 emissions, chemical industry, alternative fuels

The chemical industry is globally one of the most energy intensive industries in existence. Next to process emissions and energy related emissions, the chemical industry transforms its carbon-based feedstock into products that will eventually also release CO2-emissions into the atmosphere. A recent study on the German chemical industry, for the first time explicitly takes these emissions into account.

Three possible pathways for the German chemical industry are developed:
- The reference pathway includes efficiency gains and changes for heat & power generation, both inside and outside the chemical industry.
- The technology pathway introduces new technologies when they meet criteria on TRL, produce GHG emission savings and cost parity with respect to conventional technology. Implementation of new technologies is limited by available electricity and investment.
- The GHG-neutrality pathway implements new technologies as soon as GHG emissions savings are acheived and there are no limits on investment or electricity availability.

New technologies are significantly implemented only beyond 2030 due to the high emission factor of German grid electricity and efficient fossil fuel use within the chemical industry. Sensitivity analyses show a stronger dependence of new technology implementation on electricity and fossil fuel prices than on CO2-prices and economic parameters.

A microeconomic view is chosen to evaluate the overall development of energy demand, GHG-emissions, costs and investments. Furthermore, developments of different carbon feedstock; fossil, biomass, plastics from mechanical and chemical recycling, CO2 as well as electricity and hydrogen are discussed. The required overall electricity demand reaches the level of current German power generation within the GHG neutrality pathway and a significant demand for CO2 as carbon feedstock is derived. Additional investment reaches cumulative 68 bill. € in 2050.

6-024-20: Peer-reviewed paper

100% Renewable energy for Austria's industry: Alternative energy sources and infrastructure requirements

Roman Geyer, Austrian Institute of Technology, Austria
Sophie Knöttner, AIT Austrian Institute of Technology GmbH, Austria
Christian Diendorfer, AIT Austrian Institute of Technology GmbH, Austria
Gerwin Drexler-Schmid, AIT Austrian Institute of Technology GmbH, Austria

Panel
6. Deep decarbonisation of industry

Keywords
energy-intensive industry, renewable energy, energy supply and demand, infrastructure, decarbonisation, energy scenario

The energy system transformation raises questions such as how industry can be supplied by renewable energies. In Austria, the share of renewable energy for industry is currently 45 % in relation to final energy consumption. Comprehensive decarbonisation and the associated change of energy carriers in industry are accompanied by a strong focus on electrical energy and new challenges on the existing energy infrastructure, as well as its expansion and optimisation.

Based on three scenarios (base, efficiency, transition), differently ambitious perspectives are shown how the Austrian industry can be fully supplied by renewable energy and what is needed to achieve this. The scenarios show a range of industrial final energy consumption from 82 TWh (efficiency) to 108 TWh (transition) (cf. 94 TWh in 2017).

With the considered renewable energy potential of 231 TWh in Austria, the final industrial energy consumption can be covered in all scenarios. However, it must be noted that the energy demand for the remaining sectors is not considered in this analysis. All in all, these sectors request in total additional 220 TWh, resulting in a coverage gap of 71 to 97 TWh (depending on the scenario). This gap must be covered by ambitious efficiency gains and/or imports.

There is an increasing shift towards electrical energy, especially in the transition scenario, whereas in the base and efficiency scenario, biogenic fuels also play an important role. Depending on the scenario, there is a temporal mismatch of between 1.9 TWh (efficiency) and 7.1 TWh (transition) for electrical energy. In addition, the calculated maximum industrial power load of 14.6 GW in the transition scenario is more than twice as high as the maximum compared to 2017, which is referred to as status quo, (6.3 GW) and higher than the maximum load of the public power grid in Austria in January 2017 (10.6 GW).

6-035-20: Peer-reviewed paper

Deep decarbonisation of iron and steel industry in the age of global supply chain - Issues and solutions

Xianli Zhu, Technical University of Denmark (DTU), Denmark

Panel
6. Deep decarbonisation of industry

Keywords
decarbonisation, solutions, iron and steel, supply chains, carbon leakage

Deep decarbonisation of the global manufacturing sector is needed to achieve the climate targets under the Paris Agreement. As of September 2019, 77 countries have announced targets to be carbon neutral by 2050. However, in the age of globalisation, countries are concerned that decarbonisation leads to cost increases for industries, companies will move their production bases to countries with less strict energy efficiency and greenhouse gas (GHG) emission regulations. Such relocation of production base can demotivate countries to implement rigorous policies for industry decarbonisation and cause leakage, reducing the global impacts of decarbonisation. This paper uses the iron and steel industry as an example to check: 1) to what extent the above statement is true; and 2) how to address this global chain and cross-border issue in the decarbonisation of industries.

6-040-20: Peer-reviewed paper

Electrify everything! Challenges and opportunities associated with increased electrification of industrial processes

Johan Rootzén, University of Gothenburg, Sweden
Holger Wiertzema, Department of Space, Earth and Environment, Chalmers University of Technology, Sweden
Magnus Brolin, RISE Research Institutes of Sweden, Sweden
Jesse Fahnestock, RISE Research Institutes of Sweden, Sweden

Panel
6. Deep decarbonisation of industry

Keywords
energy-intensive industry, decarbonisation, steel, cement, chemical industry, electrification, energy systems

The aim of this study is to assess the potential for and challenges associated with increased industrial electrification. In a carbon constrained world, as all sectors of the economy seek to lower emissions, competition for energy carriers with a low climate impact (biomass/biofuels, 'green' electricity and hydrogen) will grow. Thus, how integration in this case of electrified industrial processes is managed and how interlinkages and interactions between both the supply side and demand side of the electricity system is handled will be key to the overall outcome with respect to overall systems costs, total capacity needs and security of supply.

Estimates of EU industry electricity demand in 2050 vary considerably. Depending on assumptions with regards to for example overall industry activity levels, choices of energy carriers and process technologies, estimates of industrial electricity demand in 2050 available in the literature vary from 1,000 to 4,430 TWh (from approximately 1000 TWh in 2020).

Based on experiences from two recent research projects and a review of recent literature we 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. We 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 also describe, how new options for process designs, production planning, optimisation and automation may provide benefits beyond CO2 emission reduction and how careful proactive planning provide opportunities for synergies.

6-043-20: Peer-reviewed paper

Assessment of transition pathways for the Nigerian cement sector

Maria Yetano Roche, Wuppertal Institut for Climate Environment and Energy, Germany

Panel
6. Deep decarbonisation of industry

Keywords
cement, long-term scenarios, decarbonisation, NDC, Nigeria

Nigeria is Africa's top clinker and cement producer and could be on course to be one of the top ten producers globally. Over the last two decades, the country's cement industry has grown from being a net importer to a net exporter and is currently booming. Given population and urbanisation rates, rapid ramping up of investment and capacity is foreseen. There are strong risks of locking-in outdated technology into long-term investments. Cement production currently accounts for 8 % of the world's carbon emissions and is considered to be one of the six "hard-to-abate" sectors. But reaching net-zero emissions in the cement sector by mid-century is possible by combining three major decarbonisation routes: (1) Energy efficiency; (2) Demand management and (3) Decarbonisation technologies (including fuel/feedstock switching, process change and carbon capture). Drawing from an assessment of these three options, we build two bottom-up scenarios for production of cement and three pathways for emissions from the sector up to 2040. These transition scenarios illustrate the impact of deploying the various options. The results indicate that emissions could be between 2.5 and 4 times higher in 2040 than in 2015. The production scenario with faster growth assumptions has around 30 % higher emission levels than the production scenario following the urbanisation growth rate. By 2040 the differences between an ambitious decarbonisation pathway and a business-as-usual pathway are around 11 % in each of the production scenarios. This is an exploratory study and its results are preliminary.

6-045-20: Extended abstract

Impact of carbon prices on fuel switching in the iron and steel industry

Chinedu M Nwachukwu, Luleå University of Technology, Sweden
Chuan Wang, Swerim AB, Sweden
Andrea Toffolo, Luleå University of Technology, Sweden
Elisabeth Wetterlund, Luleå University of Technology, Sweden

Panel
6. Deep decarbonisation of industry

Keywords
biomass supply, techno-economic modelling

Fuel switching in the iron and steel industry, using forest biomass, is viewed as a short to medium term solution to reducing the CO2 emissions from the steel sector. Implementing biomass as an alternative fuel or reductant in different process stages during steelmaking is met with certain challenges such as technical restrictions regarding substitution potentials and feasibility limits. Judging by the energy intensity of producing steel, the forest biomass requirement is expectedly large and this in itself results in a competition with other biomass users. More so, as a limited and spatially variable resource, the options for localising biomass conversion technologies as well as supplying both the raw material and final product furthers the complexity of biomass utilisation in iron and steel production.

In this study, a spatially explicit techno-economic modelling approach is employed as a tool for optimising the value chains of upgraded biomass products towards the goal of achieving decreased CO2 emissions from different process stages in the steel industry. The impact of carbon taxes on the fossil energy replacement with the upgraded bio-products is evaluated. The scope of the work is limited to the iron and steel sector in Sweden, where ambitious national climate goals for net-zero greenhouse gas emissions are targeted by the year 2045.

Results from the optimization model show the plant localisations for biomass conversion, and a roadmap for addressing the challenges already identified is presented based on the demonstrated relationship between carbon taxation levels and share of fossil energy substitution. The impact of biomass supply for metallurgical purposes is briefly discussed against the backdrop of the existing forest industries.

6-063-20: Peer-reviewed paper

Electrification of primary steel production based on ΣIDERWIN process: simulation on the European power system in 2050

Morgan Barberousse, EDF, France
Caroline Bono, EDF, France
Anne Debregeas, EDF, France
Matthildi Apostolou, EDF, France

Panel
6. Deep decarbonisation of industry

Keywords
steel, industry, electrification, demand response, electricity grid, decarbonisation, siderwin

The growing steel industry represents 4% of the total European carbon emissions (EU27). The current coal based blast furnace process used to make primary steel has been widely optimized over the past decades to become as efficient as possible. Because of limited opportunities for further enhancements in the existing process, the decarbonisation of the primary steel industry requires a breakthrough innovative technology.

At the same time, Europe aims to be climate neutral by 2050 and have net-zero greenhouse gas emissions. To contribute towards reaching this goal, the European H2020 – ΣIDERWIN project aims to develop a breakthrough process for the primary steel production, based on electrolysis, as a low carbon alternative to the current blast furnace.

As it is a flexible and electricity intensive technology, ΣIDERWIN's industrial development in Europe may play a significant role in the European power system in terms of electricity demand, and demand-side response capacity.
This paper focuses on the ΣIDERWIN technology and its contribution to the future European power system. Based on projections of the steel demand in 2050 and the specific energy consumption of this technology, a prospective scenario is simulated in order to assess ΣIDERWIN's contribution in production and demand balancing, and the benefits to the power system. The methodology for this study and the simulated scenario are presented, and the potential reduction of the CO2 emissions related the flexibility of the ΣIDERWIN technology is assessed. Further steps into the calculation of this potential and the simulation of different scenarios are finally discussed.

6-065-20: Peer-reviewed paper

Meta-analysis of industry sector transformation strategies in German, European and global deep decarbonisation scenarios

Sascha Samadi, Wuppertal Institute for Climate, Environment and Energy, Germany
Claus Barthel, Wuppertal Institute for Climate, Environment and Energy, Germany

Panel
6. Deep decarbonisation of industry

Keywords
meta-analysis, industry, scenarios, mitigation options, hard-to-abate sectors

This paper analyses and compares industry sector transformation strategies as envisioned in recent German, European and global deep decarbonisation scenarios.

The first part of the paper identifies and categorises ten key strategies for deep emission reductions in the industry sector. These ten key strategies are energy efficiency, direct electrification, use of climateneutral hydrogen and/or synthetic fuels, use of biomass, use of CCS, use of CCU, increases in material efficiency, circular economy, material substitution and end-use demand reductions. The second part of the paper presents a meta-analysis of selected scenarios, focusing on the question of which scenario relies to what extent on the respective mitigation strategies.

The key findings of the meta-analysis are discussed, with an emphasis on identifying those strategies that are commonly pursued in all or the vast majority of the scenarios and those strategies that are only pursued in a limited number of the scenarios. Possible reasons for differences in the choice of strategies are investigated.

The paper concludes by deriving key insights from the analysis, including identifying the main uncertainties that are still apparent with regard to the future steps necessary to achieve deep emission reductions in the industry sector and how future research can address these uncertainties.

6-077-20: Extended abstract

Towards a policy framework for a hydrogen future of German industry

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Panel
6. Deep decarbonisation of industry

Keywords
hydrogen, regulation, energy-intensive industry, decarbonisation, policy packages

Hydrogen is a key topic in the discussion on how to shape the political framework for a competitive and decarbonised industry. Scenarios assume that hydrogen can play an increasingly important role, especially in the industry sector, as it has a wide range of applications, can be produced based on renewable energy (green H2) and is easily storable and transportable.

However, for a large-scale market for green hydrogen to emerge, a number of challenges have to be addressed. A key barrier to market penetration are the high production costs, with green hydrogen being far from competitive with fossil fuel based hydrogen. Also, the provision of green hydrogen in Germany requires additional capacities for renewable electricity generation and import strategies. New infrastructures and transport options are needed.

To address these challenges, the industrial policy framework is crucial. Policy-makers are tasked with shaping framework conditions that respond to diverse interests, create financial incentives, avoid unwanted side effects or lock-ins, and ensure that forthcoming hydrogen structures support energy transition overall.

This paper aims 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 will discuss policy instruments for facilitating low-carbon hydrogen development. This will include a reform of taxes and charges, funding instruments, a regulatory push through green gas quotas, new calculation rules for renewable energy share under REDII, and guarantees of origin. It will analyse the effects and conditions of different instruments and look at potential interactions between them. Both potentials and challenges to implementation will be presented. Based on this assessment, the paper will sketch a policy package that could set the course towards a hydrogen future.

6-082-20: Peer-reviewed paper

A European industrial development policy for prosperity and zero emissions

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Panel
6. Deep decarbonisation of industry

Keywords
decarbonisation, governance, industrial policy, energy intensive industry

The objective of this paper is to outline and discuss the key elements of an EU industrial development policy consistent with the Paris Agreement. We also assess the current EU Industrial Strategy proposal against these elements. The “well below 2 °C” target sets a clear limit for future global greenhouse gas emissions and thus strict boundaries for the development of future material demand, industrial processes and the sourcing of feedstock; industry must evolve to zero emissions or pay for expensive negative emissions elsewhere. An industrial policy for transformation to net-zero emissions must include attention to directed technological and economic structural change, the demand for emissions intensive products and services, energy and material efficiency, circular economy, electrification and other net-zero fuel switching, and carbon capture and use or storage (CCUS). It may also entail geographical relocation of key basic materials industries to regions endowed with renewable energy.

In this paper we review recent trends in green industrial policy. We find that it has generally focused on promoting new green technologies (e.g., PVs, batteries, fuel cells and biorefineries) rather than on decarbonizing the emissions intensive basic materials industries, or strategies for

handling the phase-out or repurposing of sunset industries (e.g., replacing fossil fuel feedstocks for chemicals). Based on knowledge about industry and potential mitigation options, and insights from economics, governance and innovation studies, we propose a framework for the purpose of developing and evaluating industrial policy for net-zero emissions.

This framework recognizes the need for: directionality; innovation; creating lead markets for green materials and reshaping existing markets; building capacity for governance and change; coherence with the international climate policy regime; and finally the need for a just transition. We find the announced EU Industrial Strategy to be strong on most elements, but weak on transition governance approaches, the need for capacity building, and creating lead markets.

6-086-20: Extended abstract

Towards a climate-smart petrochemical process industry on the Swedish west coast

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Panel
6. Deep decarbonisation of industry

Keywords
CO2 reduction, sustainable production, plastics recycling, bio fuel, bio chemicals, district heating

The absolute majority of Sweden's refinery capacity and the largest chemical industry cluster is found in Western Sweden, which is considered to be the heart of the Swedish process industry. The here presented 10 year initiative, named “Climate Smart Process Industry”, aims to lead a transition from an industrial region based on fossil raw materials to a region where industry is world leading in the production of chemicals, materials and fuels based on renewable and recycled raw materials. By converting to new “climate neutral” raw materials and processes, the industry will contribute to the region's "Green Chemistry"-smart specialization strategy as well as the goal of reducing CO2 emissions by 80% by 2030.

The initiative creates an opportunity to gather, coordinate, communicate and finance activities in four thematic areas:
– Chemical and mechanical plastics recycling
– Renewable chemicals, materials and fuels
– Climate smart process technology
– Climate smart value chains

Identified challenges within the aforementioned thematic areas will be addressed by initiating targeted projects and activities. Additionally, new challenges will be identified and addressed by further developing and strengthening the innovation activities in the industry cluster. In this way, the initiative aims to develop new value chains between current and new industry actors with the aim of increasing circularity, resource efficiency, and reducing fossil dependence. This requires not only novel technology but new competences, business models and policy instruments.

The operational management of the initiative is performed by Johanneberg Science Park in collaboration with RISE Research Institutes of Sweden, with support from Sweden’s innovation agency, Vinnova, from Region Västra Götaland as well as from members of the industry cluster. The presentation will introduce this 10 year initiative, and provide details on planned activities and expected achievements within the coming years.

6-094-20: Peer-reviewed paper

Dynamics of cross-industry low-carbon innovation in energy-intensive industries

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Panel
6. Deep decarbonisation of industry

Keywords
innovation, energy-intensive industry, cross-industry collaboration, low carbon industry, low carbon technologies, decarbonisation, collaboration

Technological innovations in energy-intensive industries (EIIs) have traditionally emerged within the boundaries of a specific sector. Now that these industries are facing the challenges of deep decarbonisation and a significant reduction in greenhouse gas (GHG) emissions is expected to be achieved across sectors, cross-industry collaboration is becoming increasingly relevant for low-carbon innovation.

Accessing knowledge and other resources from other industrial sectors as well as co-developing innovative concepts around industrial symbiosis can be mutually beneficial in the search for fossil-free feedstocks and emissions reductions. In order to harness the potential of this type of innovation, it is important to understand not only the technical innovations themselves, but in particular the non-technical influencing factors that can drive the successful implementation of cross-industry collaborative innovation projects.

The scientific state of the art does not provide much insight into this particular area of research. Therefore, this paper builds on three separate strands of innovation theory (cross-industry innovation, low-carbon innovation and innovation in EIIs) and takes an explorative case-study approach to identify key influencing factors for cross-industry collaboration for low-carbon innovation in EIIs.

For this purpose, a broad empirical database built within the European joint research project REINVENT is analysed. The results from this project provide deep insights into the dynamics of low-carbon innovation projects of selected EIIs. Furthermore, the paper draws on insights from the research project SCI4Climate.NRW. This project serves as the scientific competence centre for IN4Climate.NRW, a unique initiative formed by politicians, industry and science to promote, among other activities, cross-industry collaboration for the implementation of a climate-neutral

industry in the German federal state of North Rhine-Westphalia (NRW). Based on the results of the case study analysis, five key influencing factors are identified that drive the implementation of cross-industry collaboration for low-carbon innovation in EIIs: Cross-industry innovation projects benefit from institutionalised cross-industry exchange and professional project management and coordination. Identifying opportunities for regional integration as well as the mitigation of financial risk can also foster collaboration. Lastly, clear political framework conditions across industrial sectors are a key driver.

6-095-20: Extended abstract

The ZEROC project; towards zero CO2-emissions in the Norwegian and Swedish industry – process solutions including associated infrastructure

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Panel
6. Deep decarbonisation of industry

Keywords
Carbon neutral, industry

To be aligned with the Norwegian and the Swedish climate targets most industry facilities will have to be carbon neutral by 2045. This paper presents the ZEROC project which analyses how the industry in Sweden and Southern Norway can achieve deep reductions in CO2-emissions by 2045. The energy intensive industry has three main options for large reduction of CO2-emissions, each of which may have its own inherent risks and challenges, namely; fuel/feed switch to biomass, electrification including renewable production of hydrogen, and CCUS/BECCS. The ZEROC project analyses relevant process solutions including associated support infrastructure (transport and storage infrastructure for CO2, biomass, hydrogen and electricity) to calculate Marginal Abatement Cost Curves (MACC) and – applying the MACC – to develop a Roadmap including timelines for a carbon neutral industry by 2045

The ZEROC project includes all industries in the region that emit at least 100 ktonnes fossil and/or biogenic CO2 annually which comprises 96 sites in Sweden and 15 sites in Southern Norway. Combined emissions from the Swedish facilities are around 17 Mt fossil-fuel based CO2 and 33 Mt biogenic CO2, while corresponding figures for the Norwegian facilities are around 3.8 and 0.7 Mt, respectively. Eleven out of the fourteen plants that emit at least 1 million tonne CO2 in Sweden are pulp and paper plants with mainly biogenic emissions. After an initial assessment it can be concluded that there are significant differences with respect to how far the industries included in the study have come in their own strategy work on how to reduce CO2 emissions. Examples of industries with relatively elaborated plans includes four industries preparing for CCS (2 in Norway and 2 in Sweden) and one consortium investigating hydrogen-based iron and steel production.

A first assessment of the possibilities and challenges for the industries covered by the ZEROC project is presented.

6-098-20: Peer-reviewed paper

Needs of electricity, hydrogen and carbon infrastructures for greenhouse gas neutral heavy industry clusters in the EU 2050

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Panel
6. Deep decarbonisation of industry

Keywords
hydrogen, carbon capture and storage, infrastructure, energy-intensive industry, decarbonisation, renewable energy, electricity, CO2 emissions, scenarios

The reduction of greenhouse gas (GHG) emissions by energyintensive industries to a net zero level is a very ambitious and complex but still feasible challenge, as recent studies show for the EU level. “Industrial Transformation 2050” by Material Economics (2019) is of particular relevance, as it shows how GHG-neutrality can be achieved in Europe for the sectors chemicals (plastics and ammonia), steel and cement, based on three main decarbonisation strategies. The study determines the resulting total demands for renewable electricity, hydrogen and for the capture and storage of CO2 (CCS). However, it analyses neither the regional demand patterns that are essential for the required infrastructure nor the needed infrastructure itself.

Against this background the present paper determines the regional distribution of the resulting additional demands for electricity, hydrogen and CCS in Europe in the case that the two most energy and CCS intensive decarbonisation strategies of the study above will be realised for the existing industry structure. It explores the future infrastructure needs and identifies and qualitatively assesses different infrastructure solutions for the largest industrial cluster in Europe, i.e. the triangle between Antwerp, Rotterdam and Rhine-Ruhr. In addition, the two industrial regions of Southern France and Poland are also roughly examined.

The paper shows that the increase in demand resulting from a green transformation of industry will require substantial adaptation and expansion of existing infrastructures. These have not yet been the subject of infrastructure planning. In particular, the strong regional concentration of

additional industrial demand in clusters (hot spots) must be taken into account. Due to their distance from the high-yield but remote renewable power generation potentials (sweet spots), these clusters further increase the infrastructural challenges. This is also true for the more dispersed cement production sites in relation to the remote CO2 storage facilities. The existing infrastructure plans should therefore be immediately expanded to include decarbonisation strategies of the industrial sector.

6-110-20: Peer-reviewed paper

Hydrogen technologies for a CO2-neutral chemical industry – a plant-specific bottomup assessment of pathways to decarbonise the German chemical industry

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Panel
6. Deep decarbonisation of industry

Keywords
market transformation, chemical industry, hydrogen technologies, CO2-neutrality

With approximately 21 % of total emissions in Germany, the industrial sector is one of the major emitting sectors, accounting for almost 30 % of final energy demand and predominantly using fossil fuels.

Hydrogen based on renewable electricity can have a key role in the transition towards a CO2-neutral industrial production, since its use as an energy carrier as well as a feedstock in various industrial process routes is promising. One of the most important industries with great potential for hydrogen use is the chemical industry, in particular the production of basic chemicals like ammonia and methanol. While many scenarios towards 2050 see an important role for hydrogen in the 2050 supply mix for the industry sector, they are less specific on the path towards 2050 and the role of hydrogen e.g. in 2030.

Here, we assess the role of hydrogen in the mid-term and further detail the possible paths towards 2050 by taking into account the specific replacement and modernisation cycles of the production plant stock and assess today's maturity of hydrogen- based technologies. The analysis includes a thorough literature review as well as the development of a plant-specific database.
By considering the age structure of basic chemical process installations in Germany, 33 % can be replaced by 2030 and 89 % by 2050. This results in 11 % that have to be replaced before the end of their lifetime for getting CO2-neutral until 2050. A replacement of 100 % would lead to cumulated capital investments of about €26 billion and yearly operating costs of €15 billion. The re-assessment and benchmarking of a scenario taken from the literature for the selected products by integrating results from the analysis of plant modernisation cycles shows, that the plant replacements and market diffusion of alternative production routes could be integrated faster than assumed in the literature.

6-120-20: Extended abstract

Net-zero industries

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Panel
6. Deep decarbonisation of industry

Keywords
low carbon industry, business models, alternative fuels, carbon capture and storage, hydrogen, biomass

The UK government recently enshrined in legislation a UK net zero emissions target by 2050, which requires ambitious reduction of emissions across all sectors of the UK economy, including industry and power, and will require rapid deployment of key decarbonisation technologies. Industrial clusters are seen as a key area for decarbonisation due to their contribution to the UK economy and their pivotal role in initiating hydrogen and CCUS infrastructure. Without deep decarbonisation options and with increasing carbon tariffs, Industry is at risk of decline, putting millions of jobs in danger. This presentation will provide an overview of the key technologies needed to achieve net-zero industrial clusters including hydrogen, CCUS, negative emissions, and fuel switching; explain the key role CCS is expected to play; and give an update on the current progress in the UK industrial cluster projects. The presentation will also discuss how the industrial sites can be converted into hydrogen as well as key business models that may be introduced to kick-start investment in deep decarbonisation technologies.

6-134-20: Peer-reviewed paper

Feasibility study of low-carbon ammonia and steel production in Europe

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Panel
6. Deep decarbonisation of industry

Keywords
decarbonisation, hydrogen, electrolysis, ammonia, steel

As stipulated in the Paris Agreement, greenhouse gas emissions have to be reduced in order to maintain the global warming well below 2°C. Moreover, the European Union committed to become carbon neutral by 2050. This will require shifting industrial production currently based on fossil energies towards the use of renewable energies. The present article considers two conceptual chemical processes that may operate in Europe with really low carbon emissions through the use of green hydrogen. The studied processes are projections of the production of ammonia and steel in the 2030s. Hydrogen is produced by water electrolysis with Proton Exchange Membrane electrolysers. It is assumed that the electricity required by the processes is entirely supplied from renewable energies. The objective of the present study is to show that it will be possible to design low-carbon emission processes in a close future. Based on current industrial sectors of both ammonia and steel productions, detailed modelling of the two decarbonised processes in Aspen Plus software are proposed. In order to prove the feasibility of these processes, an economic analysis is also presented.

6-141-20: Peer-reviewed paper

Deep decarbonisation of the German industry via electricity or gas? A scenario-based comparison of pathways

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Panel
6. Deep decarbonisation of industry

Keywords
deep decarbonisation, bottom-up, electrification, power to gas, long-term scenarios

The industry sector accounts for about 20 % of GHG emissions in Germany. Achieving long-term GHG neutrality also requires industrial emissions to approach zero in the long-term. The German government set an intermediate industry sector target in the range of 49 to 51 % emission reduction by 2030 compared to 1990. While the targets are set, it is yet mostly unclear which technology path industry will and can take towards decarbonisation. Various measures including energy efficiency, biomass, electrification, green hydrogen, power to gas (PtG), circularity, material efficiency, process switch and carbon capture and storage are on the table, but their individual contributions are highly debated.

We present results of a comprehensive bottom-up assessment comparing two alternative scenario pathways to 2050. The first is based on electrification as the main decarbonisation option, while the second builds on the broad availability of green gas. We use the bottom model FORECAST, which contains a high level of technology and process detail. E.g. more than 60 energy-intensive processes/products are included as well as a detailed stock model of steam generation technologies.

Results show that both scenarios reach a GHG reduction of about 93 % in 2050 without using carbon-capture and storage. Remaining emissions are mostly process-related. This requires a fundamental change in industrial energy supply and use, but also in the industrial structure including entire value chains. 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 337 TWh of green gas emerges by 2050, mainly replacing natural gas use, but also coal in the steel industry and feedstocks in chemical products. Both scenarios assume a substantial improvement in energy efficiency and material efficiency along the value chain for CO2-intensive products as well as a strong shift to a circular economy. E.g. the secondary steel route gains market share from about 30 % in 2015 to 60 % in 2050. In the basic materials industries a process switch to

low-carbon production routes takes place assuming the market introduction and fast diffusion of low-carbon technologies, which are today only at pilot or demonstration scale. In addition, the electrification scenario also requires a carbon source for the hydrogen-based olefine production. Here, we assess the option to use remaining process-related CO_2 emissions from lime and cement plants.

Such fundamental change in the industrial structure can only happen when the regulatory frame is adapted and addresses the major challenges ahead. Among these are for example the higher running 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.

6-149-20: Peer-reviewed paper

How does the German manufacturing industry react to the calls to decarbonise?

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Panel
6. Deep decarbonisation of industry

Keywords
decarbonisation, carbon footprint, net-zero-carbon, resources, energy consumption, implementation

Urgent action is needed to keep the chance of limiting global warming to 1.5°C or even 2.0°C. Current outlooks by IPCC, and many other organisations forecast that this will be impossible at current pace of emission 'reductions' – Germany has already hit 1.5° warming this year. Across 2019, particularly during the UN New York Climate summit, numerous organisations declared their ambition to become net carbon neutral. Amongst these were investors and companies, including quite a number of German ones.

We apply a mixed methods approach, utilising data gathered from approx. 900 companies after Climate Week in context of the Energy Efficiency Index of German Industry (EEI), along with media research focusing on decarbonisation plans announced and initiatives pledging climate action.

With this, we analyse how German companies in the manufacturing sectors react to rising societal pressure and emerging policies, particularly what measures they have taken or plan to implement to reduce the footprint of their company, their products and their supply chain. In this, we particularly analyse whether and in what way energy- and resource consumption, as well as carbon emissions are considered in the development and lifecycle of goods manufactured. This is of huge relevance as these goods determine the future footprint of buildings, vehicles and industry.

Regarding the supply chain, current articles indicate that small and medium-sized enterprises

(SME) are particularly challenged by increasing demands from their large corporate clients and an alleged lack of preparedness to be able to take and afford prompt decarbonisation action themselves (Buchenau et. al. 2019). Notably the automotive industry recently announced new models that will be 100% carbon neutral all the way through (ibid). We thus analyse if and how factors such as company size, energy intensity and sector affiliation influence a company's plan to fully decarbonize. Ownership structure and corporate culture, it appears, significantly impact on the degree of decarbonisation action underway.