Deep Decarbonisation of Materials Processing Industries

Implications for Policy, Industry and Research

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Table of Contents

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List of Figures

List of Tables

1 Introduction

The conference on “Deep Decarbonisation of Materials Processing Industries – Implications for Policy, Industry and Research” on 10th November 2017, which took place alongside COP23 in Bonn, was presented by the Ministry of Economic Affairs, Innovation, Digitalization and Energy of the State of North Rhine-Westphalia (MWIDE), the Wuppertal Institute for Climate, Environment and Energy and the Energy Agency of the state of North Rhine-Westphalia. Around 95 participants from 15 countries attended this successful event.

The conference provided cutting-edge information on relevant technologies, policies and networks. The speakers were policymakers from pioneering states and regions, representatives from leading companies, heads of industry associations, scientists and NGOs working in the field. All the speakers highlighted the fact that the decarbonisation of processing industries is a crucial topic currently gaining increasing attention.

Deep decarbonisation of materials processing industries is an enormous challenge but it can be tackled successfully by creating new networks and coalitions that cross the borders between traditional domains and include a wider range of actors, resulting in stronger international collaboration.

A new vision of a decarbonised industry and an integrated industrial policy that respects the necessity of zero emissions is needed.

The examples presented at the conference showed that there are forerunners in industry, science and policy who are willing to tackle the issue by moving beyond traditional borders – between industry, science, society and policy – to create the necessary networks, promote collaboration and find solutions.

Being home to more than 10 % of Europe’s energy-intensive industries, North Rhine-Westphalia (NRW) faces demanding challenges for the implementation of the Paris Agreement, whose ambitious goal is to limit global warming well below 2° Celsius. By focusing on the “Deep Decarbonisation of Materials Processing Industries" and interacting closely with other European and international regions, as well as with industries and societal actors, NRW aims to become a pioneer of solutions for the climate-friendly production of basic materials.

This brochure summarises the presentations of the four panels of the conference. Furthermore, five panelists from industry (Dr. Eva Blixt and Dr. Brigitta Huckestein), science (Dr. Dolf Gielen and Dr. Henning Wilts/ Dr. Holger Berg) and policy (Eva Svedling) outlined their presentations and ideas as a contribution for this document.

2 Panel Session 1: Setting the stage on near-zero carbon emission strategies for materials processing industries

With Michael Theben, Director General 'Climate Protection' at the Ministry for Economic Affairs, Innovation, Digitalization and Energy of the State of North Rhine-Westphalia; Prof. Dr. Manfred Fischedick, Vice-President, Wuppertal Institute; Dr. Dolf Gielen, Director IRENA Innovation and Technology Centre; Dr. Martin Porter, Executive Director Industry & Innovation and EU Affairs, ECF; Dr. Christoph Sievering, Head of Energy Policy, Covestro; Nico van Dooren, Director Energy and Industry, Port of Rotterdam. Chaired by Prof. Dr. Lars J. Nilsson, Lund University

The conference started with stakeholders from policy, industry and society in Panel Session 1 setting the stage on near-zero carbon emission strategies for materials processing industries. They made it clear that the approach taken by processing industries is crucial for deep GHG emissions reductions and that the necessary technologies either already exist or can be developed by industry.

However, it will only be possible to develop the new technological solutions required through a long-term process of innovation for which political and societal support is essential: an integrated global approach and an appropriate policy framework are needed. The panellists agreed on the challenges as well as options for innovating and developing the necessary technologies for net zero emissions industries.

Given the high level of demand for materials – demand that is still increasing – it also seemed obvious that more emphasis needs to be put on the value chains linked to basic materials, which could also offer the prospect of additional business opportunities. There was some discussion, however, about whether and how product and resource-efficiency can be aligned with the economically-driven goal of companies to reduce costs across their value chains and to sell more of their products.

The importance of material processing industries in the context of GHG emissions reductions was highlighted in the first panel session. As well as deep decarbonisation being a huge challenge for industries, it also presents new opportunities for both companies and regions.

Achieving decarbonisation is a challenge given the high costs and economic risks of the technologies required, as well as the international competition in many sectors. Constructive discussions involving all stakeholders are needed to identify appropriate transformation pathways and holistic approaches offering different options or pathways should be considered with open minds. There is a need for innovations and integrated industrial and climate policies to instigate and create momentum for decarbonisation but *how* this will be achieved requires further experimentation and learning.

Michael Theben emphasised the fact that greenhouse gas (GHG) emissions reductions, as well as the competitive nature of the materials processing industries, are important issues for the state of North Rhine-Westphalia (NRW) which is home to over 50 % of Germany's basic material processing industries. The state, therefore, has both great potential and great responsibility with regard to climate goals.

Prof. Manfred Fischedick made the point that GHG mitigation options in the industry sector exist along the whole value chain and go beyond pure technological options. As Mr. Theben had explained for NRW, Prof. Manfred Fischedick described how, due to efforts already made in the industry sector, the remaining energy efficiency potential is somewhat limited. He concluded that in order to achieve global GHG mitigation targets, ***serious innovation efforts*** – as well as international cooperation and an appropriate policy framework – will be necessary.

Industrial greenhouse gas emissions mitigation: the role of renewable energy and other technologies

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Abstract

The importance of industry sector greenhouse gas emissions is often underestimated. Three quarters of industry sector emissions come from materials commodity production and one quarter from other industry. There are currently few or no economically viable emissions reduction solutions at scale available for sectors such as iron and steel making, cement production, chemicals and petrochemicals production. These sectors require new technological solutions to be quickly developed and commercialised to achieve the Paris Agreement goals. Renewable energy, carbon capture and storage (CCS) and energy efficiency will play important roles moving forward.

Introduction

The Paris Agreement calls for a limit to global temperature increase to well below 2 degrees Celsius (2°C) above pre-industrial levels, with a goal of 1.5°C. This limits global anthropogenic CO_2 emissions to 880 Gt for the period 2015-2100, allocating 90 Gt for industry process emissions and 790 Gt for energy use CO_2 emissions (IRENA, 2017b).

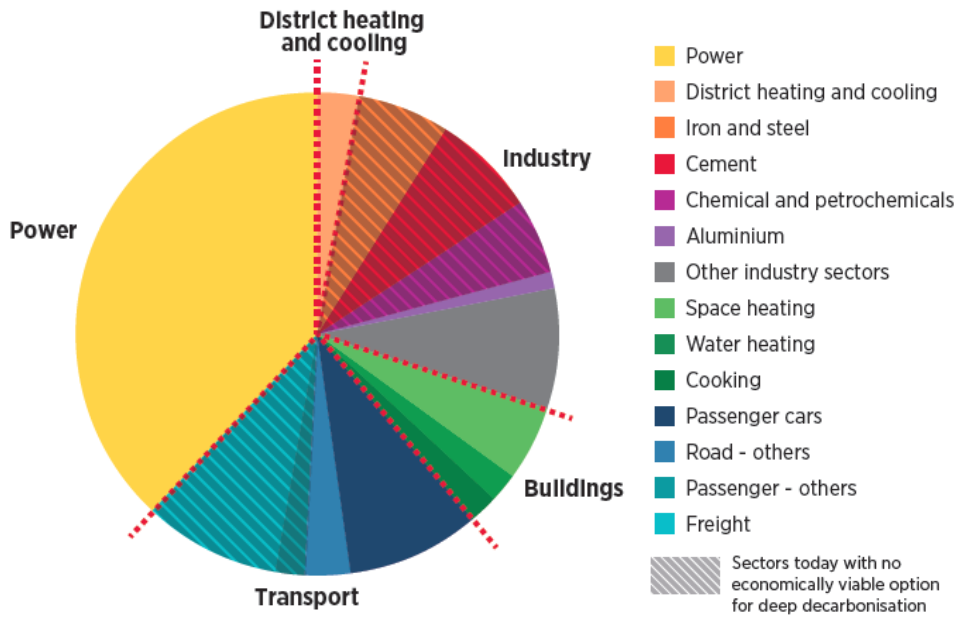
Over the past few decades, significant progress has been made in reducing industry sector emissions of substances that deplete the ozone layer, as outlined in the Montreal Protocol, as well as nitrous oxide (N_2O), sulphur hexafluoride (SF_6) and others. This demonstrates that industrial emissions reduction progress is possible under the right regulatory conditions.

The dominant remaining industrial emission is CO_2, which can be divided into energy-related emissions from fossil fuel combustion, electricity and heat, and process emissions (from limestone calcination) during the cement making process. Emissions also arise throughout the life cycle of industrial products, such as fugitive emissions during use and post-consumer plastic waste incineration (Patel et al., 2005). Industry accounts for one-third of global energy use and almost 40 % of worldwide CO_2 emissions (IEA, 2009). Direct emissions account for around three-quarters of these emissions; the remaining quarter comes from indirect emissions in power generation. This excludes emissions related to industrial product use but includes around 2 gigatons per year (Gt/yr) of industrial process emissions (Janssens-Maenhout et al., 2017).

A range of technological options, including renewable energy, CCS and energy efficiency will play key roles in achieving the Paris Agreement goals. Although renewable energy in industry has not yet received the same attention as in power generation and buildings, it is technically possible to substitute half of industrial fossil energy and fossil fuel feedstock use with renewables. Biomass accounts for 75 % of this potential, while solar heating is a second key area. Certain renewable energy applications are already cost-effective, while others are still far from being com-

mercial realities. There are still significant economic, technical and logistical barriers. Carbon leakage is often quoted as being a major deterrent, although its importance may be overstated (Gielen, 2000; Gielen and Yagita, 2002).

Figure 1: Sector Emissions – 2015



Source: IRENA (2017)

Key message: The industry sector was responsible for one third of CO_2 emissions in 2015.

Today, the pulp and paper industry and the food processing industry are the main users of renewable energy, accounting for approximately 45 % and 25 % of their energy demand respectively (Taibi et al., 2012). In total, renewable sources account for only 8 EJ, which is about 10 % of the sector's total global energy demand (excluding feedstock and electricity use) (IRENA, 2014). To date, renewable energy use in industry has received little attention despite the fact that renewable energy technologies can provide practical and cost-effective alternatives for process heat generation and as a carbon source for the production of chemicals and plastics.

Emissions reduction potential by industry

Within the sector, chemical, petrochemical and steel are among the largest energy consumers. However, less energy-intensive sectors, such as food and textiles (covered under "other industry") can also play important roles in reducing industrial CO_2 emissions. Cement has a large share due to process emissions.

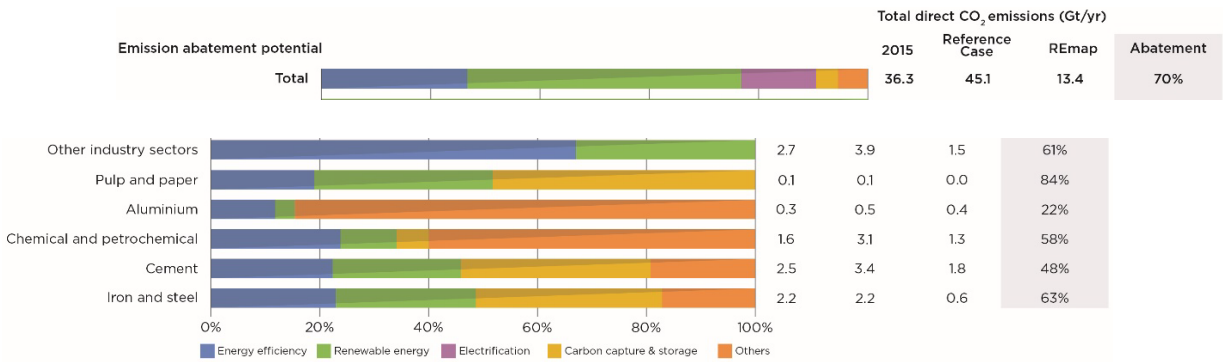
Cement production is the largest individual CO_2-emitting industry. Making cement requires the decomposition of limestone in a process called calcination, which produces large amounts of CO_2. As a result, the industry is responsible for 8 % of all

global CO_2 emissions. This is one of the few industries where CCS could play a role (Kajaste and Hurme, 2017). Under IRENA's Renewable Energy Roadmaps (REmap), 35 % of all emissions reductions in the entire industry sector come from using CCS in the cement industry. Additional emissions reductions – 20 % of the total from the sector – could come from new cement types and substitutes for clinker. Biomass and waste fuels can be injected into cement kilns and replace most fossil fuel use (IRENA, 2017b).

The iron and steel industry is currently a large coal user and emits about half as much CO_2 as the cement industry. Since the 18th century, coal and coke have been used as chemical reducing agents in blast furnaces to make iron. That process could be replaced by hydrogen-based direct reduced iron or even electrolysis, similar to the technologies being employed in aluminium making. Under REmap, emissions from the industry would decline by 90 % to 0.6 Gt in 2050 compared to the Reference Case. One-third of this reduction would be achieved by CCS, 25 % would come from renewables (largely biomass) and 40 % from energy and material efficiency measures (IRENA, 2017b).

Chemical and petrochemical industry emissions are similar in size to those from the iron and steel industry. The industry's total direct CO_2 emissions from production could be cut by approximately 1.8 Gt, i.e. from 3 Gt to 1.3 Gt, by 2050. About 1.1 Gt of these reductions could come from material efficiency improvements and the remaining, 0.7 Gt, from energy efficiency measures, renewable energy and CCS. Great potential exists for replacing fossil fuel feedstock with biomass feedstock; production of bioethylene, for example, is already a commercial technology (CEFIC, 2017). The economics, however, pose a challenge at today's oil prices and an accounting scheme for storing biomass carbon in materials is needed (Saygin et al., 2014).

Figure 2: CO_2 emissions reductions in REmap compared to Reference Case by technology, 2050



Source: IRENA (2017b)

Key message: Decarbonisation of the industry sector requires a mix of technologies.

Emissions reduction strategies

Decarbonisation of the industry sector requires a combination of various technologies. Under REmap, in the period 2015-2050, 28 % of industrial emissions reductions will come from energy efficiency, 27 % from renewable energy, 19 % from CCS and 26 % from all others (including recycling/reuse, new materials and products). This will reduce industrial CO_2 emissions from a baseline of 13.5 Gt/yr to 5.56 Gt/yr by 2050 (IRENA, 2017b).

The industry sector can benefit from the cost savings that come from improvements in energy efficiency. As a result, energy efficiency is important – but has limited potential under a business-as-usual scenario (IEA, 2007; IEA, 2009; Saygin et al., 2011; Saygin et al., 2014). In the industry sector as a whole, energy efficiency would improve by about 1 % per year under REmap over the 2015-2050 period (compared to 0.3-0.5 %/yr in the Reference Case). Exceeding this increase in efficiency is difficult as processes near their thermodynamic minimum.

CCS is a key technology under REmap for the industry sector; however, its prospect is uncertain and realising its potential will depend on location, geology, water resources and other factors. The difficulties of deploying CCS thus pose a major challenge to the successful implementation of the Paris Agreement. In fact, using CCS in industry is even more challenging than using it in the power sector, because industry plants tend to be process specific, smaller and more scattered than power plants (Leeson et al., 2017). The CCS process itself may also have to be redesigned for the industry sector, as it reduces plant efficiency and results in residual emissions because the capture process also requires heat and electricity. Costs for most CCS technologies throughout the industry sector were found to vary widely, ranging from $20 to $120 per tonne of CO_2 avoided. These challenges will need to be quickly overcome if the technology is to play a role in the sector (Leeson et al., 2017).

IRENA's REmap analysis shows that the share of renewable energy can grow to between 38 % and 46 % in industry by 2050, depending on the system boundaries that are applied (Table 1). Biomass, solar thermal and electrification using renewable electricity all have important roles to play.

Table 1: Industry sector renewable energy shares, 2015-2050

	2015	Reference Case		REmap	
		2030	2050	2030	2050
Excl. NEU, electricity & DHC	9 %	12 %	15 %	28 %	44%
Incl. electricity & DHC	9 %	13 %	16 %	23 %	38 %
Incl. NEU, electricity and DHC	10 %	14 %	17 %	33 %	46 %

Notes: NEU = non-energy use; DHC = district heating and cooling

Source: IRENA (2017b)

Biomass, due to its versatility, has the highest potential of the different renewable energy options in the industry sector. Biomass can be used as a feedstock for replacing fossil fuels, it can be used to produce low, medium and high temperature

heat, and it can be used as a fuel for localised electricity production. Current direct renewable energy use in industry (8EJ) is predominantly in the form of biomass (IRENA, 2014). This is mainly due to by-products and waste use, such as bagasse and rice husk in sugar production and other traditional industries; biogas from sewage and farms for food processing; and black liquor in the pulp and paper sector. The versatility of biomass also results in competitive uses within and between the industry sector and other sectors of the economy. Realising cost-effective and sustainable biomass potential depends on a number of factors, including local availability and access of plants to the biomass sources.

With low and medium temperature heat accounting for 45 % of total industrial process heat use, solar thermal systems possess large potential. Under REmap, the use of solar water heaters would increase for industry and buildings from negligible to about 35 EJ in 2050. High initial capital costs, low operational hours and land requirements at site form the main barriers, but cost reductions can be achieved by increasing solar thermal deployment. Only with higher rates of deployment, and subsequent learning, will the technology become cost-competitive. Industry associations and other organisations collecting and disseminating information about deployment opportunities will be necessary to enable this (IRENA, 2014).

Electricity demand is expected to continue to grow in the manufacturing industry, partly due to the electrification of production processes and production growth in electricity-intensive industries, such as the non-ferrous metals sector. Relocation of such industries close to renewable energy power plants is one option that would increase the renewable energy share in the electricity sector, but even more important is the decarbonisation of the power sector in general. Several large manufacturing companies are integrating renewable energy power generation into their existing manufacturing plants, either through solar PV panels on the production facilities, wind turbines on site, or other sources of renewable energy. Process technology R&D should also focus on electricity-based alternatives, ensuring that the electricity sector is decarbonised. An interesting trend is the direct corporate sourcing of renewable power.

Conclusions

By 2050, total energy-related CO_2 emissions will need to decrease to below 10 Gt/yr to meet the Paris Agreement goals. CO_2 emissions from the power and buildings sectors will be almost eliminated while industry and transport would remain the main sources of emissions in 2050. CO_2 mitigation potential for the industry sector would total 9.5 Gt CO_2/yr in 2050 (energy + process) and the average CO_2 mitigation cost would total 81.7 USD/t CO_2 in 2050 (IRENA, 2017).

Achieving higher penetration levels for renewable energy in industry is key to realising substantial reductions in the sector's fossil fuel demand and related CO_2 emissions. The potential to reach a share of between 38 % and 46 % of renewable energy in the industry sector can only be achieved if specific policies are developed to create a business environment conducive to private sector investment. Greater technological development is required to increase the number of renewable energy options for the industry sector. Promoting the development of cheaper and more effective

solar thermal, geothermal and heat pump technologies, so they are cost-effective in comparison with both fossil fuels and biomass, is an important area that governments can support through R&D grants, the creation of knowledge networks and information provision (IRENA, 2014; IRENA, 2017b).

Increased investment in innovation needs to start now to allow sufficient time for developing the fundamental new solutions required for multiple sectors and processes, many of which have long investment cycles. Solutions will also be required to overcome institutional barriers in these sectors, such as addressing carbon leakage in industry. Moving forward, a global sectoral approach is needed.

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The importance and benefits of a more ambitious approach in the circular economy were highlighted by **Dr. Martin Porter**, as processing industries are not only energy-intensive but are also resource-intensive. From a non-governmental perspective, he argued that strategies for a circular economy are necessary to achieve the urgent climate-related objectives in materials processing industries and, at the same time, to contribute to other global sustainable development goals.

Dr. Christoph Sievering pointed out that being an energy-intensive industry within a sector dominated by fossil-fuel electricity generation results in a large carbon footprint. Despite this, Covestro has been able to reduce its carbon footprint by 40 % over the last ten years. Dr. Sievering claimed, however, that this cannot be extrapolated. He outlined three crucial dimensions for making further significant progress on emissions reductions. First, technical solutions (and he is quite optimistic that these solutions will be developed); second, societal aspects such as the social acceptance of industries; and third, market aspects – if a company makes a commitment to producing zero-carbon products, consumers need to buy those products instead of choosing cheaper but more carbon-intensive alternatives.

Nico van Dooren explained the importance of the issue for the Port of Rotterdam as 1/3 of Europe's crude oil imports go through Rotterdam and the port produces 20 % of Netherland's CO_2 emissions. Nevertheless, he is optimistic that a net carbon-neutral port is possible, provided that a holistic approach with different pathways is pursued. He underlined the fact that the port is ambitious and is already working to achieve this goal. As an example, old coal-fired power plants were decommissioned in the summer of 2017 and in 2030 all coal-fired power plants in the port will be closed down to meet Dutch regulations.

3 Panel Session 2: On the road to near-zero carbon processing industries: technologies, infrastructure and pilots

With Eva Blixt, Research Manager and Senior Advisor Environmental Issues, Swedish Steel Industry Organisation; Prof. Dr. Görge Deerberg, Deputy Director of Fraunhofer UMSICHT; Tomas Wyns, Doctoral Researcher, Institute for European Studies; Dr. Henning Wilts, Head of Research Unit Circular Economy, Wuppertal Institute; Dr. Brigitta Huckestein, Senior Manager Energy and Climate Policy, BASF SE. Chaired by Dr. Bettina Wittneben, University of Oxford & Dr. Chris Bataille, IDDRI

Panel Session 2 presented an impressive portfolio of possible breakthrough technologies in energy-intensive industries and inspiring pilot projects from different industries, which demonstrated to what extent the technologies and solutions are already being implemented. However, it became clear in the discussion that new forms of cross-industrial cooperation, as well as significant technological and business model innovation, are needed to achieve industrial decarbonisation. The point was made that the whole value chain of a more circular economy could open up potential new areas for value creation. The panellists called for strong industrial and innovation policies to support the development and financing of near-zero carbon processes while not jeopardising the competitiveness of European industry.

By way of introduction, an impressive portfolio of possible breakthrough technologies in energy-intensive industries was displayed by **Tomas Wyns** to the panel. He emphasised the role of technology and innovation in achieving the industrial decarbonisation challenge in the EU and proposed respective policy options. The panel contributed concrete examples of inspirational projects showing how the deep decarbonisation of processing industries is possible. Panellists highlighted the challenges faced by these tangible projects, as well as possible future visions for the industry.

The cluster project Carbon2Chem aims to convert process gases from steel production into base chemicals. Project coordinator, **Prof. Dr. Görge Deerberg,** outlined the current situation in the German steel industry and explained that the Carbon2Chem approach will lead to an annual reduction in CO_2 emissions from the German steel industry of 20 million tonnes. On a cross-sector basis, with 19 project partners from business and science, the project links various sectors and tackles climate emissions.

Steel for a sustainable future – meeting UN global goals

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The world must stop emitting CO_2 – this fact is clearly stated in both the UN Global Goals and in the Paris Climate Agreement. The Swedish steel industry, Sweden's largest emitter of CO_2, agrees. However, to make this happen, huge investment in energy, research and infrastructure from both industry and society is required.

Introduction

The Swedish steel industry has developed a long-term vision for 2050: Steel shapes a better future. The intention is for the industry to play an active role in the shift towards a sustainable society by taking responsibility for people and the environment. The vision makes three commitments: the industry will excel in technical development, attract and develop creative people and ensure that all outputs bring value to society. While the two first commitments show the necessity of being at the forefront of technological and innovation development, the third commitment expresses the industry's promise to transform its operational and business models.

Methodology/Ongoing Activities

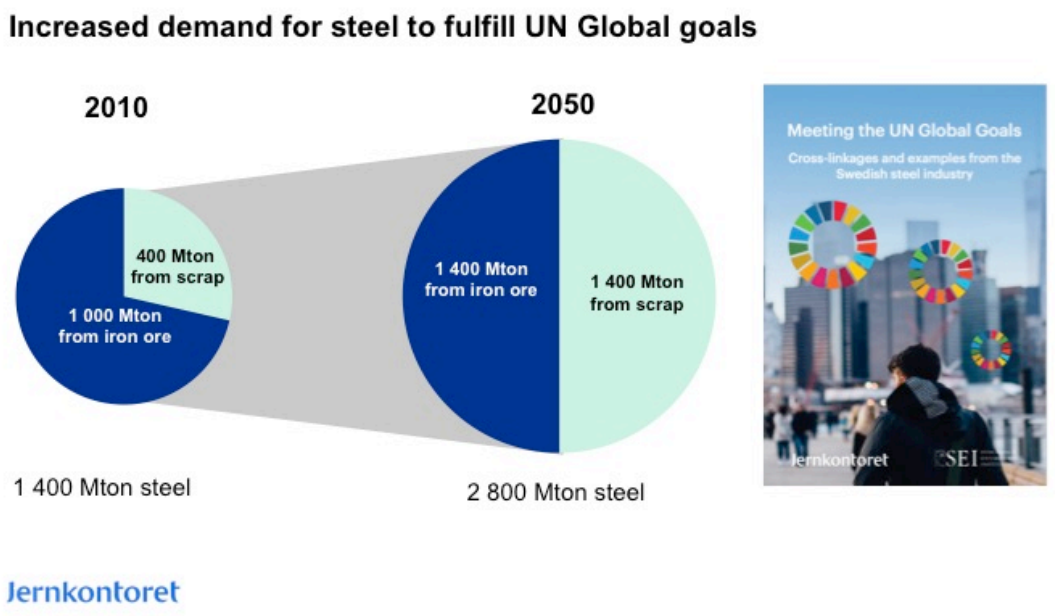
From early 2015 to May 2016, the Stockholm Environment Institute (SEI), Jernkontoret and the Swedish steel industry carried out a joint project – Swedish steel industry for increased societal value. The project delivered a strategic plan for reaching the steel industry's commitments under its 2050 vision and laid out an approach for how different players' contributions to societal value creation could be assessed. The project showed that focusing on societal value creation could potentially enhance the industry's competitive edge and that the Swedish steel industry, in close cooperation with other domestic and international players, has a clear comparative advantage in producing products and solutions needed in the global sustainability transition to meet the goals of the Climate Agreement and the SDGs.

Figure 3: The 10 action point strategic plan

Clearly, CO_2 as such is not something that adds value to society but making steel from iron ore (reducing iron ore using coke) is currently not possible without producing CO_2. A platform for carbon-free steel production was established in 2016 between SSAB (a steel company with iron ore-based production), LKAB (an iron ore mining company) and Vattenfall (an energy company). The goal is to use hydrogen instead of coke to reduce iron ore, which produces iron and water as the only outputs. This relies on the high availability of CO_2-free electricity (such as the Swedish), a more efficient process to electrolyse water to hydrogen and a solution for the storage and distribution. The challenges are far too significant and widespread to be solved by industry alone and, consequently, long-term cooperation between government, academia and industry is needed.

Meanwhile, Swedish industry is one of the most advanced steel quality producers in the world and, as a result, facilitates for example the production of lighter cars using less gasoline and emitting less CO_2. As less material is required to produce these steel products, resource efficiency also increases. Best of all, steel is recyclable repeatedly and the steel industry is key in a circular economy. If the Eiffel tower was recycled and rebuilt with modern advanced steel, we would have four new towers. Why, therefore, make steel from iron ore if it is possible to recycle scrap? The answer is simple; there is not enough scrap to meet the global demand for steel. As a growing number of people exit poverty, the demand for steel increases.

Figure 4: Demand for steel by 2050 and one example connecting steel and global goals



Source: Global CCS Institute (2010), "Global Technology Roadmap for CCS in Industry. Steel Sectoral Report. https://www.globalccsinstitute.com/publications/global-technology-roadmap-ccs-industry-steel-sectoral-report

Some people argue that we will not need steel in the future as there are many other materials that can be used. The current global demand for steel is 1.5 billion tonnes p.a. Which other material is equally suitable and cost-efficient? Even if it was possible to substitute all steel with wood, yearly wood production would have to double, which is neither sustainable nor practically possible. If we agree that steel is a necessary material for the future, we need to use the tools available to reinforce the sector's competitiveness and underpin new investment.

Results/Findings

The SDGs are indivisible goals for sustainable societal development. While each of the goals is important in itself, the potential trade-offs between them are not well researched. In order for the steel industry to use the global goals to steer towards societal value creation, it is important to understand how contributing to one goal may have positive or negative spillovers on the attainment of the others. In a co-creation process we have analysed the 17 SDGs with regard to how they relate to and influence one another in our sector and for society. If this is not done scientifically, there is a huge risk of sub-optimisation. A second joint research project in 2017 between the Swedish steel industry and SEI Swedish steel is focusing on societal value creation, by using the global goals and their interlinkages.

The Swedish steel industry has a positive impact on many more of the SDGs than it may seem on a first glance – particularly considering overlaps and links between the goals. The steel industry contributes to 1) No Poverty and 2) Zero Hunger and strengthens 3) Good Health and Well-Being through job creation and sustainable infrastructure, as well as by providing stainless steel used in healthcare. The steel industry has a positive impact on 4) Quality Education and 5) Gender Equality by

supporting technical and industrial education. Iron powder is used for 6) Clean Water and Sanitation.

Specialised steel applications for wind turbines, stronger and lighter vessels and safer buildings contribute to 7) Affordable and Clean Energy, 9) Industry, Innovation and Infrastructure and 11) Sustainable Cities and Communities. Steel plants can generate 8) Decent Work and Economic Growth and provide regional development to help achieve 10) Reduced Inequalities. If the 2050 vision "Steel shapes a better future" is successful, industry would also provide support to 12) Responsible Consumption and Production and 13) Climate Action. The steel industry integrates along value chains and private-public platforms, which contributes to 17) Partnerships for the Goals and 16) Peace, Justice and Strong Institutions.

However, steelmaking has negative impacts on 13) Climate Action, 14) Life below Water and 15) Life on Land, which highlights areas for improvement. By-products from steelmaking could be further utilised, reducing the need for new materials, which, in turn, will have a positive impact on the ecosystem. A Swedish initiative between SSAB, LKAB and Vattenfall – HYBRIT[1] (Hydrogen Breakthrough Ironmaking Technology) – is therefore in the process of researching a solution to eliminate CO_2 emissions by replacing coking coal with hydrogen in the process of turning iron ore into iron. If successful, the hydrogen-based steel production will have the potential to generate integration cycles with systems for 7) Affordable and Clean Energy, where hydrogen plays a central role in energy storage and in feeding fuel cells. This would also contribute to 11) Sustainable Cities and Communities and 12) Responsible Consumption and Production.

During 2018, the "Agenda 2030 compass" is developed to guide development toward societal value creation within the steel industry. Such a compass will, for example, make it easier to communicate the full range of benefits of today's products and processes to new applications or production from now until 2050.

[1] Further information available: http://www.hybritdevelopment.com/

Figure 5: First prototype of the Agenda 2030 compass[2]

Full o																		
	0,01	0,03	0,02	0,03	0,03	0,02	0,01	0,04	0,02	0,03	0,02	-0,01	-0,02	-0,01	-0,02	0,01	0,02	0,25
	0,03	0,01	0,03	0,02	0,03	0,02	-0,01	0,03	0,00	0,03	0,00	-0,01	-0,01	-0,01	-0,01	0,02	0,02	0,21
	0,03	0,02	0,00	0,03	0,02	0,01	0,00	0,04	0,00	0,02	0,00	0,00	0,00	0,00	0,00	0,01	0,01	0,22
	0,04	0,03	0,02	0,01	0,02	0,02	0,00	0,06	0,02	0,02	0,02	0,02	0,02	0,00	0,00	0,03	0,03	0,34
	0,04	0,03	0,03	0,05	0,01	0,03	0,00	0,05	0,02	0,03	0,02	0,02	0,00	0,00	0,00	0,03	0,02	0,38
	0,03	0,02	0,03	0,02	0,02	0,00	0,00	0,02	0,01	0,01	0,02	0,02	0,00	0,02	0,01	0,02	0,02	0,27
	0,03	0,01	0,02	0,02	0,02	0,01	0,00	0,04	0,02	0,01	0,02	0,00	0,00	-0,01	-0,01	0,01	0,01	0,22
	0,04	0,05	0,03	0,05	0,03	0,01	0,02	0,01	0,03	0,02	0,03	-0,01	-0,02	-0,02	-0,03	0,03	0,04	0,34
	0,03	0,02	0,02	0,02	0,02	0,01	0,02	0,04	0,00	0,01	0,02	0,01	-0,01	0,00	-0,02	0,01	0,03	0,24
	0,03	0,03	0,03	0,02	0,03	0,01	0,01	0,03	0,01	0,00	0,01	0,00	-0,01	-0,01	-0,01	0,03	0,03	0,25
	0,02	0,02	0,02	0,02	0,02	0,01	0,02	0,03	0,02	0,01	0,00	0,02	-0,01	0,00	-0,01	0,01	0,01	0,22
	0,02	0,03	0,03	0,03	0,03	0,03	0,02	0,05	0,03	0,02	0,03	0,00	0,03	0,03	0,03	0,04	0,03	0,44
	0,00	0,00	0,02	0,02	0,00	0,02	0,00	0,01	0,00	0,00	0,00	0,03	0,00	0,03	0,01	0,02	0,03	0,22
	0,00	0,00	0,02	0,00	0,00	0,02	-0,01	0,00	-0,01	0,00	-0,01	0,01	0,00	0,00	0,02	0,02	0,02	0,09
	0,00	0,00	0,02	0,02	0,02	0,02	-0,01	0,00	-0,01	0,00	-0,01	0,02	0,02	0,02	0,00	0,02	0,02	0,17
	0,03	0,02	0,02	0,02	0,02	0,01	0,00	0,03	0,01	0,01	0,01	0,02	0,01	0,02	0,01	0,00	0,03	0,28
	0,02	0,02	0,02	0,02	0,02	0,02	0,01	0,04	0,02	0,01	0,01	0,02	0,02	0,02	0,01	0,03	0,01	0,33
	0,38	0,33	0,37	0,41	0,34	0,28	0,10	0,53	0,23	0,28	0,22	0,16	0,04	0,08	0,00	0,34	0,36	4,46

The greener the field in the figure and the higher the number in the field, the higher the contribution of the steel industry to societal value creation. Even if the number is not significant in itself, Compass is to be used to compare different options of investments/policies/action before the latter are implemented. Most other models are analysing afterwards, e.g. indicators.

In April 2018, the Swedish steel industry also launched a roadmap for a fossil fuel-free steel industry based on the current situation and future needs to transform industry, where both society and industry need to take significant action.

Conclusion

The potential for contributing to the SDGs represents a number of business opportunities. However, there are also negative impacts that will require continuous attention and improvement. A long-term partnership between the public and the private sectors is key for success. The Swedish steel industry invites all stakeholders to

[2] Update in May 2018

discuss the way forward in terms of e.g. legislation, research, energy and infrastructure to enable sustainable development with a CO_2-free Swedish steel industry and a society which meets the objectives of the Paris Agreement and Agenda 2030. One tool that might be useful is the Agenda 2030 compass. Even if it is just a prototype for now and needs more research and data input, it is shown that one can use the global goals to quantify societal value before taking action and without sub-optimising on one goal.

A fundamental point of departure was, and still is, the fact that SDGs are indivisible and a set of integrated parameters to approach holistically, with impacts from products and processes assessed across all the goals and targets as well as for any policy to be decided.

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Circular economy 4.0 – opportunities for near-zero carbon processing industries

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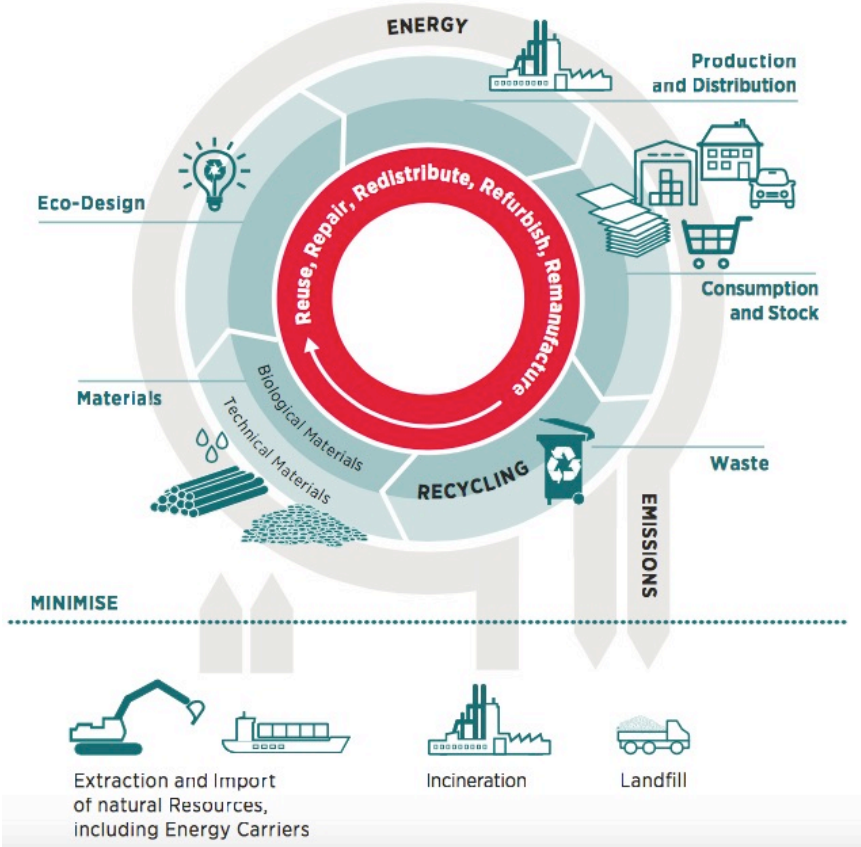
The transition towards a circular system will be crucial for decarbonising industrial production processes. However, the circular economy is not yet effective on a sufficiently large scale. Recyclates, i.e. secondary raw materials recovered from waste, are being fed back into production and usage processes at volumes far below the potential. In German industry, for example, only about 14 % of raw materials used are derived from recycling processes; the remainder are still sourced from primary materials (IW, 2010). If this system were to be improved, loss of value, dependence on volatile commodity markets, lower resource productivity and externalities in the form of environmental pollution could be avoided.

Transition towards a resource-efficient and decarbonised circular economy

The fundamental idea behind the circular, or closed-loop, economy is to retain as much value as possible for as long as possible from products and components when they reach the end of their use. This requires an integrated approach which, for example, takes the recyclability of products into account during the design phase, extends their usage and ensures materials can be substantially recovered after use. This is illustrated in Figure 6, which shows how products can be managed in the production and use cycle through various means, including reuse and recycling.

Figure 6: The circular economy concept



Source: Wilts and Berg (2017)

As indicated above, there are high hopes associated with this system:

- It is projected that the circular economy will lead to the much more efficient use of natural resources and that the reduction in demand for materials will also make a substantial contribution towards a low carbon economy.

- The system should also ensure the competitiveness of specific markets, for example by reducing supply risks for strategic materials or by supporting innovative business models related to new forms of resource provision, such as sharing or leasing.

- In addition, it is anticipated that the circular economy will also create jobs and new employment opportunities.

The European Commission estimates that the introduction of circular economy principles by 2030 will provide 580,000 new jobs within the EU, reduce greenhouse gas emissions by 450 million tonnes and reduce costs by €600 million for European companies, i.e. around 8 % of Europe's annual turnover, creating new and lasting competitive advantages for Europe (EC, 2015). The following table provides an overview of projections for different countries and areas.

Table 2: Projections for Circular Economy Impact

Country	Source	Projections	Projected GHG Savings
China	13th Five Year Plan of PR China	• Water quality expected to reach Grade III by 2020 (70 % of country's surface water) • Use 90 % of polluted soil (increase from 70.6 % in 2015) • Increase of resources productivity by 15 % • Utilisation rate of 73 % for solid waste • Over 75 % of national industrial parks should practice complete CE strategies by 2020 • Output value of recycling industry should reach $450 bn	18 % reduction of CO_2 emissions per unit of GDP
India	Ellen MacArthur Foundation	• 30 % cost savings of Indian GDP by 2050 • $16 billion material costs by 2030 (for constructing buildings) • CE could create annual value of $624 billion by 2050 • 38 % lower material consumption in 2050 • 41 % reduced energy consumption in 2050 • 24 % lower water usage in the construction industry in 2050 • 49 % lower water usage in agriculture by 2050 • 71 % lower fertiliser and pesticide use by 2050	44 % reduction of GHG emissions by 2050 31 % less GHG emissions from agriculture 68 % less GHG emissions from transportation
EU	EU Commission	• $600 billion net savings for EU companies • two million jobs by 2030	20 % reduction of GHG emissions by 2020
	Ellen MacArthur Foundation	• $630 billion material costs by 2025 (subset of manufacturing industries) • $700 billion material costs (global fast-moving consumer goods sectors)	580 kg of CO_2 per tonne of diverted food waste Reduction of 1.3 million tonnes of CO_2 for remanufacturing mobile phones
UK	Waste & Resources Action Programme	• €400 billion cost savings by 2020 (focus on food and beverage, built environment and manufactured goods) • 160,000 jobs by 2020	Reduction of 500 Mt of CO_2 emissions by 2020
	Ellen MacArthur Foundation	• $172 profits per tonne of processed food waste	7 million tonnes of CO_2 (emissions from household, retail and hospitality)

In light of this potential, we are faced with the question of why we are still so far from operating closed-loop systems. Central to the effective design of the circular economy is the observation that efforts in this area have, until now, failed primarily as a result of problems concerning information; e.g. information about the quality of recyclates or the available quantities of recycled resources.

Digital transformation as the ideal enabler for the circular economy

The transition to a circular economy will require better coordination of material and information flows if the issues described above are to be tackled. Information about the quantity, and especially the quality of products and the raw materials they contain must be gathered and recorded. This data must also be retained and forwarded with the materials in the cycle so that waste can become a processable resource. A key challenge in this process lies in effectively generating, collecting, processing and making available the volume of information about the material composition of each individual product, its use patterns, its location within the waste system, etc. This is necessary to establish functioning markets and cycles in the next stage. This approach, as opposed to relying solely on regulation, will make efficient, market-based solutions possible.[3] Conversely, regulations such as quota systems will also require such information systems as otherwise, there is no guarantee that sufficient recyclates will even be obtainable.

Until now, it has not been possible to overcome this information deficit. However, digital transformation now allows for tracking and tracing as described above and digital applications could, therefore, provide a solution. The following are some examples of ways in which this could be achieved:

- Cyber-physical systems allow products to carry information through the entire production process. Hence, data on quality and materials/ ingredients can be stored and transported.

- In an intelligent integrated system of this kind, it would even be conceivable that material available for recycling could automatically create its own market via the Internet of Things by marketing itself on exchange platforms on the basis of information about composition and possible uses. Some recyclates are already less expensive than primary materials and the concept of automated "self-marketing" could increase this trend. Recyclability would then become a technical competitive advantage.

- Information sharing should be enabled in ways that guarantee trustworthy exchange without violation of property rights. "Trustless" business through block chain and smart contracts could offer an alternative.

If the circular economy is to become established, ***industry, the waste management sector and ICT companies*** *developing software and technologies for the*

[3] See Wilts/Berg 2017 for details.

digital transformation will need to cooperate to build a functioning value creation network. Therefore, recycling solutions need to be taken into account simultaneously with the implementation of such a network for the most cost-effective results. The window of opportunity for this is now! The transition to Industry 4.0, the Internet of Things and similar developments are already underway. Delay to the establishment of an integrated circular economy will require significant additional cost as well as expensive system adjustments.

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Reducing greenhouse gas emissions – challenges for the chemical industry

Dr. Brigitta Huckestein, BASF SE, Germany. Brigitta.Huckestein@basf.com

Chemical products help to reduce carbon emissions in many sectors, but to reach the climate target of the Paris Agreement, emissions from production processes must also be reduced. Significant progresses require the development of fundamentally new production processes as efficiency improvements to conventional technologies will become marginal following decades of continuous improvement. The transition will require massive investment and huge amounts of cheap and constantly available low-carbon energy. An enabling, long-term political framework turning new processes into business cases for the globally competing chemical industry will be needed to make the change feasible.

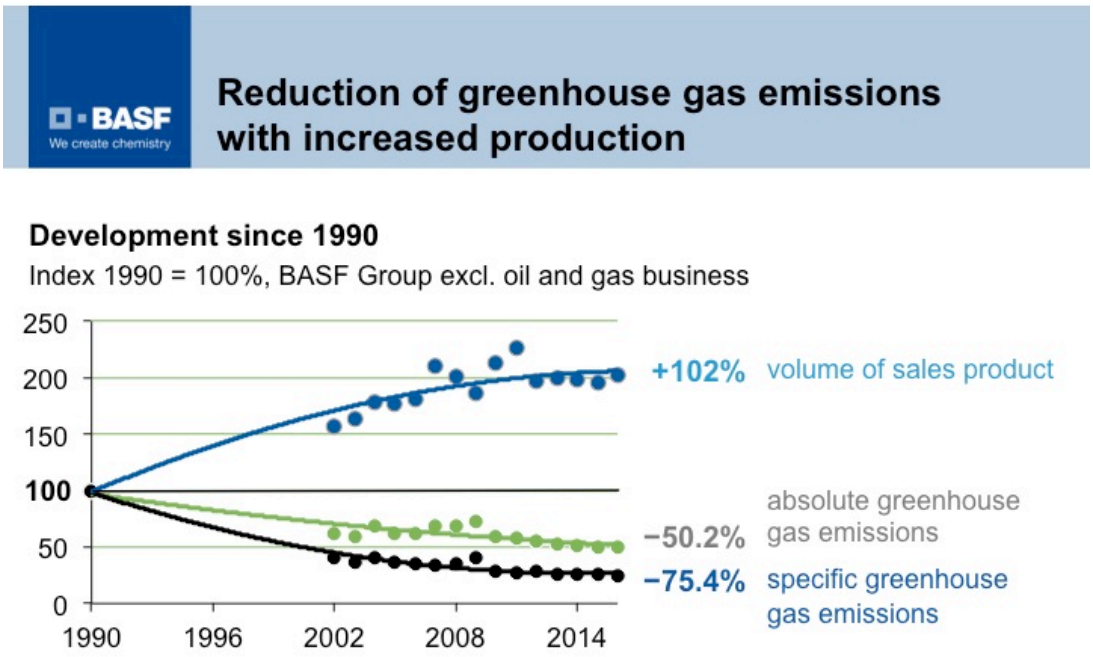
The chemical industry will play a key role in a carbon-neutral future. Chemical products contribute to reducing carbon emissions in many sectors – in lightweight cars, energy-efficient buildings or wind turbines and solar panels for renewable energy. New, tailor-made materials provided by the chemical industry will further stimulate climate protection, batteries for e-mobility being just one example. Many chemicals save more greenhouses gases in their life-time than they emit during their production but to reach carbon neutrality in the second half of the century, a significantly greater reduction in emissions from the production processes will also be needed.

The most energy- and emissions-intensive area of chemical production is the basic products, which constitute the beginning of the chemical value chain. To significantly reduce their carbon emissions, breakthrough technologies for these processes will be required. To enable such a transition, competitiveness and economic growth must be safeguarded, allowing businesses to make full use of their innovative power.

BASF supports steps towards carbon-neutrality

Climate protection is at the centre of BASF research and development activities, both for products and our own processes. Since 1990, we have lowered overall greenhouse gas emissions from our operations by about 50 % while doubling our production, thus reducing specific emissions (i.e. per tonne of sold products) by about 75 %.

Figure 7: Reduction of greenhouse gas emissions with increased production



The energy for heat and electricity for the production site is generated in our highly efficient combined heat and power plants, after minimising our demand by heat integration. We are committed to energy management that helps us analyse and continue improving the energy efficiency of our plants. We will further optimise the energy efficiency of our current processes, but improvements are reducing. For bigger steps, new leapfrog technologies for deep reduction in greenhouse gas emissions will become necessary.

An overview of new technologies is provided by a study from DECHEMA (Society for Chemical Engineering and Biotechnology), commissioned by Cefic, the EU chemicals association (DECHEMA, 2017). It examines multiple technological options and pathway scenarios towards a 2050 carbon-neutral chemical sector. Electricity benefitting from progressive decarbonisation of the power sector can be used directly, e.g. to produce chlorine or heat. In addition to biomass-based production, which will be limited in its contribution, renewable energy and hydrogen produced by electrolysis have been considered. However, fundamental changes in production processes cause massive costs and uncertainty. The results show:

- The transition requires massive investment and huge amounts of cheap low-carbon energy.

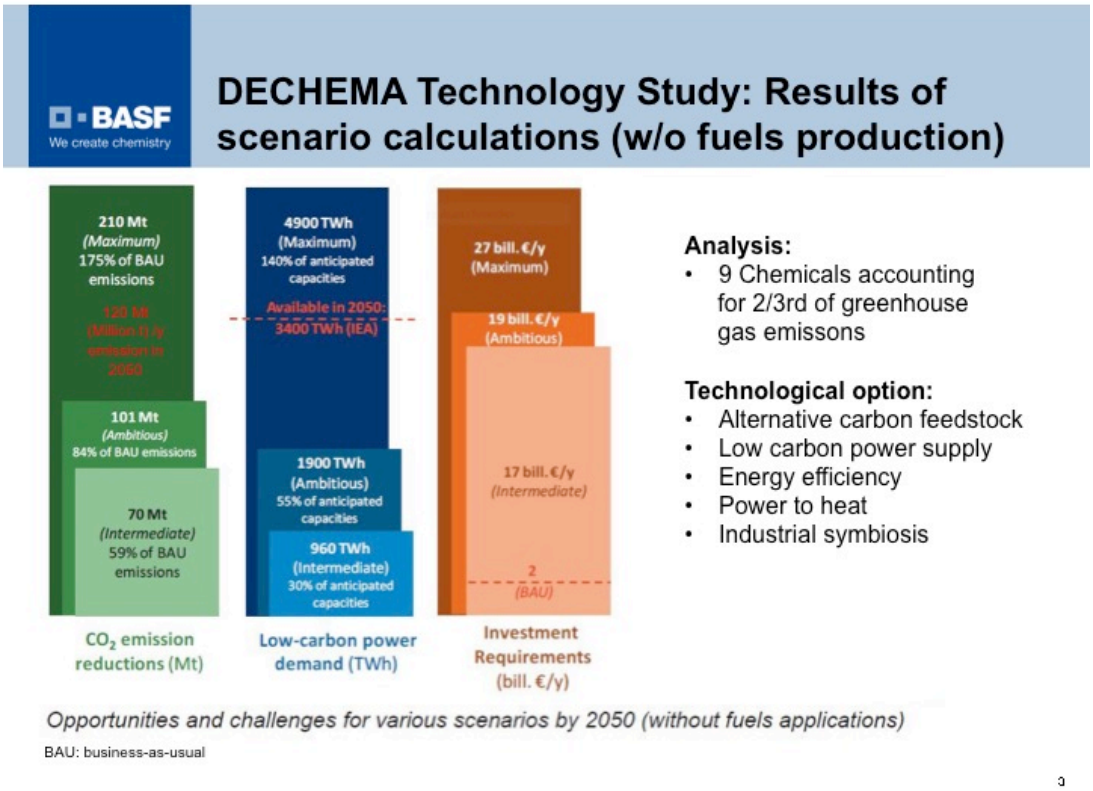
- Energy needs will be two- to fivefold higher than for conventional processes.

- The renewable electricity needs may exceed the availability of renewable energy in Europe, even when the high capacities anticipated by the IEA (International Energy Agency) are taken into account.

- Additional investment of more than €20 billion per year compared to business-as-usual is required and production costs will increase. For instance, production costs for ammonia, methanol, olefins and some aromatics would be two to five times higher.

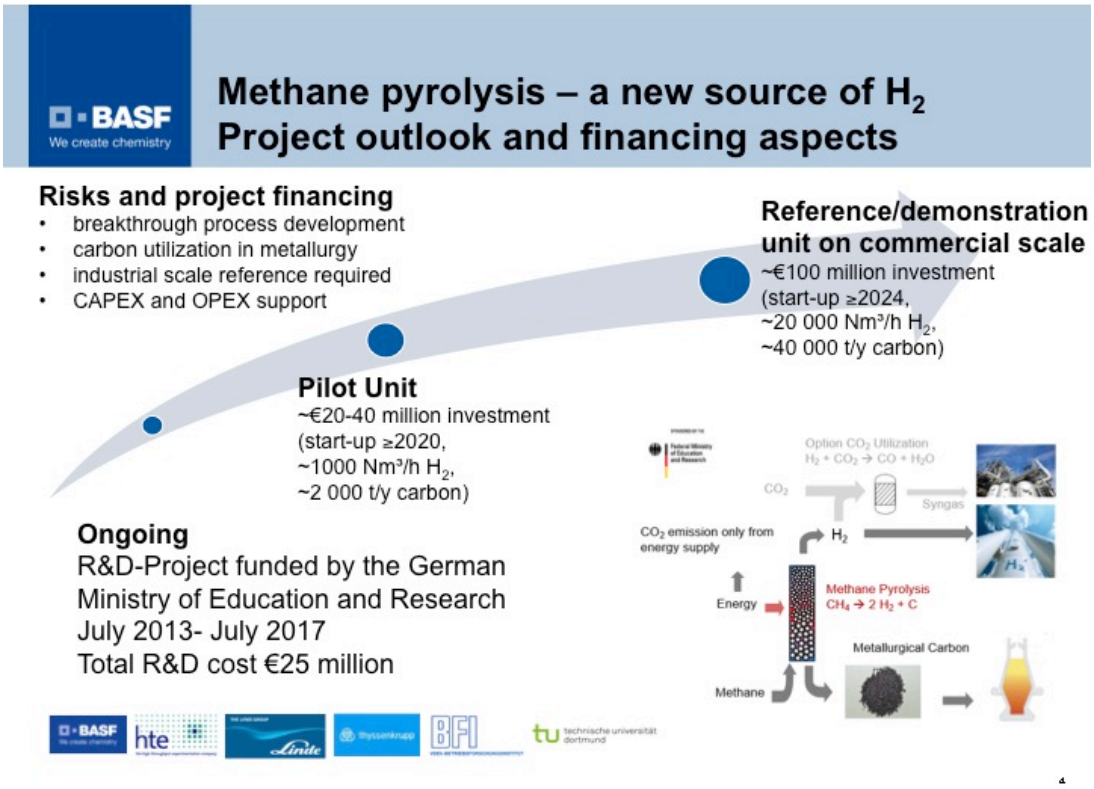
- Except climate protection, there are few co-benefits – which means that the profitability of processes will depend, for a long time, on political regulations.

Figure 8: DECHEMA Technology Study – Results of scenario calculations (w/o fuels production)



A key technology not considered in the calculations, which deserves further attention, is the methane pyrolysis process. It is the most promising route for producing hydrogen, a key molecule for many downstream production processes. Methane pyrolysis enables hydrogen to be produced with a very low carbon footprint compared with other processes, due to no direct emissions and lower energy demand than for water splitting by electrolysis (Machhammer et al., 2016). The methane feedstock could stem from fossil sources, but if available at low costs, also from biogas, landfill gas or synthetic natural gas. The carbon product is potentially applicable in the carbon industry depending on the applied technology; e.g. for metallurgical processes or possibly for storage.

Figure 9: Methane pyrolysis – a new source of H_2



BASF coordinated a four-year research project with several industrial and academic partners funded by the German Ministry of Education and Research. It successfully showed the technical viability of the process in laboratory conditions and tested carbon samples for different applications. A concept for a pilot plant was developed, but the reactor concept still bears high risk. Next steps would require high investment for further R&D activities, a future pilot plant and ultimately a commercial-scale reference plant. Currently, there is no business case to build such a commercial plant without public funding.

A long-term political framework is needed. Both technological developments and political regulations are key for climate protection. The Paris Agreement has started this process. However, regional climate policies differ significantly, both in level and focus. BASF strongly supports global CO_2 pricing (e.g. described by the B20 commitment in 2017), which would allow for more progressive projects.

Carbon pricing is already an effective instrument in some regions. Most stringent measures can be seen in the EU ETS. As a regional carbon price would impose a unilateral burden on companies and carry the risk that investment and jobs could be relocated to less ambitious regions, the free allocation of ETS certificates to lower the burden for industry is envisaged. However, industrial growth in Europe under a declining ETS cap will require new approaches: there must be a business case for large production units with a very low carbon footprint. A thorough compatibility check of existing policies focusing on the need to steer leap-frog transformational processes is required.

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4 Panel Session 3: How to spur industrial progress: roadmaps, funding and cooperation

With Dr. Artur Runge-Metzger, Director 'Climate Strategy, Governance and Emissions from non-trading sectors', DG Climate Action; Shiro Kobayashi, Sustainability Director, Nippon Sheet Glass; Johannes Kerner, BMWi IIC6; Dr. Gerhard Dell, Managing Director, Government of Upper Austria; Michael Theben, Director, MWIDE NRW. Chaired by Timon Wehnert, Wuppertal Institute & Dr. Christoph Wolff, ECF

The goal of creating a net zero society has been taken up by forerunning policymakers and companies. Representatives from the EU and the German government, as well as from two industrialised regions (North-Rhine Westphalia and Upper Austria), made it clear that they are prepared to take signification action in cooperation with industry and have already implemented novel policy instruments to better align their efficiency and innovation activities with the needs of stakeholders. Arthur Runge-Metzger outlined the European Commission's willingness to deliver strong support to innovative projects implemented by industry, as currently half of their innovative projects are not being realised. The newly established ETS Innovation Fund will be an instrument for this.

Dr. Arthur Runge-Metzger presented the European climate targets and the resulting tasks arising for the different sectors. For the public sector, different instruments are available to reach those targets. The regulatory framework, which includes for example the EU-ETS, is one of them. The European Commission (EC) also has several R&D programmes in place which help to get demonstration projects to commercialisation, such as Horizon 2020. The European Structural and Investment Fund (ESIF) invests in energy efficiency, creating the demand for new and more efficient products. Dr. Runge-Metzger outlined the risks that the EC, as a public entity, is willing to take to support these programmes as half of the innovative projects are not being realised. Regarding the newly established ETS Innovation Fund, the EC needs a dialogue with the industry to discuss how the money should be spent.

Johannes Kerner discussed the German energy transition which follows a long-term strategy with specific targets. He presented the results achieved so far and stated that a sound mix of energy efficiency instruments is the key to achieving Germany's emissions reduction targets. In terms of energy efficiency in appliances and products, measures should boost the development and market penetration of energy-efficient products and define certain minimum energy efficiency standards as market entry conditions via the specific and dynamic design of its set of regulatory instruments.

Shiro Kobayashi gave a presentation on climate change activities undertaken by the Japanese Nippon Sheet Glass group (NSG Group). The company's various prod-

ucts can contribute to energy generation and conservation and are essential for the decarbonisation of society. Not only has the company a roadmap to reduce CO_2 emissions but it is also part of the Japan Climate Leaders' Partnership. Established in 2009, the partnership is a network of 43 companies (as of September 2017) that aim to create a net zero society based on the belief that low-carbon development is a prerequisite for economic activity.

With its long industrial history, the state of North Rhine-Westphalia can be seen as a blueprint for other regions in Europe. **Michael Theben** stated that, as a federal state, NRW developed a climate protection plan that included intense stakeholder dialogue over a period of two years and has set its own CO_2 emissions reduction goals. One of the platforms for dialogue was "Climate Protection and Industry in NRW", bringing together energy-intensive industry, NGOs, government representatives and other stakeholders to discuss low-carbon technologies and potential pathways for their implementation. Currently, there is high motivation to increase the R&D efforts for low-carbon technologies, which will hopefully lead to the establishment of a "Low Carbon Centre".

Dr. Gerhard Dell presented the experiences of another European region, Upper Austria, which is responsible for 25 % of Austria's industrial exports, e.g. iron, steel and chemicals. He emphasised the fact that Upper Austria has managed to decouple its energy consumption from its economic growth. More than 30 % of the gross domestic energy consumption comes from renewables, particularly biomass and hydro. For the year 2050, the region has set itself the target of reducing its energy intensity by 70 % to 90 %; a reduction of 1.5 % to 2 % per year. The political measures taken by Upper Austria are a combination of regulatory measures ("sticks"), such as emissions and efficiency standards as well as clear goals for 2030 and 2050, financial measures ("carrots"), such as investment grant programmes or regional R&D programmes, and information & training ("tambourines").

5 Panel Session 4: Make it happen: the role of (international) innovation, trade, industry, energy and climate policies

With Eva Svedling, State Secretary to the Minister for International Development Cooperation and Climate Sweden; Dr. Reinhold Achatz, CTO, thyssenkrupp; Prof. Dr. Stefan Lechtenböhmer, Director, Future Energy and Mobility Structures, Wuppertal Institute; Prof. Dr. Joyashree Roy, Professor of Economics at Jadavpur University, Kolkata in India and IPCC AR4&5 CLA on Industry. Chaired by Dr. Martin Porter, ECF & Prof. Dr. Lars J. Nilsson, Lund University

The concluding panel with leading representatives made it clear that all stakeholder groups are ready to take on the challenge of achieving GHG neutrality along the whole supply chain. The panellists agreed that the innovations (often radical) towards near-zero emissions in processing industries need to be supported. This so-called "great leap" for industry also needs to significantly step up in terms of its ambition for policy, industries and society. Companies are instrumental not only in terms of their own emissions, but also as solution providers for technological or business models, and it is important for them to invest in order to maintain their competitiveness. This motive holds true not only for European but also for e.g. Indian industries as top IPCC expert Prof. Joy emphasised.

Prof. Dr. Stefan Lechtenböhmer explained, in summary, that the topic is gaining momentum – not only in North Rhine-Westphalia but also in several other regions such as Austria, Japan, Netherlands and Sweden, as well as within the European Commission. There is already a lot to learn from others' experiences and the conference panel sessions showed that there might be a nucleus for joining forces internationally and more intensively to advance this challenging topic – a topic which is definitely too big to be tackled unilaterally, be it by companies or governments. The examples presented had an important element in common: they all go beyond traditional approaches and cross borders between sectors, such as the steel, chemical and energy industries; innovative instruments are being developed and stakeholders from new realms are being involved. The distinctive challenges of the topic can only be tackled successfully when new networks and coalitions are created that cross the borders of traditional domains and include a wider range of actors. He explained that the challenges and risks for industries and companies arising from decarbonisation, as highlighted by some speakers, and the necessity of decarbonising the processing industries, as outlined by others, are two sides of the same coin. The problems can only be solved using a joint approach. Prof. Lechtenböhmer concluded that a new vision of integrated industrial policy is needed. This vision needs to:

be supported by industries as well as societal stakeholders;

include policies on energy, the circular economy and on trade, as well as on innovation and digitalisation; and

regard itself as one of the key instruments for achieving global GHG mitigation targets.

Whereas the topic has received very little attention so far, the examples presented at the conference showed that there are active front-runners in industry, science and policy.

Dr. Reinhold Achatz talked about the objectives for a company like thyssenkrupp: carbon neutrality, sustainability – which for the company primarily means profitability – and social acceptance. To achieve those objectives, thyssenkrupp analysed its CO_2 production as well as that of their vendors and started the so-called Groupwide Energy Efficiency Program (GEEP), aiming to achieve sustainable efficiency gains by 2020. Furthermore, the company is continuously working on improving the efficiency of their products, for which there is still a lot of potential despite improvements made in the past. However, to achieve the objective of GHG neutrality, a paradigm shift is needed. Thyssenkrupp was the initiator of the project Carbon2Chem[4] with the idea of combining different industry sectors: individually, each industry sector has a long tradition of improvement and optimisation, but to achieve the long-term target, the steel, chemical and energy sectors need to take a joint approach. The ten-year project is divided into three steps: first, laboratory research; second, a pilot plant; and, finally, the upscaling of the pilot plant. Currently, the pilot plant is under construction with the official opening scheduled for spring 2018. As there are many similar steel plants worldwide, in the long term this concept will be replicated. The approach is modular, so not confined to the steel industry – the module technology can also be transferred to other industries. The cement industry was selected for the pilot plant as, apart from the steel industry, it is the most CO_2-intensive.

With regard to renewables, Dr. Reinhold Achatz pointed out that the aim is not only to replace fossil power plants but also to replace fossil input into the industrial processes. However, this means that the required amount of renewable input is much higher than the necessary amount to replace today's power production. His concern is that there will soon be a shortage of renewable energy. Furthermore, the new system he described needs to be more flexible, given the fluctuating availability of most renewables. As a first solution, thyssenkrupp has developed a large-scale storage element, the Redox Flow Battery, for flexible energy storage.

Prof. Dr. Joyashree Roy emphasised the fact that the industrial sector has not only been leading in areas such as energy efficiency and material efficiency, but that other sectors are now learning from that experience. She presented the experiences from the Indian manufacturing industry and explained that, whereas until the mid-1990s, the Indian industry was unable to separate industrial growth from energy use, intensive energy use has reduced over the last decade. This was achieved through investment made by Indian industry; some industries pay $100 per tonne of carbon. Such payments are undertaken because of to the cost-competitiveness of the Indian industry; other reasons include the influence of policy, price consideration, consumer demand or exportability. The climate-related policy regime in India started with in-

[4] Further information: https://www.thyssenkrupp.com/en/carbon2chem/

dustrial lobbying; the industry wanted to be rewarded for their actions. This led to, for example, the National Enhanced Energy Efficiency Mission in 2008 or the Energy Certificates Market, a trading system similar to the EU-ETS but for fossil fuel energy intensity reduction rather than for carbon emissions. Furthermore, there is a Coal Cess in India, a coal tax, which increases every year. Nevertheless, current Indian policies are not sufficient for achieving deep decarbonisation and carbon pricing could further reduce emissions. Prof. Roy campaigned for a global sector-wide industrial sectoral approach in contrast to the individual industry approach that dominated in the climate negotiations in the early 2000s.

The Industrial Leap – a new support scheme for technology shifts in process-related Swedish industry

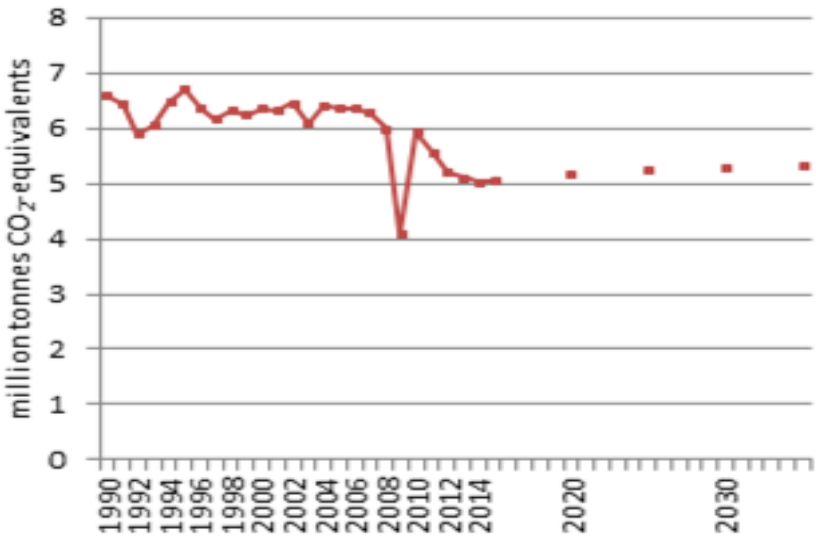
Eva Svedling, State Secretary to the Minister for International Development Cooperation and Climate Sweden.

In June 2017, the Swedish Parliament decided to introduce a climate policy framework with a climate act for Sweden. This framework is the most important climate reform in Sweden's history and sets out the implementation of the Paris Agreement in Sweden. By 2045, Sweden aims to have zero net emissions of greenhouse gases into the atmosphere. The Swedish government has also set the target that Sweden will be the first fossil-free welfare nation in the world. Today, emissions from industrial combustion and processes account for about one third of total emissions in Sweden. This means that a significant change in industry will be needed during the coming decades to meet the Swedish climate objectives. To support the transition, the Swedish government has, therefore, launched the Industrial Leap, a new support scheme for technology shifts in process-related industry.

Industrial process-related emissions in Sweden

Emissions from industrial combustion and processes account for about one third of total emissions in Sweden. Emissions have fallen since 2006, but to varying degrees in different sectors. The decrease since 2006 is mainly due to changes in fuel consumption and reduced production volumes. Emissions from industrial manufacturing processes were almost constant until the 2009 financial crisis and subsequently decreased slightly due to reduced production volumes and new technology in the chemical industry. Without further measures, emissions from industrial processes are expected to increase over the next few decades (see figure below from the Swedish Environmental Protection Agency).

Figure 10: Historical and projected emissions of greenhouse gases from industry



Source: Swedish Environmental Protection Agency (2017)

A large proportion of direct industry emissions come from a few energy- and CO_2-intensive industries – including steel and cement production and refineries. Most of these industries have a large proportion of so-called process-related emissions that are difficult to reduce.

Compared to global norms, Swedish heavy industry is very efficient but to further reduce emissions, technology shifts are necessary – including the introduction of unproven technologies. Such endeavours will, in many cases, be costly, risky and time-consuming for the industries. Investment must be made in technologies that are not yet developed, which implies significant risks and hence justifies government support. As a leading manufacturing country dependent on its industrial base, there is a strong interest in the ability of Swedish industry to improve/maintain its long-term competitiveness both for securing Swedish jobs and welfare and significantly reducing emissions. Industries with process-related emissions in Sweden employ about 32,000 people. The Swedish government is convinced that Sweden should export tomorrow's solutions, not emissions. The companies and countries that lead the development in finding the future's solutions will, in the long run, have major competitive advantages.

Measures to reduce process-related emissions

In October 2016, the government commissioned the Swedish Energy Agency to coordinate the government's innovation-promoting efforts to reduce process emissions in Swedish industry.

As a next step, the government has now launched the Industrial Leap, a SEK 300 million per year support scheme of comprehensive measures to significantly reduce process emissions in industry. The Industrial Leap is a long-term arrangement that begins in 2018 and is scheduled to continue until 2040. The long-term scope of the

scheme is important, since investment cycles in industry processes are long and include research, development and investment. The Industrial Leap will consist of both support for preliminary studies, including detailed design studies, and support for full-scale investment. The target group for the support is industries with large process-related emissions, but also universities and research institutes.

Summary – What is the Industrial Leap?

• The purpose is to support industry to reduce its process-related emissions to achieve the goals set in the climate policy framework – i.e. no greenhouse gas emissions released into the atmosphere by 2045 at the latest.

• The Industrial Leap is a commitment of SEK 300 million per year to support comprehensive measures to significantly reduce process-related emissions in industry.

• The Industrial Leap is a long-term reform, planned to begin in 2018 and continue until 2040.

• The main industries with process-related emissions are iron and steel, metal, chemicals, refineries and the mineral industry including cement.

• The Industrial Leap can provide funding to support preliminary studies, including detailed design studies and investment support. The target group for support is industries with large process-related emissions, but also university and research institutes.

• The Swedish Government is working closely with Swedish industry in the implementation of the Industrial Leap.

• The Industrial Leap will be administered by the Swedish Energy Agency.

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Source of the historical data:
http://cdr.eionet.europa.eu/se/eu/mmr/art07_inventory/ghg_inventory/envwot3qq

Source of the scenarios:
http://cdr.eionet.europa.eu/se/eu/mmr/art04-13-14_lcds_pams_projections/projections/envwvofta/

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