Strategies for deep decarbonization of processing industries

Energy-intensive processing industries (EPI) provide basic materials like steel, aluminium, pulp, paper, cement, plastics, chemicals, etc. Processes in EPIs, however, are still highly carbon intensive and responsible for a large share of global GHG emissions. Currently the EU and its Member States are preparing important policies, such as a new industrial policy on the EU level (EC 2017) and the Mid-century low emissions strategy. Together these will describe the industrial as well as energy and climate policy of the years to come with a long term horizon towards a decarbonised European economy by 2050. This paper provides a brief overview of the respective technological, infrastructural as well as innovation and policy strategies for a comprehensive approach that is needed to deeply decarbonise processing industries

DOI 10.12910/EAI2018-44

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Basic materials processing industries are important emitters of greenhouse gases. Five core branches alone, steel, cement, plastics, paper and aluminium are directly and via their energy use responsible for over 20% of global CO_2 emissions and their production has been and is rapidly growing (see Figure 1). Globally growing wealth and infrastructures are expected to be important levers for further strong growth in basic materials use and production.

The fact that a decent wealth and supply with public goods needs materials makes it clear that the issue of energy and emission intensive basic materials is difficult to tackle. That societies will continue to heavily rely on their supply, however, does not mean that the processing industries will not see major technological as well as structural shifts in the future. From a global perspective it seems clear that an increasingly circular economy by improving material efficiency in manufacturing and in product design, product-service efficiency and also service demand

reduction (e.g. via sustainable consumption patterns) (Fischedick et al. 2014) is a core contribution to reduce the demand of primary or virgin materials needed.
Further, it seems to be plausible that the materials themselves might face massive changes as compared to todays and historic situation. A stronger service orientation in the material and manufacturing process will strengthen the shift from a traditional perspective in which materials and their producers including subsequent manufacturers of products are very often defined according to the main chemical elements of their basic material. In the future, however, materials will increasingly be designed to fulfil desired properties with a minimum carbon and environmental footprint, regardless which substance would have been their physical basis. Further, materials such as plastic sheets and paper could increasingly converge, with plastics becoming increasingly bio-based and biodegradable and getting haptic like paper, and paper with hydrophobic properties enabling it to serve in functions today reserved for plastic foils. Together with potential large changes in the costs of materials in a greenhouse gas neutral future these developments have the potential to initiate significant changes regarding the materials that are actually used for products and packaging but possibly also those used in manufacturing and construction.

Technical strategies for deep decarbonisation of processing industries

Figure 2 shows the circular value chain of steel as an example. It indicates at which steps of the value chain which GHG mitigation options (according to Fischedick et al. 2014) are relevant.
While energy efficiency is relevant in all sectors and around the value chain, emissions efficiency is par-

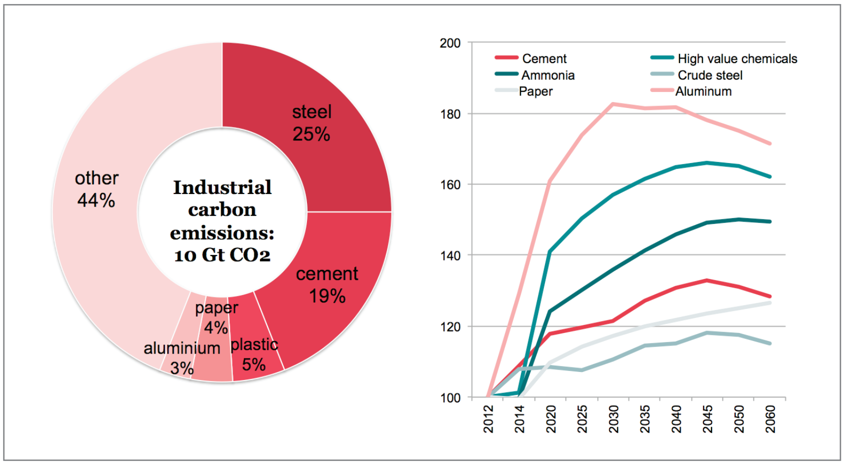

Fig. 1 Global industrial carbon emissions (2005) and expected growth rates of important basic materials by 2060
Source: own figure, data from Allwood et al. 2011 (left), IEA 2017 BY2DG (right) (2012 production volumes = 100)

ticularly relevant and challenging for the primary (and secondary) processing industries as these use a high share of the energy in the value chain. The deep decarbonisation of these industries is particularly challenging as many of the technologies needed (e.g. to electrify steel making or chemical feedstocks) are not yet available and the overall structures of these industries do not necessarily support fast decarbonisation (cp. Wesseling et al. 2017).

In principle the following technical options to emissions efficiency in processing industries are available (cp. Bataille et al. 2018, Lechtenböhmer et al. 2016):

- Direct electrification of industrial processes based on renewable (RES) electricity. This strategy is available for stationary power and low-to mid temperature heat. For high temperature applications as well as for specific processes the development of respective technologies (e.g. plasma technology, microwaves, electrolysis etc.) is necessary.
- Indirect electrification of processes via fuels based on RES-electricity such as hydrogen and liquid as well as gaseous synthetic hydrocarbons. Production of these requires huge amounts of electricity but in the case of hydrocarbons potentially hardly any changes in the process technologies using them. For hydrogen energy losses are lower and combustion emissions can be almost completely avoided but handling as well as use technologies require (partly challenging) technical changes.
- Next to the energetic purposes synthetic hydrocarbons also can be used as base materials for plastics.
- A very promising option for energetic as well as material uses is biomass. It can be directly used energetically or gasified and converted into biobased products via several routes. Its disadvantage, however, is the limited availability of land to sustainably source vast bio resources without outcompeting e.g. food uses.
- Finally carbon capture can be used as a technology to strip carbon at places of emission and either store the carbon or use it for the production of synthetic hydrocarbons. (In these cases, however, only the material use leads to a more long term storage of the carbon for years or decades.)

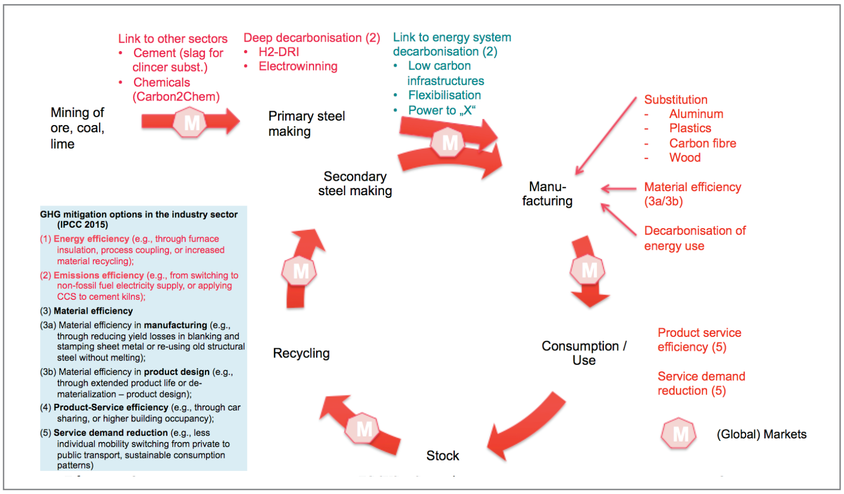

Fig. 2 GHG mitigation options along the value chain of steel products
Source: Lechtenböhmer and Vogl 2017; strategies from Fischedick et al 2014

Electrifying of basic materials as well as converting to biomass feedstock would need enormous amounts of biomass or RES-based electricity. For the EU that could e.g. mean to increase electricity production by around 60% just for basic materials production (Lechtenböhmer et al. 2016). A number that also indicates the significant need for clean energy infrastructures supplying the above mentioned emission efficiency or deep decarbonisation strategies. These infrastructures need to be developed in parallel or possibly even in advance to enable the large scale conversion of industrial processes to electricity or other options.

Therefore it becomes obvious that on top of inventing and developing the technologies to decarbonize basic materials processing it is important to curb basic material demand globally, by reducing material intensity of products and services, as indicated by the strategies 3 to 5 in Figure 2 above.

To spur developments into this direction a dedicated industrial policy is needed that integrates climate, energy and infrastructure policies as well as innovation and resource productivity in an intelligent way.

A new paradigm for industrial policy to tackle the decarbonisation challenge

Industrial policy traditionally has a rather poor reputation as mainly trying to prevent structural changes. Therefore, until the recent past industrial policy has rather been a barrier to climate mitigation than an asset. The high amount of environmentally harmful subsidies still paid is a proof of this. A recent OECD study found that OECD member states are still financing fossil energies with 70 bln $ a year vs. only 20 bln for renewables.

More recently there has been emerging a new connotation: the green industrial policy or green growth idea. Policymakers in Korea and the EU but as well as in many other countries and also companies like Siemens found that green markets were actually among the fastest growing sectors – a point that was particularly strong during the financial crisis – with also good prospects for further growth. This observation has lead many policymakers including the EU to put not only the challenges of climate policies but increasingly the chances of mitigation policies at the center stage of their "re-industrialisation" strategies. The latest development in the EU can be found in the most recent EC communication on "A renewed EU Industrial Policy Strategy" (EC 2017).

It is important but by far not enough that industrial policy discovers climate mitigation as a chance for innovation, growth and jobs and tries to harvest these options that are given by energy transition and climate leadership. Industrial policy needs to identify its crucial role in achieving the ultimate goals of sustainability and decarbonisation: Without a targeted new industrial policy, economies will not be able to innovate fast enough to have the technologies in place to deeply decarbonise materials processing industries, which is needed around mid of the century at the latest. Further, without such new policy approach governments will not be able to provide the necessary infrastructures (e.g. green electricity and sustainable biomass) for such a development, nor will companies and societies be able to harvest the potentials of dematerialisation which are embedded along the value chain and therefore often out of the views of traditional players in industries and policymaking.

Important elements of such a targeted and integrated new industrial policy with a focus on the processing industries many elements of which have been developed by Aiginger (2014). Nilsson et al. (2017) point out that "an industrial policy for well below 2 degrees Celsius" requires profound changes in industrial processes as well as innovation, trade, circular economy, energy and climate policies. They provide a brief overview of such a policy together with the innovation challenges for the processing industries and argue that a strong combination of technology push and market pull created by policy and regulation is needed in addition to the self-propelling voluntary markets. For this governments need long term visions, that can emerge from climate policy by looking beyond mid term targets, and by including all stakeholder groups e.g. using continuous joint participatory processes (Mathy et al., 2016).

These points make it clear, that deep decarbonization of processing industries needs not only strong technological innovation and strong new infrastructures but particularly a new targeted and integrated industrial policy approach which is;

- Target oriented; i.e. puts sustainability and decarbonisation at the center stage of its target system,
- Integrated as it integrates climate, energy, infrastructures, innovation and resource efficiency, and
- Inclusive by engaging industrial stakeholders together with all societal stakeholders and enabling them to revitalize a positive narrative around industrial production.

Such an industrial policy for a well below 2° future would clearly mean a new paradigm for industrial policy which goes far beyond traditional views of industrial policy as well as green growth strategies.

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