Pathways towards a European Low Emission Society
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Decarbonisation pathways for manufacturing & production sector

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Headlines

- With current technologies and trends in manufacturing, the industry sector will only achieve minor reductions of greenhouse gases (GHG) by 2050. Therefore, this sector is far from delivering the ambitious objectives of the Paris Agreement to keep global temperature rise to a well-below 2°C rise since pre-industrial times.
- The extent to which energy-intensive industries in the European Union will contribute to a decarbonised future will strongly depend on their ability to implement innovative, new technologies, and the development of new products with an increased material efficiency.
- The manufacturing sector and product markets have a number of GHG-reducing actions available. These include moving towards hydrogen-based chemicals, electricity-based steelmaking or low-carbon cement, changing product design and materials choice, moving away from primary to larger-scale secondary materials industries, and a switch in the energy carrier mix towards renewable electricity or fossil-free hydrogen.
- The industrial sector can reduce its GHG emissions by 90% against a business-as-usual trend by exploiting the full potential of GHG reduction options, considering barriers to implementation and other limitations.
- Barriers to the implementation of innovative technologies and even existing best available technologies include the high level of up-front investments that are needed, long investment cycles as well as wider sustainability concerns, regulations and standards or the scarcity of raw materials. Furthermore, possible lock-in effects, which describe the situation of customers being dependent on a single supplier or manufacturer for a specific service, whilst being unable to switch to another provider without substantial costs or inconvenience, may hinder the implementation of these technologies.

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The EUCalc model and the Transition Pathways Explorer

The EUCalc model user interface - the Transition Pathways Explorer - is a tool that allows users to build a pathway to a net-zero carbon future at European and Member State level. Its scientific mission is to provide a sophisticated, yet accessible, model to fill the gap between integrated climate-energy-economy models and the practical needs of decision-makers. The model relates emission reduction with human lifestyles, the exploitation and/or conservation of natural resources, job creation, energy production, agriculture, costs, etc. in one highly integrative approach and tool which enables decision-makers to get real-time policy support underpinned by comprehensive trade-off analyses.

Politicians, innovators and investors can use the EUCalc Transition Pathways Explorer to create their own pathways to a low-carbon future online, in real-time and together. This tool can help policy makers in the EU28 + Switzerland explore the routes they can take to delivering climate protection, whilst securing energy and other important policy priorities.

Background

The European manufacturing sector accounted for 750 $MtCO_2eq$ in 2015 or 19% of the total greenhouse gas (GHG) emissions (including land use, land-use change and forestry) according to the European Environment Agency (European Environmental Agency, 2015). CO_2 is the most significant GHG emitted from industrial processes with 720 million tonnes of direct emissions in 2015. Less than 5% of the industrial emissions (calculated in CO_2 equivalent) consist of other GHGs. The scope of the EUCalc model is to assess the decarbonisation potential that could be employed in the European manufacturing and production sector, primarily in the energy-intensive sectors such as iron and steel, chemicals, non-metallic minerals, and pulp and paper. Since the use of the best available technologies is not sufficient to meet the EU carbon mitigation goals by 2050, additional, energy efficiency improvements, the use of low-carbon energy and deepening the concept of circularity are required to perform the transition to a low-carbon future. The aim of this policy brief is to focus on the aspects of technological innovation necessary to meet the EU 2050 mitigation goals in most relevant European industries and to highlight the conditions and requirements needed for successful deployment.

Challenges in the European manufacturing and production sector

Industrial CO_2 emissions are a major concern as Europe tries to achieve the deep emission reductions required for its climate commitments. In the European Commission's "Roadmap 2050" (European Commission, 2011), one-quarter of the CO_2 emissions remaining mid-century is expected to come from industry, especially from energy-intensive sectors producing basic materials. The final report of the High-Level Panel of the European Decarbonisation Pathways Initiative states that in the European industrial sector considerable efforts are required to achieve compliance with the Paris Agreement and to reach carbon neutrality (EC, 2018).

To narrow the "emissions gap", i.e. the gap between the reduction commitments of CO_2 emissions and the actual CO_2 emission reduction, low-carbon and innovative technologies are required. This is a field in which European industries historically have a strong record in pioneering.

According to the EU Reference Scenario (Figure 1) (EC, 2016) available in the list to example pathways on the EUCalc Transition Pathways Explorer (see weblink at the end of this brief), industry as a whole is expected to make substantial efforts on energy efficiency, shifting towards less carbon intensive fuels. Following the economic crisis of 2008, a reduction in final energy consumption as well as emissions in the industrial sectors has been observed, exposing especially energy-intensive sub-sectors to a significant risk of carbon leakage - with businesses transfering production to non-European countries with laxer emission constraints leading to an increase in their total emissions.

Figure 1: Example of key behaviour selection the EUCalc model and ambition levels for the case of food waste.

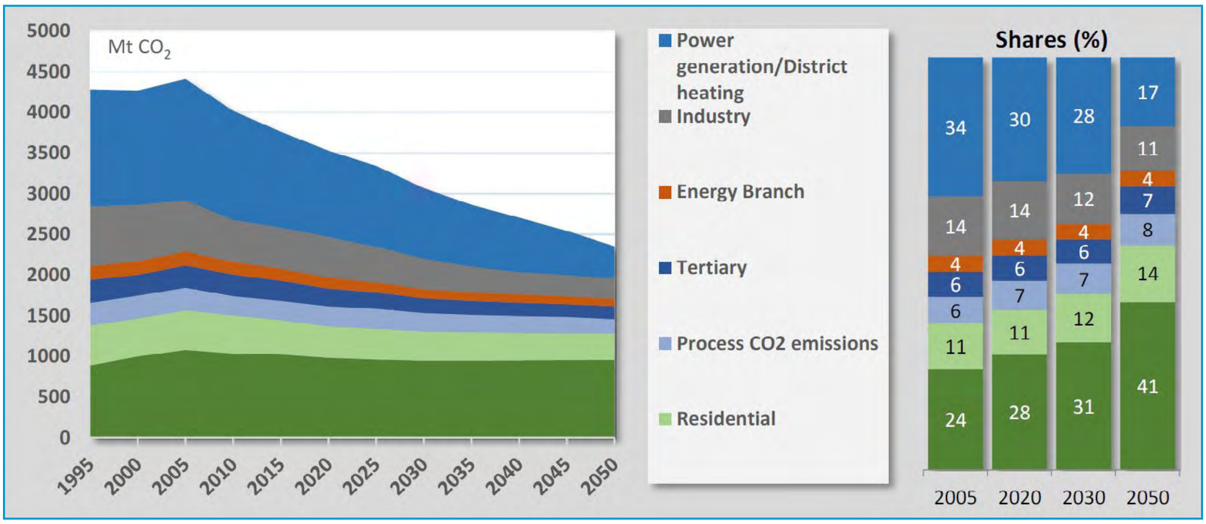

Figure 1: Evolution of carbon emissions [Mt CO_2] per year by sector in the European Union (EU REF 2016).

Low-carbon technologies

The dominant energy carriers in the European manufacturing sector are gas, electricity, coal and oil (Herbst et al., 2018). These are needed for a number of processes including production and assembly, steam and cogeneration, process heating, cooling and lighting. Options for transition scenarios in this sector are, for example, higher energy efficiency, fuel switching to renewable energy sources, innovative production technologies, circular economy elements, carbon capture and storage (CCS), material efficiency or material substitution. Due to the various production processes and the characteristics of materials used in the industrial sector, the options for energy and emission reductions are highly diverse. Therefore, no single technology can independently solve the decarbonisation challenge but a portfolio of technology options, aligned with other sectors is needed.

The "valley of death" on data availability and challenges of energy system modelling

Despite increased research initiatives in the field of low-carbon technologies in the energy and material intensive industries (e.g. Chan et al., 2019; Bataille et al., 2018; De Vita et al., 2018; Axelson et al., 2018; IEA, 2018; Nilsson et al., 2017; Material Economics, 2018), compiling data for technology mapping is a complex task. Inconsistencies in the available databases for the European industrial sector may reduce the accuracy of the results presented in the EUCalc model. Therefore, the model involves a series of cross-checking variables in order to reduce these uncertainties. It is also challenging to narrow the scope of analysis and determine the main assumptions for the modelling approach, whilst also keeping the calculator sufficiently robust and relatively easy to use by the targeted audience (policy makers, business leaders and NGOs).

Energy system models seem opaque and often inaccessible to outsiders, which may range from detailed, highly technical models of small sub-systems to large pure economic models covering whole economies. Therefore, the aim of the EUCalc model is to facilitate an open discussion in the energy system modelling community and to provide a shared, transparent knowledge-base on the evolution of low-carbon technologies and its assumptions.

Carbon mitigation simulations for the EU manufacturing & production sector

The manufacturing module in the EUCalc model requires a large set of input data, comprising main drivers such as activity data from demand modules (transport, lifestyles and buildings), technology specific parameters on energy and emissions, as well as policy parameters. The output of the model is calibrated to most recent EUROSTAT statistics, such as the Joint

Research Centre's Integrated Database of the European Energy Sector (JRC-IDEES) (Mantzos et al., 2018), including the energy balances, employment, energy prices, and industrial production at both country and processing levels. Technology data on costs, efficiencies and production shares were taken from literature or based on discussions with industry representatives and the technology database initiative. In addition to data on emissions and energy consumption, the technology database in the final version of the EUCalc model will also include data on air pollutants, technology efficiencies and costs.

Based on activities in demand sectors (buildings, transport, lifestyles), the projections underlying the EU Reference Scenario in EUCalc imply that a significant part of the energy-intensive industrial productions would remain constant by 2050 (Figure 2). The projection keeps track with a slight recovery of activity growth, which in the short term implies that sectors mainly use existing equipment, including less efficient ones.

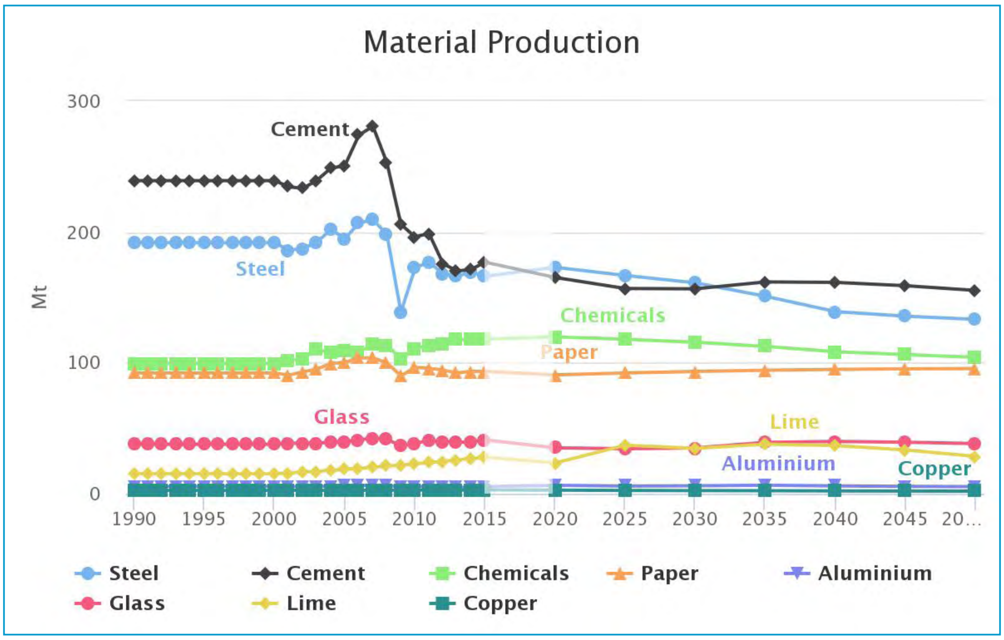

Figure 2: Material production [Mt] in the European Union by material until 2050 in the EU Reference Scenario, EUCalc Transition Pathways Explorer.

Subsequently, the technology pathways in the European steel and the cement sector are outlined, as they are the industry sectors with the highest shares of material production.

Technology pathways in the European iron and steel sector

Currently, steel is produced mainly via the primary steel making route in Blast Furnaces (BF) and Basic Oxygen Furnaces (BOF), primary steel making using Direct Reduction Iron plants (DRI), and the secondary route, in which steel scrap is re-melted in Electric Arc Furnaces (EAF).

Besides the optimisation of existing technologies and individual process steps or switching to alternative fuels (which are not part of the scope of this analysis), two technological options enter the stage, offering the production of "CO_2 -free" steel. The first option is the secondary steel, mainly produced from steel scrap and renewable electricity. If the electricity used in the process is generated from a renewable energy source, then the steel production could be close to "CO_2 -free" at the industrial level. Although the amount of collected scrap steel is not sufficient to meet the current market demand, it is expected to increase continuously towards 2050. The energy saving potential is estimated to be 70 % and CO_2 emission reduction of more than 90 % by 2050 (compared to conventional BOF).

The second option for deep decarbonisation in the iron and steel industry sectors emanates from hydrogen-based steelmaking. Currently intensively researched, the substitution of coal-based primary steelmaking with direct reduction of iron ore with hydrogen coming from renewable energy sources, can lead to a close to "CO_2 -neutral" production process at the industrial level. The economic viability of this process largely depends on electricity prices and, predominantly, the price for CO_2. The Swedish company SSAB and the Austrian Voestalpine, for example, are leading in the demonstration of this novel technology.

According to sector roadmaps, the penetration rate of these two technologies in a most ambitious scenario is 10% each in Europe in 2050, reducing emissions by 73% (Figure 3).

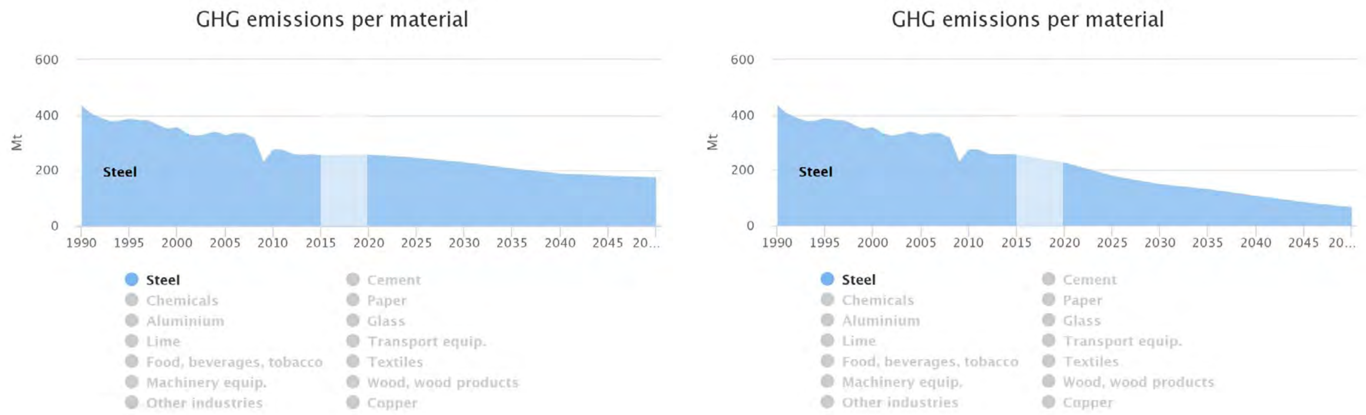

Figure 3: Greenhouse gas emissions in the iron and steel sector for the EU Reference Scenario (left) and most ambitious level (right), EUCalc Transition Pathways Explorer. Note: Iron and steel combined.

Technology pathways in the European cement sector

Cement is a mixture of finely granulated clinker and other additives, such as granulated slag, fly ash, lime and gypsum. Clinker is the core ingredient of cements and the most energy-intensive one. It is burned to pellets from limestone and clay in a rotary kiln at temperatures of 1,450°C. Cement plants are typically sized to meet a domestic, local market. Major production technologies are wet and dry kilns, with dry kilns (more than 90%) being the major technology in Europe. Cement production generates two types of emissions, combustion emissions, to heat the kilns and process emissions due to the chemical reaction.

Potential technology options for deep decarbonisation of cement are geopolymers. They provide the same function as ordinary Portland cement with a different underlying chemistry. Compared to Portland cement geopolymers do not generate any process emissions during production, removing more than 50% of cement-related emissions. The manufacturing of geopolymers is a low temperature process, thus avoiding most of the combustion emissions (estimated technology readiness level (TRL) of 9).

Another alternative technology is the cement produced from basic magnesium silicate rocks, containing no bound CO_2 in the used material. With an estimated TRL below 5, which means that the technology is tested in an experimental setup, this technology needs more research and technology development to achieve market readiness.

The potential for emission reductions in the European cement sector is estimated to be 76 % in the most ambitious scenario by 2050 (Figure 4) against the EU Reference Scenario, particularly due to the large-scale deployment of alternative binder technologies. However, most of the options to decrease the clinker-to-cement ratio and the related carbon footprint come with limitations to the availability of alternative binder materials and hence not technically feasible.

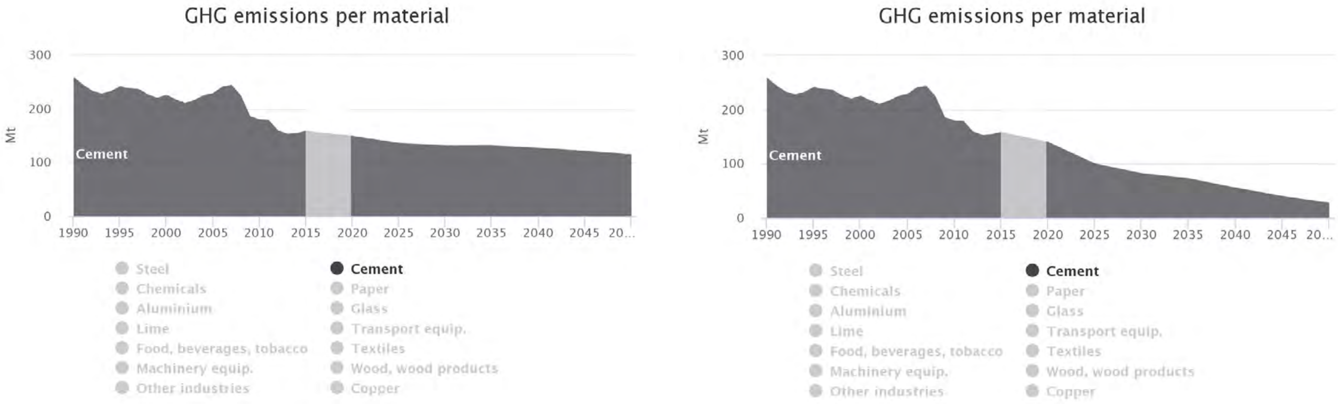

Figure 4: Greenhouse gas emissions in the cement sector for the EU Reference Scenario (left) and most ambitious scenario (right), EUCalc Transition Pathways Explorer.

For the definition of Technology readiness levels, see:
https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

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Further information on the EUCalc project:

The EUCalc project aims at providing a highly accessible, user-friendly, dynamic modelling solution to quantify the sectoral energy demand, greenhouse gas (GHG) trajectories and social implications of lifestyle and energy technology choices in Europe.

The novel and pragmatic modelling approach is rooted between pure complex society-energy systems and integrated impact assessment tools. The EUCalc model with its user interface - the Transition Pathways Explorer - has been designed to be both accurate but also accessible to decision-makers and practitioners. It covers all sectors and can be used by one or many people. The model is also open source so that experts can refine the model itself. The tool will have an e-learning version, the "My Europe 2050" tool as well as a Massive open online course (MOOC). See more on the EUCalc project, its scientific reports and all other outputs and access the Transition Pathways Explorer at:

www.european-calculator.eu

EUCalc partners:

Potsdam Institute for Climate Impact Research	
Imperial College London	
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Buildings Performance Institute Europe ASBL	
ÖGUT	
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Policy Briefs - Pathways towards a European Low Emission Society

The Policy Briefs on Pathways towards a European Low Emission Society, summarises key finding of the EUCalc project with a clear policy orientation, which provides practical climate change mitigation insights to both EU and individual Member States decision-makers. These policy briefs cover the following topics:

No. 1	The role of lifestyles changes in EU climate mitigation - Insights from the EU Calculator
No. 2	Innovation and technology development - Decarbonisation pathways for manufacturing & production sector
No. 3	Long-Term Renovation Strategies: How the building sector can contribute to climate neutrality in the EU
No. 4	Avoid, shift, improve - Decarbonisation pathways for the transport sector in Europe
No. 5	Mitigating GHG Emissions through Agriculture and Sustainable Land Use - An Overview on the EUCalc Food & Land Module
No. 6	Decarbonizing the EU electricity sector - From ageing powerplants to renewable energy futures
No. 7	Implications of decarbonizing the EU economy on trade flows and carbon leakages - Insights from the European Calculator
No. 8	Impacts of European air pollution on human health - A brief assessment of the EUCalc scenarios
No. 9	Pathways towards a fair and just net-zero emissions Europe by 2050

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