Breakthrough Strategies for Climate-Neutral Industry in Europe

Policy and Technology Pathways for Raising EU Climate Ambition

SUMMARY

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IMPRINT

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Policy and Technology Pathways
for Raising EU Climate Ambition

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ACKNOWLEDGEMENTS
We wish to thank the following colleagues for their contributions in various ways: Dr. Patrick Graichen, Frank Peter, Dr. Matthias Deutsch, Dr. Camilla Oliveira, Matthias Buck, Andreas Graf, Mara Marthe Kleiner, Fiona Seiler, Ada Rühring, Janne Görlach, Nikola Bock, Christoph Podewils (all Agora Energiewende), Prof. Dr. Manfred Fischedick, Prof. Dr. Stefan Lechtenböhmer, Clemens Schneider, Dr. Georg Holtz (all Wuppertal Institute), Hauke Hermann (Oeko-Institut)

This publication is available for download under this QR code.

Layout: RadiCon | Berlin, Kerstin Conradi
Cover: Matt_Brown | iStock
Proofreading: WordSolid

Please cite as:
Agora Energiewende and Wuppertal Institute (2020): Breakthrough Strategies for Climate-Neutral Industry in Europe (Summary): Policy and Technology Pathways for Raising EU Climate Ambition.

197/01-Z-2020/EN
Version 1.0, November 2020

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Preface

Dear reader,

The basic materials industries are a cornerstone of Europe's economic prosperity, increasing gross value added and providing around 2 million high-quality jobs. But they are also a major source of greenhouse gas emissions. Despite efficiency improvements, emissions from these industries were mostly constant for several years prior to the Covid-19 crisis and today account for 20 per cent of the EU's total greenhouse gas emissions.

A central question is therefore: How can the basic material industries in the EU become climate-neutral by 2050 while maintaining a strong position in a highly competitive global market? And how can these industries help the EU reach a higher 2030 climate target – a reduction of greenhouse gas emissions of at least 55 per cent relative to 1990 levels?

In the EU policy debate on the European Green Deal, many suppose that the basic materials industries can do little to achieve deep cuts in emissions by 2030. Beyond improvements to the efficiency of existing technologies, they assume that no further innovations will be feasible within that period. This study takes a different view. It shows that a more ambitious approach involving the early implementation of key low-carbon technologies and a Clean Industry Package is not just possible, but in fact necessary to safeguard global competitiveness.

We hope you enjoy reading this study.

Dr. Patrick Graichen,
Executive Director, Agora Energiewende

Prof. Dr. Manfred Fischedick
President, Wuppertal Institute

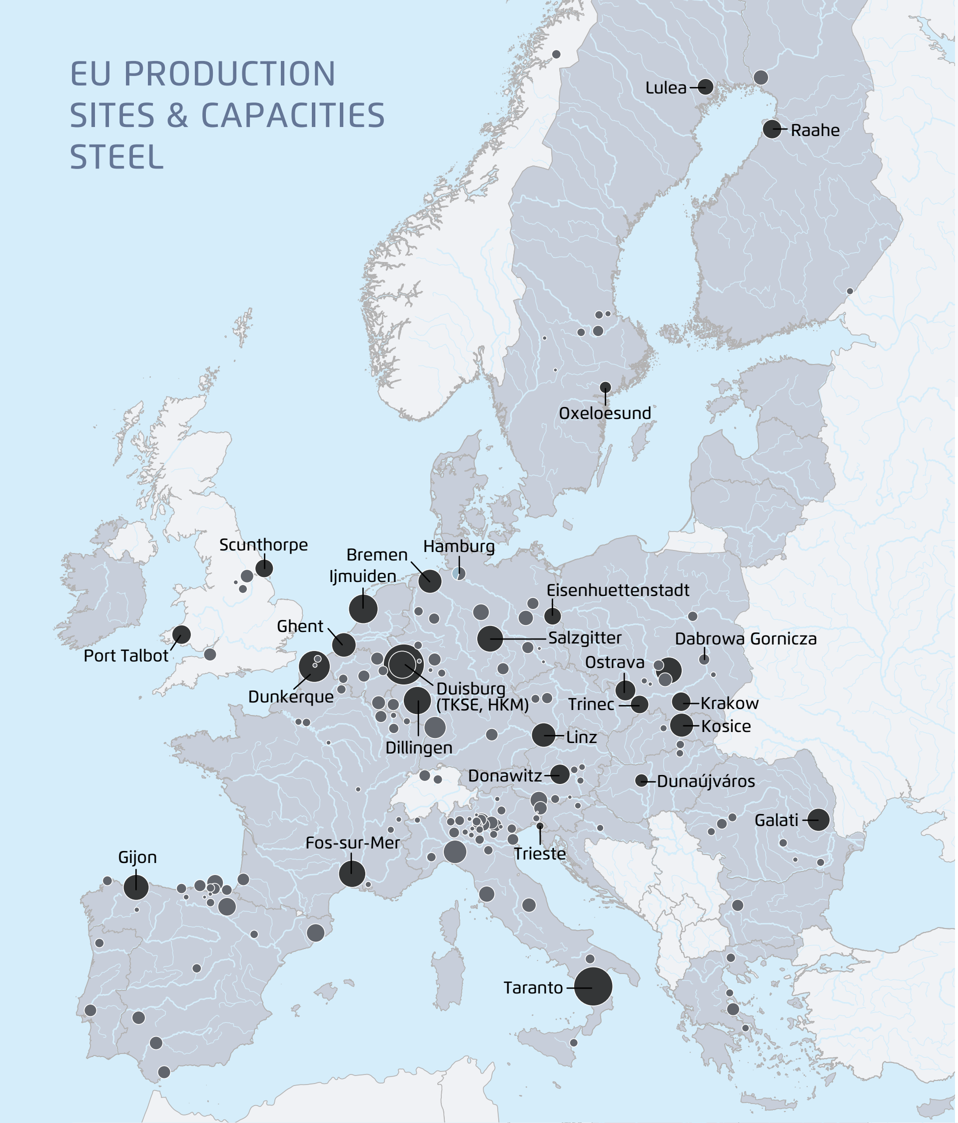
Key conclusions at a glance:

1. **Given the new paradigm of achieving climate neutrality by 2050, current climate and industry policies will lead to investment leakage or risk stranded industrial assets.** Industrial companies understand: The EU objective of climate neutrality by 2050 has clear implications for industrial reinvestment in the 2020s. Carbon-intensive technologies have lifetimes of up to 70 years. Reinvestments into long-lived assets will not be made unless there is an investment framework to deploy climate-neutral technologies.

2. **With a new policy framework, the basic materials industries can support an increased EU 2030 climate target of at least -55 per cent. Key low-carbon technologies are available and can be deployed well before 2030.** The CO_2 abatement potential of key low-carbon technologies in the steel, chemicals, and cement sectors alone amounts to 145 Mt of CO_2 by 2030, exceeding the required emission reductions from industry under the EU ETS. Their deployment will represent a breakthrough in Europe's industrial sector and ensure it a leading global role.

3. **By 2030, 30 to 50 per cent of existing assets in cement, steel, and chemicals will require major reinvestment. New policies are needed now to create a business case for breakthrough technologies.** Key low-carbon technologies are available, but their abatement costs are still in the range of 100 to 170 €/t of CO_2. The EU should adopt policy instruments to cover the gap between these abatement costs and the EU ETS price as soon as possible.

4. **Europe needs a Clean Industry Package in 2021 to kick-start breakthrough investments and protect existing assets.** By refining existing carbon leakage protection instruments it will be possible to protect existing plants until they can be replaced. At the same time, decisive support for investments in breakthrough technologies is needed. This should come in the form of carbon contracts-for-difference, planning and financing for clean-energy installations and infrastructure, and standards to create markets for climate-neutral and circular products.



Direct CO_2 emissions from the steel industry in the EU27 (+UK) in 2017
188 $MtCO_2$ (+12.6 $MtCO_2$ in the UK)

Steel production in the EU27 (+UK) in 2017
161 Mt of crude steel
(+7.5 Mt of crude steel in the UK)

Steel demand in 2017 (EU28)
159 Mt of finished steel

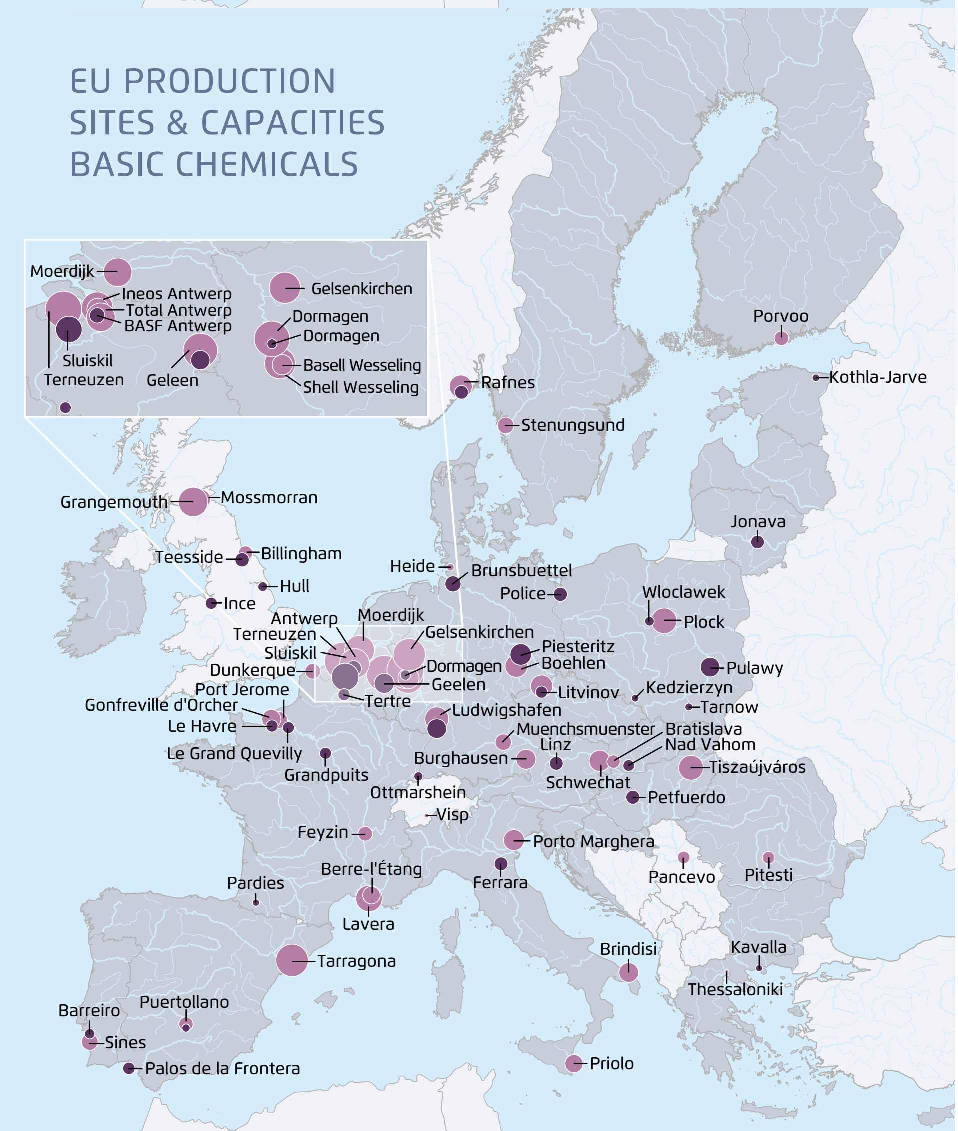
LEGEND

Production capacity crude steel

- Integrated blast furnace route (BF-BOF)
- Direct reduction with natural gas (DRI)
- Electric arc furnace with steel scrap (EAF)

- 1,000 kt/a
- 2,000 kt/a
- 3,000 kt/a
- 4,000 kt/a

Wuppertal Institute, 2020



Direct CO_2 emissions from the chemical industry in the EU27 (+UK) in 2017
129 $MtCO_2$ (+11 $MtCO_2$ in the UK)

Chemical production in the EU27 (+UK) in 2017
40.2 Mt of HVC (high value chemicals)
(+5.3 Mt of HVC in the UK)

Chemical demand in 2017 (EU28)
40.7 Mt of HVC

LEGEND

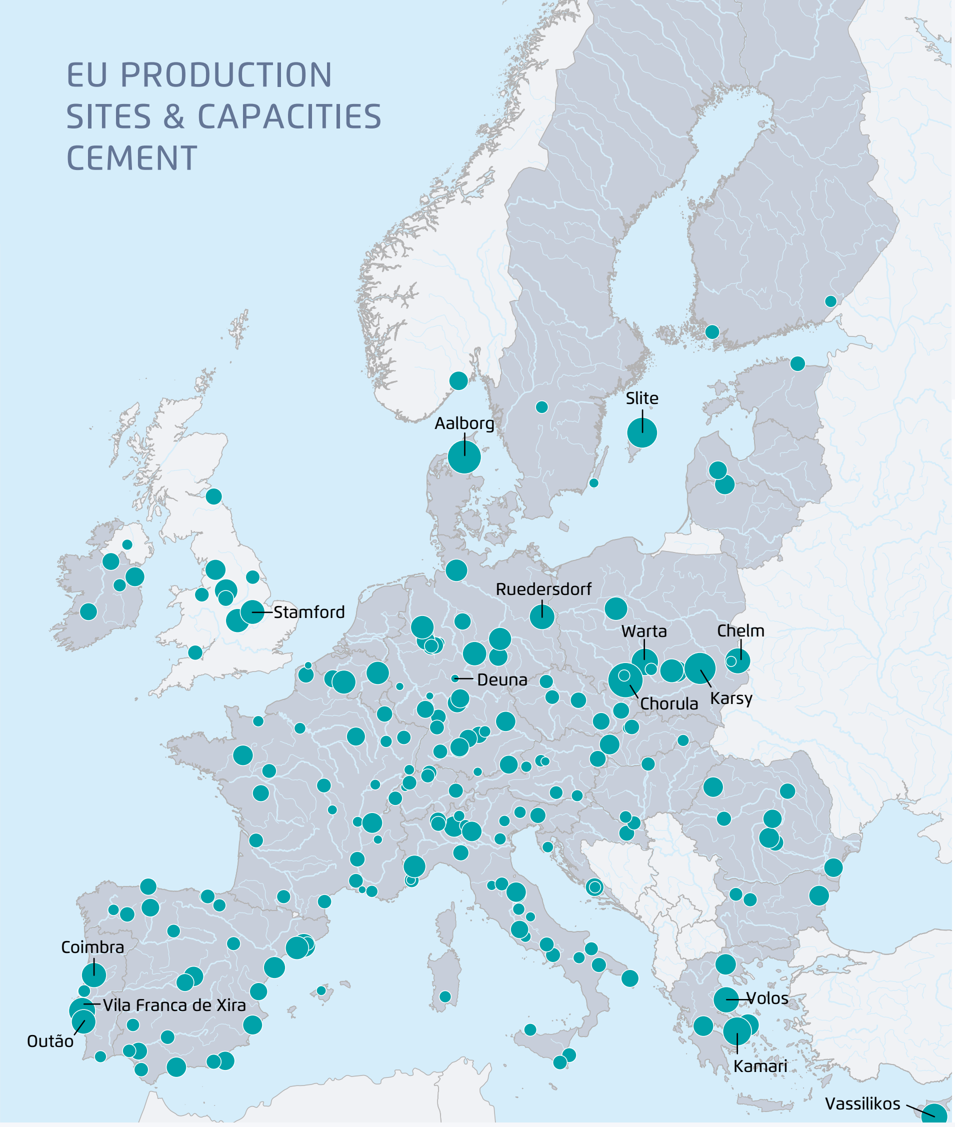
Production capacity basic chemicals

- Ammonia (kt/a)
- Steam crackers (kt HVC/a)

- 1,000 kt/a
- 2,000 kt/a
- 3,000 kt/a

Wuppertal Institute, 2020

EU PRODUCTION SITES & CAPACITIES CEMENT



Direct CO_2 emissions from the cement industry in the EU27 (+UK) in 2017
112 $MtCO_2$ (+6 $MtCO_2$ in the UK)

Cement production in the EU27 (+UK) in 2017
159 Mt of cement (+8.6 Mt of cement in the UK)

Cement demand in 2017 (EU28)
168 Mt of cement

LEGEND

Production capacity cement

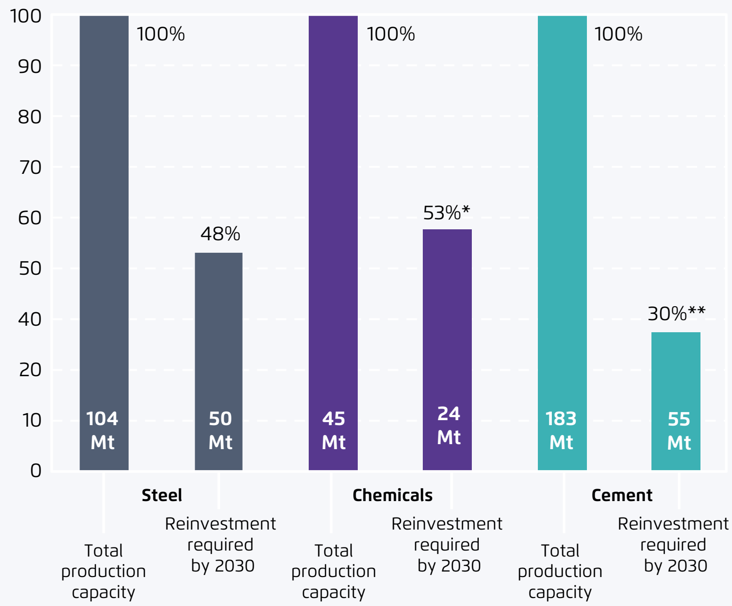
Cement clinker (kt/a)

1,000 kt/a
2,000 kt/a
3,000 kt/a
4,000 kt/a

Wuppertal Institute, 2020

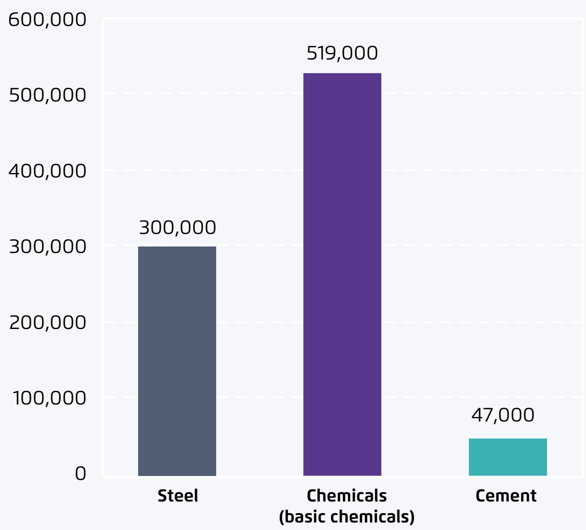
REINVESTMENT NEEDS BY 2030 AND DIRECT EMPLOYMENT IN CEMENT, STEEL AND BASIC CHEMICALS IN THE EU

REINVESTMENT REQUIREMENTS FOR PRIMARY PRODUCTION CAPACITY IN EU27 BY 2030



Source: Wuppertal Institute, 2020

PEOPLE DIRECTLY EMPLOYED BY THE SECTORS IN 2017



Source: Eurostat, 2020

Agora Energiewende/Wuppertal Institute, 2020

* Steam crackers are normally maintained and modernised continuously so that they do not have to be replaced all at once. Nevertheless, the graph provides a rough estimate of the reinvestment needs for existing facilities.

** Cement data represent numbers for Germany only. We estimate that the reinvestment requirements for the EU27 are in a similar range.

Content

1 Introduction

Under the European Green Deal and the 2030 Climate Target Plan, the European Commission has recommended that the EU reduce its greenhouse gas emissions by at least -55 per cent by 2030 (relative to 1990 levels) and achieve climate neutrality by 2050. European industry has a vital role to play in delivering this target. Direct industrial emissions accounted for 719 MtCO2eq in 2017, equivalent to approximately 20 per cent of annual net greenhouse gas emissions in the EU27 (Eurostat, n.d.).[1]

By 2030, EU industry will therefore need to reduce greenhouse gas (GHG) emissions in the range of 22 to 25 per cent compared with 2015 levels. To achieve climate neutrality by 2050, the EU will need to reduce its combined industrial emissions by approximately 95 per cent and offset residual emissions with carbon sinks.

So far, discussions have focused mostly on measures for meeting 2030 objectives. Based on the European Commission's Impact Assessment that accompanied the 2030 Climate Target Plan Communication[2] for industry, the targets represent a reduction of between 168 and 188 $MtCO_2eq$, i.e. 25 to 28 per cent of emissions in 2018.[3] According to the European Commission, this can be achieved using best available technologies referenced in the Impact Assessment.[4]

1 The figure excludes emissions from energy sectors such as upstream power and heat production, refining, and solid fuel production.

2 In the following this will be simply referred to as the Impact Assessment.

3 Since industrial GHG emissions have grown in recent years, the gap is larger for 2018 than for 2015.

4 See Impact Assessment, 2020.

We believe that a more sustainable approach is to define the path for industrial transformation based on the 2050 climate neutrality target. Hence, in this study we identify strategies and investments that meet the increased 2030 target and achieve climate neutrality by 2050. To those ends, we recommend the rapid introduction of key low-carbon breakthrough technologies that takes advantage of the EU's industrial modernisation needs over the coming decade. During this period, some 48 per cent of the EU's production capacities in the steel industry, 53 per cent of its capacities in the chemical industry, and 30 per cent of its capacities in cement production will need replacing or refurbishing. Reinvestment[5] in traditional production processes, even if the best available technologies are used, is not an option so long as those processes are not easily convertible to zero-carbon or carbon-negative operation.

Though the necessary breakthrough technologies exist, their deployment will require appropriate policies. In this regard, the EU is at a crossroads: either institute breakthrough technologies aligned with the European Green Deal and a sustainable recovery from the Covid-19 economic crisis, or face a high risk of accelerated deindustrialisation, job losses, stranded assets, and carbon leakage.

This paper presents concrete strategies and pathways that capitalise on opportunities for breakthrough development in European industry. We opt for a dual approach that deploys breakthrough technologies for industrial capacities in need of reinvestment while allowing industrial assets with traditional processes to continue operation until they are scheduled for replacement.

5 Reinvestment refers to investments that are required to maintain production capacities when existing production capacities reach the end of their lifetime.

The goal of this study is to define a Clean Industry Package at the EU and member-state levels that mobilizes investments that are compatible with meeting an EU 2030 climate target of at least -55 per cent while laying the groundwork for long-term climate neutrality and economic prosperity.

2 Where do the EU basic materials industries currently stand?

2.1 The role of industry in the economy

Basic materials industries are a cornerstone of the EU's economy and prosperity. In addition to making a major contribution to GDP, they directly provide over 1.8 million high-quality jobs.[6] As the starting point of Europe's industrial value chains, they provide basic materials such as steel, chemicals, and cement that are essential to every-day life today and the climate-neutral infrastructure of the future. These industries are also the fundament of several millions of indirect manufacturing jobs and the foundation of regional industrial clusters that often extend beyond the borders of individual member states. Naturally, the EU wants to preserve the competitiveness and strategic role of these sectors while reducing their GHG footprint. This means preventing market share loss and carbon leakage and maintaining the integrity of European value chains to ensure resilience against future crises.
To do both, the EU needs a technology transition that puts its basic materials industries on a steady and sustainable path to climate neutrality.
A transformation based on smart policies and key low-carbon technologies will ensure long-term economic prosperity, jobs, and income, and it will position the EU as a leader in technologies, markets, and standards that align with the new climate-neutrality paradigm.

6 The employment numbers for 2017 are based on Eurostat 2020.

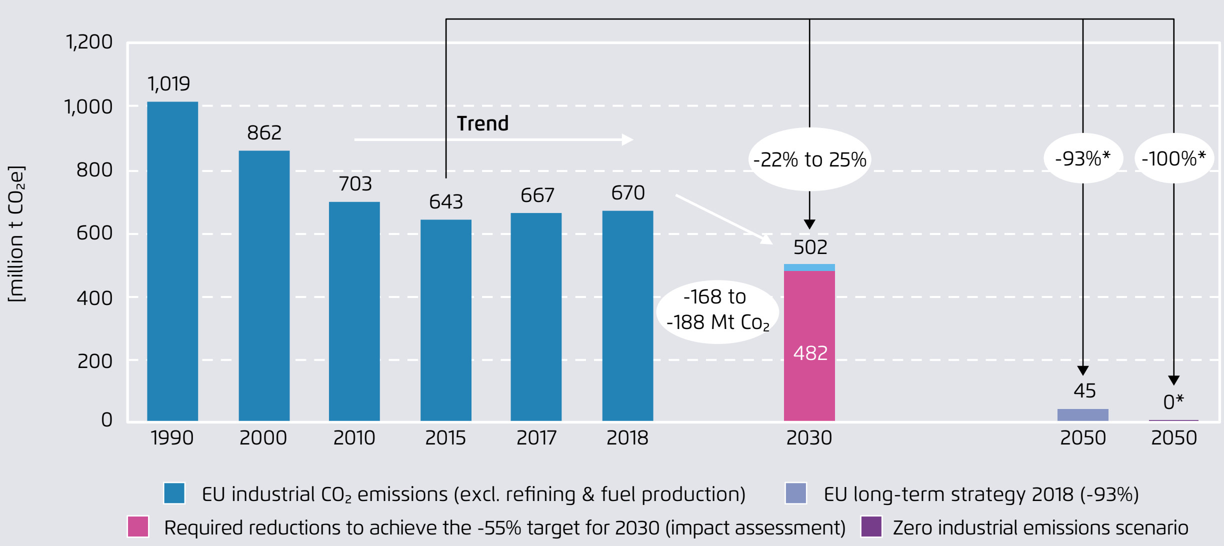
2.2 Opportunities and challenges for industry to achieve higher climate ambition in 2030 and climate neutrality in 2050

The EU has set itself the goal of achieving climate neutrality by 2050. This means that all sectors, including the so-called "hard-to-abate" industries such as steel, chemicals, and cement, will have to become virtually climate-neutral within the coming three decades. In addition, the European Commission recommended in its 2030 Climate Target Plan Communication from September 2020 to increase the EU's greenhouse gas reduction targets from -40 per cent to at least -55 per cent by 2030 (relative to 1990 levels). On 7 October 2020 the EU parliament even voted in favour of increasing this greenhouse gas reduction target for 2030 to -60 per cent. A final decision on the EU 2030 climate target has not been taken yet, but is expected in December 2020.

An EU climate target of at least -55 per cent would require heightened emission reduction efforts for the industrial sector. Despite reductions during the 1990–2010 period through energy efficiency measures, industrial greenhouse gas emissions have stayed mostly constant since then (see figure ES.1). In 2015, emissions began to rise along with economic growth. Though energy efficiency continues to be important, it alone will not suffice for a -22 to 25 per cent reduction by 2030, as indicated in the European Commission's Impact Assessment. Moreover, there is a risk that pressure or incentives to invest in efficiency measures for GHG-intensive assets with long lifetimes offers only a marginal GHG abatement benefit while increasing capital allocation and operational lifetimes. The result would be that short-term mitigation conflicts with the long-term climate neutrality objective.

CO_2 emitted by the EU27 industrial sector from 1990 to 2018 and proposed sector targets for 2030 and 2050

Figure ES.1



Agora Energiewende, 2020, based on data from Eurostat, European Comission & EEA

Note: Data are for CO_2 emissions only. They exclude non-CO_2 emissions from industry, from refining, solid fuel production for energy and non-energy uses.

* To achieve climate neutrality, residual emissions will have to be offset by negative emissions technologies, many of which could be developed in the industrial sector such as BECCS. By capturing and using CO2 from other non-industry sectors, industry can provide net-negative emissions.

This is why the introduction of key low-carbon technologies is needed for industrial plants when they are scheduled for replacement or refurbishment. These technologies can make up for the stagnating emission reductions of the last decade and initiate a steady path to climate neutrality.

Currently, the EU's basic materials industries are preoccupied with the immediate economic effects of the Covid-19 pandemic. Due to lockdowns and significantly decreased economic activity in virtually all EU member states, it is clear that the demand for basic materials such as steel, cement and some chemical products will be significantly lower in 2020 than in previous years. For instance, the steel industry in Europe was particularly affected by decreased demand from key sectors such as car manufacturing and machinery production and cement companies faced a decline in construction activity. It is uncertain when and if demand will return to pre-crisis levels. The difficult economic environment has already started to force some companies to make temporary plant closures permanent, as with ArcelorMittal's Krakow plant in Poland. The risk is that productive capacities will be eliminated and that the crisis will accelerate the relocation of industrial capacities to other countries. And because most other countries have more GHG-intensive production methods than Europe, this will lead to carbon leakage.

At the same time, the crisis has also created opportunities. For instance, the unprecedented amount of public funding for economic recovery such as the *Next Generation EU Facility* and the national rescue funds can be used to give public investment support for the industrial transformation. *Next Generation EU* provides members states 750 billion € to be spent during the 2021–2025 period; 30 per cent must be spent on climate-related measures.

This funding is in addition to the general EU budget (the *Multi-annual Financial Framework* or MFF) and the new *EU Innovation Fund*.[7] The question now is how these funds can be best allocated to maximise long-term benefits as well as short-term economic recovery. As a principle, it is important that the funds are used to accelerate the energy transition across all sectors. This means that investment support should target innovative solutions that are compatible with climate neutrality and readily available for deployment. Moreover, they must offer sustained greenhouse gas abatement and other economic benefits.

From the perspective of the industrial transformation, it is important to create an adequate regulatory framework for investment in key low-carbon technologies. With the effective use of *Next Generation EU* funding, the EU and its member states could kickstart a green industrial revolution in energy-intensive sectors. Besides compensating for the immediate economic impacts of the Covid-19 crisis, the development and commercialisation of key low-carbon technologies during the coming decade would put European companies at the forefront of growing domestic and international markets for clean basic materials, production technologies, and climate-neutral consumer products.

Climate neutrality is emerging as the new paradigm not only in the EU but also at the international level. China, the largest emitter of greenhouse gases and producer of energy-intensive basic materials, has announced a plan for carbon neutrality by 2060. Japan, the world's third largest economy, and the Republic of Korea, another heavyweight in energy-intensive industries, have also announced net-zero targets for 2050. Moreover, the designated US president Joe Biden has pledged that his administration will make achieving climate neutrality by 2050 a top priority.

Such pledges are not limited to countries. In September 2020, ArcelorMittal, the world's largest steel producer, announced its commitment to company-wide carbon neutrality by 2050. Thyssenkrupp Steel Europe, the EU's second-largest producer after ArcelorMittal, has vowed to make itself climate-neutral by mid-century. LafargeHolcim and HeidelbergCement, the world's number one and two cement producers by volume, have announced targets of carbon neutrality by 2050 backed by the science-based target initiative.

Because industrial assets have long lifetimes – 40 years on average – the investments in new production capacities need to be assessed based on their compatibility with respective climate or carbon neutrality targets. Therefore, the transition to a climate-neutral industry in China and other major industrial economies will need to start well before 2030. In fact, it would not be surprising to see the first signs of this paradigm shift to carbon neutrality in China's 14th Five Year Plan (2021–2025). These announcements do not only open the door for international cooperation on the transition to climate neutral industry; they also herald the creation of large future markets for climate-neutral basic materials and key low-carbon technologies. The EU must not miss the opportunity to position itself as a global leader in this unprecedented transformation. The key low-carbon technologies to achieve climate neutrality are either already available or nearly market-ready – with many of them being developed in and by EU companies.

7 https://ec.europa.eu/info/live-work-travel-eu/health/coronavirus-response/recovery-plan-europe/pillars-next-generation-eu_en

2.3 A portfolio of climate-neutral technological solutions in the offing

Technological solutions that could be harnessed to make energy-intensive basic materials industries almost entirely climate-neutral are already known. Some solutions, such as the production of green hydrogen from renewable energies, are nearly market-ready and are set to be scaled up during the coming years. Other examples of key low-carbon technologies include: the direct reduction of iron ore with natural gas or hydrogen in the steel industry (instead of conventional reduction in coal-fired blast furnaces); the chemical recycling of plastics (instead of their production from virgin fossil fuels and the incineration of the resulting waste plastics); and carbon capture and storage (CCS) for cement emissions. Figure ES.2 describes 13 key technologies that can significantly reduce greenhouse gas emissions in the steel, chemical, and cement industries. Other promising key low-carbon technologies such as smart crushing for cement recycling, recarbonation, circular economy and material efficiency measures also have much potential for reducing industrial greenhouse gas emissions.

At present, the key low-carbon technologies are still significantly more expensive than conventional manufacturing processes. Furthermore, the additional costs cannot be passed on to customers because of fierce international competition. To stimulate investment in these breakthrough innovations now,

Overview of possible key technologies for nearly carbon-neutral basic materials industries — Figure ES.2

Steel	Key technology	Earliest possible market readiness
	Direct reduction with hydrogen and smelting in the electric arc furnace	before 2025 (initially with natural gas)
	Alcaline iron electrolysis	2040 – 2045
	HIsarna® process in combination with CO_2 capture and storage	2030 – 2035
	CO_2 capture and utilisation of waste gases from integrated blast furnaces	2025 – 2030
Chemicals	**Key technology**	**Earliest possible market readiness**
	Heat and steam generation from power-to-heat	From 2020
	CO_2 capture at combined heat and power plants	2030 – 2035
	Green hydrogen from renewable energies	2020 – 2030
	Methanol-to-olefin/-aromatics route	2025 – 2030
	Chemical recycling	2025 – 2030
	Electric steam crackers	2035 – 2045
Cement	**Key technology**	**Earliest possible market readiness**
	CO_2 capture with the oxyfuel process (CCS)	2025 – 2030
	CO_2 capture in combination with electrification of the high temperature heat at the calciner	2025 – 2030
	Alternative binders	2020 – 2030 (depending on product)

Agora Energiewende/Wuppertal Institute, 2020 the government needs to create concrete policy proposals signalling to industry actors that it will actively support the transformation.

2.4 European industry at the crossroads

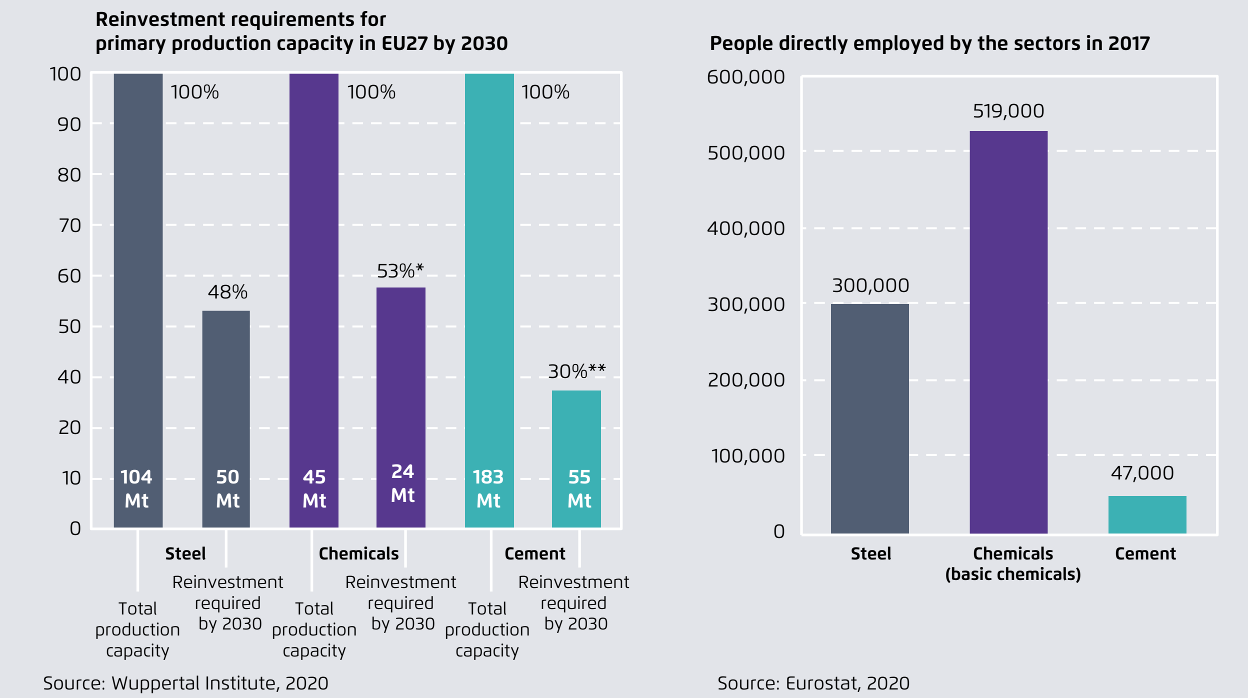
Because of the long lifetime of productive assets, the European basic materials industries stand at the crossroads: between now and 2030, roughly half of the EU's primary steel manufacturing and steam cracker facilities and an estimated 30 per cent of its cement production plants will reach the end of their lifetimes.

Since the lifetimes of these industrial assets range from 20 to 70 years (see figure ES.4), the reinvestment and location choices that companies in the steel, chemical, and cement sectors make during the next decade will create long-lasting path dependencies. Against the background of the 2050 climate neutrality target, this means that from now on all major investment must be focused on technologies that can operate with zero- or net-negative carbon emissions, if stranded assets (i.e. the premature shutdown of well-functioning plants) and high economic losses are to be avoided.

A special case is the relining of blast furnaces in the steel industry. While new and integrated steelworks have a technical lifetime of 50 years, blast furnaces – which make up the core operation of steel plants – must be relined every 20 years or so. A relining in 2025 can extend a plant's operational lifetime to 2045

Reinvestment needs by 2030 and direct employment in cement, steel and basic chemicals in the EU

Figure ES.3

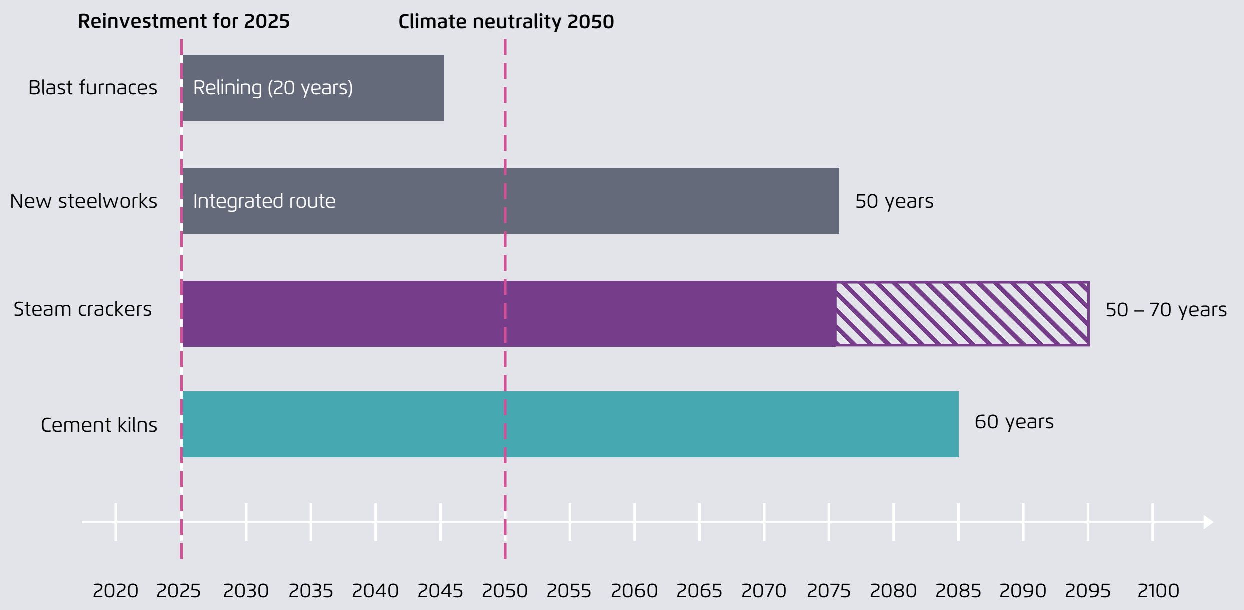


Agora Energiewende/Wuppertal Institute, 2020

* Steam crackers are normally maintained and modernised continuously so that they do not have to be replaced all at once. Nevertheless, the graph provides a rough estimate of the reinvestment needs for existing facilities.
** Cement data represent numbers for Germany only. We estimate that the reinvestment requirements for the EU27 are in a similar range.

Technical lifetime of selected primary production plants in the steel, chemical, and cement sectors scheduled to receive reinvestment in 2025

Figure ES.4



Agora Energiewende / Wuppertal Institute, 2020

and in theory is still compatible with the EU's 2050 climate-neutrality target. But relining conventional blast furnaces runs the risk of making them stranded assets, representing a lost opportunity for building a steady path to climate neutrality. Under the more ambitious EU 2030 climate target of at least -55 per cent, the European Commission's Impact Assessment projected that the share of coal will represent no more than 2 per cent of the EU's 2030 power mix. By 2035, conventional blast furnaces would be some of the last coal-based, high-emitting assets in the entire EU economy. In such an environment, continued operation until 2045 would be questionable. Such an asset would face increasing carbon prices, stricter environmental regulations, pressure from NGOs, and declining demand for its high-carbon products both domestically and abroad. Moreover, the transition to a climate-neutral industry is about more than replacing individual assets. It is also about transforming the logic of existing industrial clusters and the related energy infrastructure, a process that requires much time and planning. At the same time, it is important to transform the skills and capacities of the industrial workforce, the service providers, and the equipment industry.

However, this reality is not yet widely understood. For example, in its Impact Assessment, the European Commission largely focused on the deployment of conventional best available technologies to achieve the required industrial emission reductions under the EU ETS for an increased EU 2030 climate target of at least -55 per cent. While this may, in theory, be a sound strategy to achieve the CO_2 abatement requirements of 2030, given the long lifetimes of industrial assets and the 2050 climate neutrality target, this would not be a sustainable strategy beyond 2030 for major reinvestments in the basic materials industries. Moreover, the use of technologies that do not allow zero-carbon or carbon-negative operation (or that cannot be easily converted to provide such operation) would also represent a lost opportunity in preparing for the broader transition to climate neutrality. Any rationally acting company and financial investor in Europe will foresee the long-term risks of stranded assets and will be reluctant to make reinvestments in CO_2-intensive assets in the 2020s. Besides, the promise of future conventional plant conversions to use clean hydrogen[8] or carbon capture and storage may prove elusive, especially for reinvestments in regions where access to clean hydrogen or the transport of CO_2 to sites for carbon capture are unlikely to be developed.

Whether a particular investment or technology does or does not provide a solid foundation for the steady path to climate neutrality depends of course on the sector, process, and site. Ultimately, it will be up to industry and financial investors to decide on the best course of action. But state aid guidelines and policy instruments should be optimized to ensure effective investment incentives. The regulatory framework should promote technologies that have demonstrated their compatibility with climate neutrality by 2050, are readily available for deployment, and offer sustained greenhouse gas abatement and other economic benefits. At the same time, there must be clear policy guidance at the EU level that both limits the risk of high-carbon technology lock-in and reduces the possibility of future state aid for "bailing out" GHG-intensive investments that are clearly incompatible with the climate neutrality goal.[9]

In the absence of a sound Clean Industry Package to steer a steady path to climate neutrality by 2050, the EU basic materials industries remain in limbo. Right now, there is no viable business case for investments in key low-carbon technologies. At the same time, investing in conventional assets that are marginally more efficient from the perspective of greenhouse gas emissions but create a certain level of carbon lock-in and therefore risk being stranded under increasingly stringent greenhouse gas abatement targets and carbon prices is not a viable option, either. As a result, many companies may decide not to invest in the EU and move their production to other parts of the world with less climate ambition.

If the uncertainty continues, it is very likely that Europe will lose productive capacity, resulting in reduced GDP, the destruction of industrial networks and integrated value chains, the loss of jobs, carbon leakage, and increased global greenhouse gas emissions.

Based on this analysis, there are two possible pathways for the future of individual assets and industrial sectors. Depending on the specific situation of each installation and member state, different pathways may and will occur, of course. However, the objective of an adequate regulatory framework under an EU Clean Industry Package must be to optimize the outcome from an economic, social, and environmental perspective. Figure ES.5 illustrates two scenarios:

→ **Scenario 1:** New investment outside Europe (carbon and investment leakage), *without dedicated policy intervention*
→ **Scenario 2:** Green investment under the EU Green Deal, *with a Clean Industry Package investment framework*

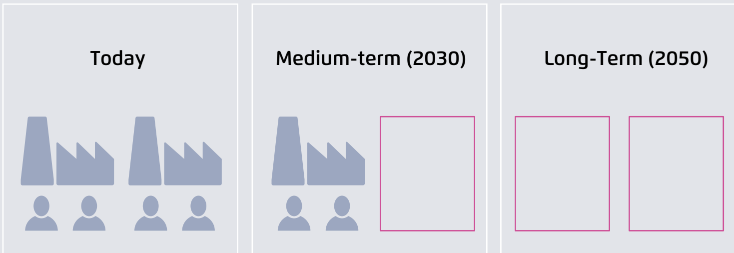
Which pathway the basic materials industries will take will be determined by the investment choices in the 2020s which will have a major impact on innovation, climate ambition, the economy, and hundred thousands of jobs in the EU's steel, chemical, and cement sectors (see figure ES.5). These choices, in turn, will be shaped by regulatory conditions. While it is clear that scenario 2 is the most desirable option, the situation today of the EU basic materials industries is

8 "Clean hydrogen" includes both "green hydrogen" (produced from water electrolysis with renewable electricity) and "blue hydrogen" (produced from fossil fuels with carbon capture and storage) as well as "turquoise hydrogen" (from methane pyrolysis with storage of the resulting carbon black).

9 One possible way to do this is via the establishment of climate-neutral technology standards under, say, the Industrial Emissions Directive, and which would apply to major investments with lifetimes beyond 2030 (see Section 5.2).

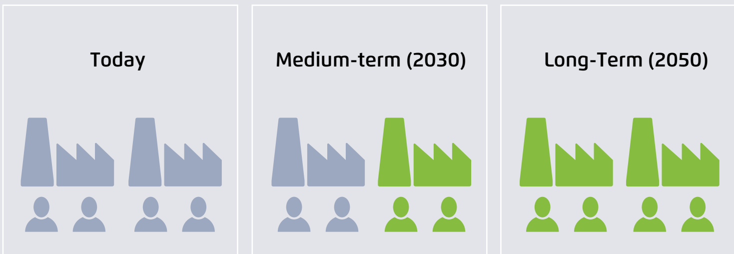
Two scenarios for new investment in the 2020s and their implications for climate change, the economy, and employment in the EU — Figure ES.5

Scenario 1: New investment outside Europe (carbon and investment leakage), *without dedicated policy intervention*



- → **Reinvestment requirements:** are not met in Europe because there is no business case for either conventional or low-carbon technologies
- → **Climate ambition:** massive carbon leakage as industry production moves to other parts of the world with less climate ambition
- → **Economy:** loss of gross value added, increased import dependency
- → **Employment:** high job losses in 2020s, high uncertainty for 2040-2050

Scenario 2: Green investment under the EU Green Deal, *with a Clean Industry Package investment framework*



- → **Reinvestment requirements:** are met with key low-carbon technologies
- → **Climate ambition:** complies with EU 2030 and 2050 climate targets
- → **Economy:** innovation in key technologies; technology export likely
- → **Employment:** future-proof green jobs in the medium- and long-term; just transitions within incumbent companies

Agora Energiewende, 2020

closer to scenario 1. Rational companies will foresee the long-term risks for reinvestment in conventional CO_2-intensive technologies, but because they do not have a credible business case for investment in key low-carbon technologies, they may decide not to reinvest in Europe at all. The result would be a creeping decline of the basic materials industries in Europe. What is worse, the stark economic consequences of the Covid-19 pandemic have already put immense pressure on basic materials companies in virtually all EU member states, making them more reluctant to make unsafe bets in Europe.

For all that, scenario 2 is still within reach, but requires an adequate investment framework for key low-carbon technologies. As the next section demonstrates, meeting the urgent reinvestment requirements with a swift deployment of key low-carbon technologies in the 2020s will allow EU industry to meet an increased EU 2030 climate target of at least -55 per cent. In contrast to reinvestment in conventional best available technologies, this will put the EU's industry on a steady path to climate neutrality.

3 Breakthrough technology pathways for climate-neutral industry

3.1 How much do EU ETS industries need to contribute to higher EU climate ambition 2030?

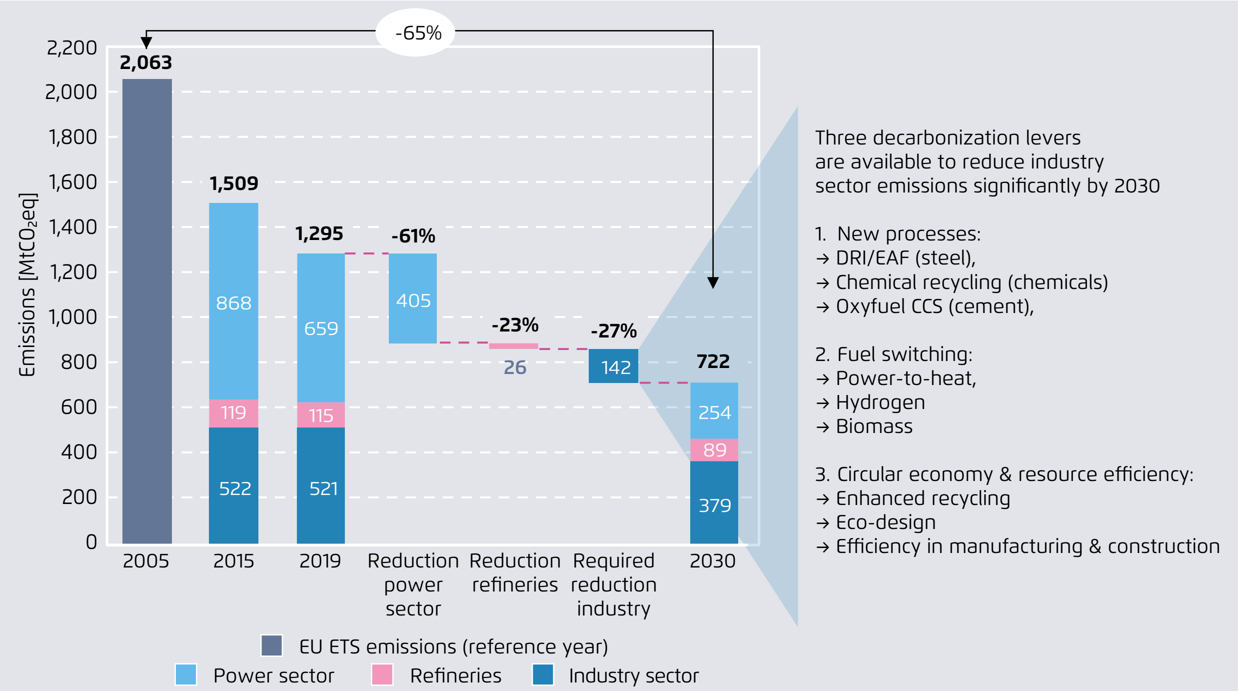
To meet the increased EU 2030 climate target, significant emissions reductions have to be delivered by the energy-intensive basic materials industries under the EU Emissions Trading Scheme (EU ETS).[10]

10 The significant greenhouse gas emission reduction potential in non-ETS industry sectors was not included in this study.

Based on the European Commission's "MIX" scenario in the Impact Assessment, a -55 per cent economy-wide climate target for the EU by 2030, we have assumed a 65 per cent reduction of the greenhouse gas emissions cap for the EU ETS relative to that in 2005 (see figure ES.6).

This would represent an ambitious reduction target for current EU ETS sectors and would require gradually reducing the emissions cap from 1,295 $MtCO_2eq$ in 2019 to 722 $MtCO_2eq$ in 2030. Following the Impact Assessment, we assume that

Expected emissions reductions from EU ETS industry for the EU's 2030 -55% climate target, along with decarbonisation levers to deliver those reductions — Figure ES.6



Agora Energiewende, 2020, based on data from European Commission, EEA, and Eurostat.

Note: Emissions that relate to industrial processes such a coking plants and power plants for industrial use are accounted for in the industry sector and not in the transformation sector. ETS emissions in 2005 are notional base-year emissions with respect to the 2030 target, i.e. they account for the change in the ETS scope and size of the EU since 2005.

by 2030 the power sector will have reduced its emissions by 71 per cent and that refineries will have lowered their emissions by 25 per cent (both relative to 2015 levels).

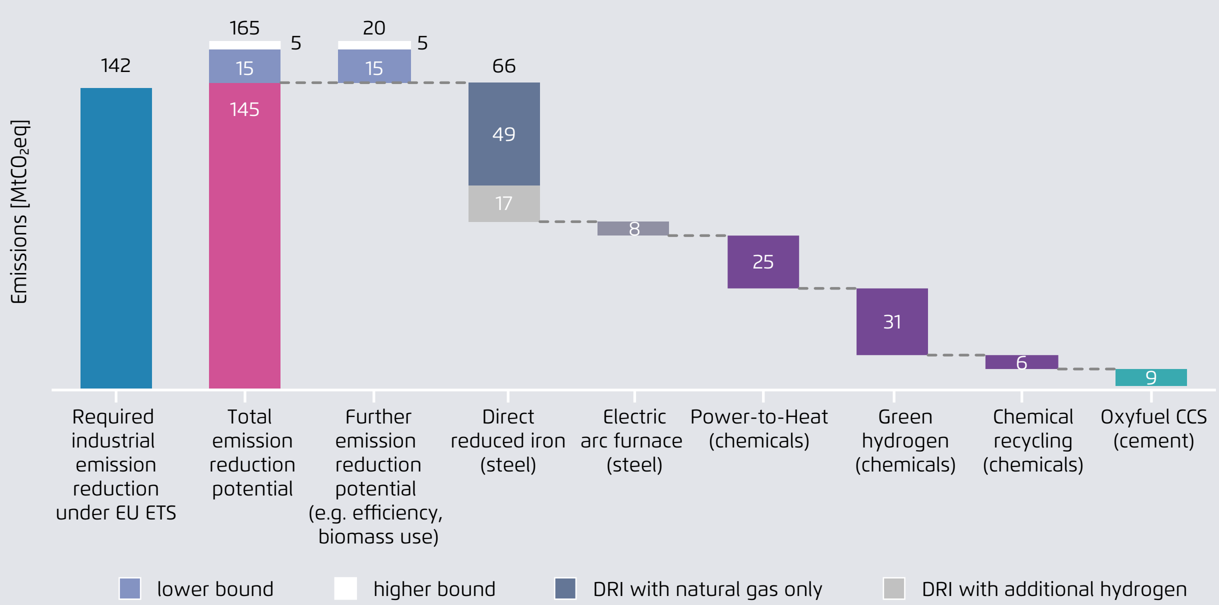
This latter assumption is derived from the required emission reductions of the transport sector (approximately 20 per cent relative to 2015 levels) and from the assumed *partial* adoption of more efficient technologies to limit EU ETS compliance costs[11]. For industry sectors covered by the EU ETS, this would mean a need to reduce emissions by 27 per cent relative to 2015 levels, or a total of **142 MtCO_2eq** relative to 2019 levels.

11 See pages 178 and 213 of the Impact Assessment.

3.2 GHG abatement needs can be met with key low-carbon technologies

The strategic deployment of key low-carbon technologies in the basic materials industries has great potential to significantly reduce CO_2 emissions by 2030 and prepare the path to climate neutrality. Indeed, the required CO_2 reductions for industry under the EU ETS, for an EU 2030 climate target of at least -55 per cent, can be achieved by a decisive deployment of key low-carbon technologies in the steel, chemical and cement sectors *alone*. Overall, the abatement potential of these three sectors amounts to **145 MtCO_2** and thus exceeds the required emissions reductions of *all* industry sectors under the EU ETS (see figure ES.7). Further significant emission reduction potential exists through cross-cutting strategies such as biomass use, energy efficiency, and circular economy measures in other industry sectors of the EU ETS.

CO_2 abatement potential of selected key low-carbon technologies in the steel, chemical, and cement sectors by 2030 — Figure ES.7



Agora Energiewende / Wuppertal Institute, 2020

By contrast, the Impact Assessment greatly relies on a switch to conventional best available technologies to meet GHG abatement requirements for 2030. The problem is that these technologies are not always compatible with the climate-neutral objectives for 2050. We have thus devised a scenario that focusses on climate neutrality as defined by the European Green Deal to spur innovation and green investment and secure future-proof industrial jobs and economic resilience.

For this vision to become reality, industrial companies will require a framework for investing in key-low carbon technologies, an infrastructure for clean hydrogen and CCS, and a sufficient and stable supply of green electricity (see sections 4 and 5). Our estimates are not based on a modelled scenario, but, rather, illustrate the CO_2 abatement potential of certain key low-carbon technologies if deployed in the industrial sector based on their effective or projected technological availability by 2030. Greenhouse gas abatement potential was calculated based on the 2017 asset base and production levels.

In the scenarios below, we apply only technologies that would be available with high confidence for large-scale deployment by 2030. Accordingly, we ignore a host of supply-side key low-carbon innovations that could nonetheless further contribute to the transition to climate neutral industry beyond 2030. Furthermore, our estimates do not include demand-side measures to increase recycling rates and quality or to improve material efficiency in final products. Hence, our estimates are somewhat conservative in what they assume about total mitigation potentials by 2030 and for the path to climate neutrality by 2050.

3.2.1 Key low-carbon technologies in steelmaking

In line with the EU Green Deal's overarching vision of innovation, future-proof investments, and increased climate ambition, we assume that there will be no new investment in conventional coal-based blast furnace technology. Instead, the 48 per cent of primary steel capacity that requires relining or reinvestment before 2030 will be replaced with key low-carbon technologies that are already available and that are compatible with the climate neutrality target. Based on these criteria, we selected the production of direct reduced iron as a technology for primary steelmaking and the electric arc furnace for secondary steelmaking.

Direct Reduced Iron (DRI) for primary steel production: DRI with clean hydrogen is the only key low-carbon technology close to market readiness that can significantly reduce emissions in primary steelmaking – by up to -97 per cent relative to the blast furnace route. Moreover, the technology is sufficiently mature, so that it can be deployed in the 2020s to meet reinvestment requirements in the EU steel industry. It can be initially fuelled by natural gas, which will reduce emissions by approx. -66 per cent compared with the conventional blast furnace route (1.8 t of CO_2/ t of crude steel). The residual emissions can be largely eliminated by substituting natural gas with increasing shares of clean hydrogen. With its capability and flexibility, DRI can serve as an anchor for increasing investment in the production and transport of hydrogen and so contribute to the creation of clean hydrogen-based industrial clusters.

We therefore assume that 90 per cent of the conventional blast furnaces that reach the end of their lifetime before 2030 will be replaced by DRI reactors. Until enough clean hydrogen is available, DRI plants will operate with natural gas. For the envisaged production of 41 Mt DRI steel with natural gas, the CO_2 abatement potential is **49 $MtCO_2$** (see figure ES.7, DRI with natural gas only). Later, increasing amounts of clean hydrogen can replace fossil gas in the DRI plants without major retrofits. For 2030 we assume that, on average, DRI plants will run on 65 per cent green hydrogen and 35 per cent fossil natural gas, for an emissions reduction of -89 per cent relative to the blast furnace route. Compared with natural gas DRI, this produces an additional CO_2 abatement of **17 $MtCO_2$** by 2030 (see figure ES.7, DRI with additional hydrogen).

The required amount of green hydrogen (ca. 50 TWh) in the steel industry is equivalent to 15 per cent of the planned green hydrogen production (333 TWh) within the EU by 2030, as described in the *EU Hydrogen Strategy*. To date, steel companies in Sweden (1x), Germany (3x), Romania (1x), and Italy (1x) either have planned or operate DRI pilot and demonstration plants or have announced concrete plans to produce DRI steel on a commercial scale before 2030.

Electric arc furnaces for secondary steel production: Another low-carbon transformation strategy in the steel sector in line with climate neutrality is to increase the share of secondary steel, replacing primary steelmaking with coal-based blast furnaces. Studies have shown that the share of secondary steel production in the EU could rise from ca. 40 per cent today to between 60 and 70 per cent by 2050[12]. We conservatively assume that 10 per cent of the primary steel production capacity that requires reinvestment before 2030 will be converted to electric arc furnaces, equivalent to an increased production of 4.6 Mt of secondary steel in 2030. The specific emission reduction per ton of crude steel is 1.68 t of CO_2 (-93 per cent), which translates into emission reductions of **8 $MtCO_2$** for 2030. The Swedish steel company SSAB has already announced plans to replace approx. 1.5 Mt of conventional steelmaking capacity in Oxeloesund with electric arc furnaces by 2025.

3.2.2 Key low-carbon technologies in the chemical sector

In the chemicals industry the key low-carbon technologies that are already available or can become available on a commercial scale in the 2020s are power-to-heat, clean hydrogen, and chemical recycling. These technologies can contribute to a significant reduction of greenhouse gas emissions before 2030.

Power-to-heat (PtH): In light of the accelerated EU coal phase-out under the increased 2030 climate target of at least -55 per cent and the efficiency gains over clean hydrogen, PtH technologies are particularly attractive from environmental and economic perspective. In the -55 per cent scenarios of the European Commission's Impact Assessment, coal accounted for a mere 2 per cent of the European power mix in 2030. As a result, electricity generation will have to be based on a significant expansion of renewable sources. Specific greenhouse gas emissions per kWh of electricity will be comparably low, offering a convenient opportunity to substitute the use of fossil fuels for heat production.

Based on country-specific data for low- and medium-temperature heat in the chemicals sector (i.e. steam demand of up to 500°C), we assume that a total demand of 342 TWh_{th} can be supplied by an evolving mix of technologies. Today, heat demand in the chemicals sector is supplied by a combination of combined heat and power plants (CHP) as well as natural gas-fired boilers with a greenhouse gas intensity of 223 g of CO_2/kWh_{th}. Starting from this baseline, we assume a gradual evolution with increasing shares of PtH.

For lower temperatures, we assume the use of high-temperature heat pumps, corresponding to about 10 per cent of total heat demand. Another 40 per cent of total heat demand can be supplied by electrode boilers. The remaining 50 per cent of heat in 2030 will continue to be supplied with natural gas-fired boilers and conventional CHP plants, as is largely the case today. When assessing the greenhouse gas abatement potential for these technologies, we make the simplified assumption that both PtH technologies operate at 8,000 full-load hours.

To determine the GHG abatement potential for 2030, it is necessary to estimate the specific greenhouse gas intensity of the future electricity mix. For this purpose, we relied on the modelling results of an accelerated coal phase-out scenario that is compatible with the -55 per cent target of the Impact Assessment (Agora Energiewende 2020, forthcoming). Based on this modelling we assume an average grid emission

12 Material Economics. (2019). *Industrial Transformation 2050.*

factor of 76 g CO_2/kWh for the EU27 power mix. We also factored in the specific average grid emission factors for Germany (113 g CO_2/kWh), Poland (154 g CO_2/kWh), the Czech Republic (119 g CO_2/kWh), and Spain (46 g CO_2/kWh). CO_2 emissions can be reduced by **25 $MtCO_2$** compared with when supplying steam demand from natural gas-fired boilers with a greenhouse gas intensity of 223 g of CO_2/kWh_{th}. The additional electricity required for this strategy will amount to 148 TWh, with 11 TWh for heat pumps (with a coefficient of performance of 3) and 137 TWh for electrode boilers with 100 per cent conversion efficiency.

Considering the flexibility of PtH, this analysis is somewhat simplistic but its estimates of the greenhouse gas abatement potential are conservative. In reality, PtH would operate mainly in times when renewable electricity is cheap and abundant. The specific greenhouse gas intensity of electricity during those times is lower than on average, generating an even higher reduction in greenhouse gas emissions. Moreover, PtH will cease when renewable power generation is scarce and the greenhouse gas intensity of grid electricity is high, because industries will rely on conventional heat sources from CHP and natural-gas boilers. Thanks to this flexibility, PtH in the chemical industry can efficiently use renewable electricity when it is abundant and compensate for its lack when wind and solar generation is low. To make effective use of this solution and its benefits for the power sector and the economy, it will be necessary to establish market mechanisms that align with cost efficiency and minimise GHG emissions.

Hydrogen use in the chemical industry: By 2030, the EU chemicals industry will be among the largest users of clean hydrogen (AFRY 2021, forthcoming). The European Commission's *Hydrogen Strategy for a Climate-Neutral Europe* envisages by 2030 a total production of 333 TWh of renewable electricity-based green hydrogen within the EU borders, another 333 TWh of imports from countries such as Ukraine and Morocco, and a significant amount of blue hydrogen. We estimate that the chemical industry will use around 115 TWh of green hydrogen in the production of ammonia (91 per cent) and methanol (9 per cent). Producing 115 TWh of green hydrogen via electrolysis can reduce **31 $MtCO_2$** relative to conventional hydrogen production based on the steam-methane reforming of natural gas with specific emissions of 9t CO_2/t of H2.

Chemical recycling: The recycling of plastic waste with chemical methods is an important opportunity for material substitution because chemically recycled plastic waste can serve as a substitute for petroleum-based naphtha. By replacing this fossil source, it closes the carbon cycle and avoids greenhouse gas emissions. While the technology has not yet been implemented on a commercial scale, we assume that this will be possible over the coming years, provided that the appropriate policy incentives are introduced. We assume that by 2030 five per cent of chemical raw materials for the production of two million tons of *high-value chemicals* (HVC) can be supplied by feedstock generated from the chemical recycling of plastic waste. This will replace an equivalent volume of petroleum-based naphtha in plastic production and avoid the CO_2-intensive incineration of plastic wastes. Conventional petroleum-based plastics production and the subsequent incineration of plastic waste generates about 4.5 t of CO_2 per t of HVC. Chemical recycling by the pyrolysis of plastic waste and the use of pyrolysis oil in conventional steam crackers will enable GHG emission reductions of 3.1 t of CO_2/t of HVC, or 69 per cent relative to the status quo. In 2030, this will amount to a CO_2 abatement potential of **6 $MtCO_2$**.

The commercial proof of concept indicates that the share of chemical recycling can be increased after 2030. Moreover, the greenhouse gas reduction potential can be further increased through technological optimisation such as the electrification of steam crackers and the gasification of the heavy fuel oil fractions coupled with methanol-to-olefin technology. The emission reduction potential of this fully *integrated chemical recycling route* amounts to 93 per cent (4.2 of CO_2/t of HVC) relative to conventional processes.

3.2.3 Key low-carbon technologies in the cement sector

An array of measures to reduce emissions along the value chain is available for the cement sector. Demand-side measures such as efficient design can reduce the amount of concrete needed, lowering demand for cement. The total amount of cement per unit of concrete, in turn, can be lowered by the more efficient application and packing of granules. Furthermore, the clinker content of cement can be reduced by substituting a portion of the clinker with other binders, such as so-called limestone and calcinated clay substitutes ("LC3" solutions).

Another promising approach is based on the principle of material circularity: concrete from demolition is crushed and the aggregates are separated and then either re-used as cement substitute directly (unhydrated cement) or brought back to cement plants for recarbonation and recycled to be used to produce new recycled clinker.

But even with recycling, the industry will still need to produce new cement clinker in the future. Roughly one-third of the emissions from clinker production (energy-related emissions) can be avoided in the future through the use of biomass or the electrification of kiln heating. The remaining two-thirds of process-related emissions, however, will require carbon capture technologies if the cement sector is to achieve climate neutrality and possibly even negative emissions.

Oxyfuel CCS: Oxyfuel CCS can play a key role in delivering significant emission reductions. CCS infrastructure in coastal areas could be developed by 2030 for cement as well as for the production of blue hydrogen. We assume that by 2030 eleven cement plants that are close to the Atlantic Ocean or navigable rivers could be connected to long-term CO_2 storage sites that are being developed in the Netherlands and Norway. This will require an infrastructure to transport CO_2 via pipelines or ships. Compared with the conventional production of cement with specific emissions of 0.61 t of CO_2/ t of cement, Oxyfuel CCS can capture and store 90 per cent of CO_2 emissions. By 2030, this technology can cut emissions by a total of **9 MtCO_2**. Bio-energy coupled with CCS, known as BECCS, can achieve even better results. For instance, a 25 per cent share of biomass in the fuel mix coupled with Oxyfuel CCS can make a cement plant climate neutral; higher shares of biomass have the potential to produce negative emissions.

Further reduction levers:

Significant reduction potentials also exist in EU ETS industry sectors outside steel, chemicals, and cement. Moreover, a number of additional options such as energy efficiency, biomass use, and circular economy measures can be used across all the sectors. The Impact Assessment of the European Commission has shown that by solely relying on an ambitious deployment of best available conventional technologies, the industry sectors under the EU ETS could reduce emissions by **144 MtCO_2** by 2030. Though our scenario rules out most conventional best available technologies in steel, chemicals, and cement because of CO_2-intensive lock-in, cross-cutting technologies such as pumps, drive systems, compressors, and ventilators can still do much to lower emissions generally.

Power-to-heat applications in EU ETS industries other than chemicals, biomass, and further circular economy measures also have great potential. We conservatively estimate a combined CO_2 reduction potential of **at least 15 to 20 MtCO_2** by 2030, or about 10 to 14 per cent of the best available conventional technology potential in the Impact Assessment. We have not quantified here the potentials of circular economy and material efficiency measures because our focus was on the development of supply-side breakthrough technologies. Nevertheless, the potentials in these areas point to the many technical levers that EU

ETS-compliant industry sectors have at their disposal for reaching a -65 per cent ETS cap in 2030.

To realise this breakthrough scenario and embark on the path to climate neutrality, the EU's industry will require a comprehensive framework for investment in key low-carbon technologies that must be created as soon as possible.

4 A Clean Industry Package to kickstart industrial transformation

Industry-wide transformation at scale depends on the fulfilment of certain basic conditions along the entire industrial value chain. This is one reason why the EU doesn't need a magic bullet policy to unlock industrial transformation; it needs a Clean Industry Package. In this chapter we explain the importance of introducing such a package as soon as possible.

4.1 Insufficient policy action will lead to deindustrialisation and carbon leakage

Due to the upcoming modernisation requirements and the long lead times for the licensing and construction of new plants (typically 5 years or more), companies in the basic materials industries will soon have to decide which reinvestment to make in Europe. The current regulatory framework does not create a business case for investment in conventional CO_2-intensive technologies, which are likely to lead to stranded assets; nor does it create a business case for investments in key low-carbon technologies, which are significantly more expensive than conventional CO_2-intensive technologies. The regulatory limbo demands a breakthrough strategy with a more ambitious vision than that offered by the European Commission's Impact Assessment, which neglects the large CO_2 reduction potentials of truly transformative low-carbon technologies. While the Impact Assessment shows that industries governed by the EU ETS can achieve the EU's 2030 climate target of -55 per cent by adopting the best available conventional technologies, this is not a sustainable strategy for climate neutrality in the steel, chemicals, and cement sectors given the inevitability of carbon lock-in and stranded assets.

However, the EU is ready to begin investing in a portfolio of key low-carbon technologies during the next 5 years. Key low-carbon technologies such as direct reduced iron in the steel sector; green hydrogen, power-to-heat, and chemical recycling in the chemicals sector; and carbon capture and storage technologies in the cement sector can be deployed well before 2030. Provided an appropriate regulatory framework and necessary infrastructure are in place, the introduction of key-low carbon technologies for needed reinvestment alone will ensure that EU ETS industries can meet the 2030 reduction target.

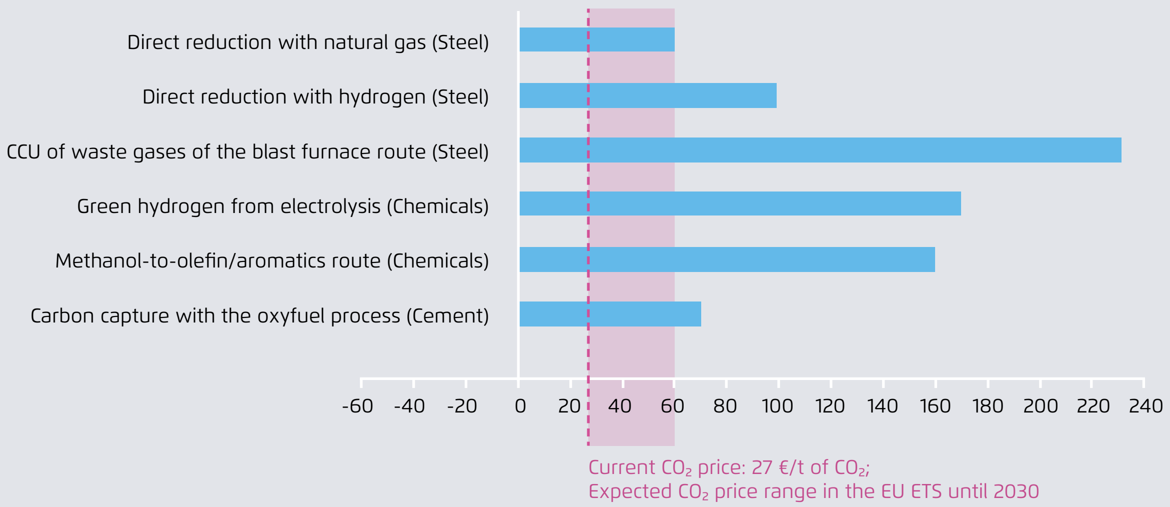
4.2 Carbon pricing and border carbon adjustments alone will not be sufficient

The costs of key low-carbon technologies are significantly higher than today's conventional technologies. Even under optimistic assumptions (lower bounds for 2030), the estimated CO_2-abatement costs of key low-carbon technologies are well above he carbon price range of 45-60€/t of CO_2 that the Impact Assessment projects for the EU-ETS through 2030, as shown in the European Commission's 2030 Climate Target Plan (see ES.8).

In fact, the CO_2 abatement costs of these technologies are likely to be even higher before 2030. First-of-a-kind plants still face certain unique project risks, because of the learning curve for new technologies and the need for proof of concept on a commercial scale. This means that even assuming the EU can overcome the many obstacles to swiftly implementing a well-functioning border carbon adjustment mechanism in the 2020s, the expected CO_2 prices are not sufficient to create

Estimated CO_2 abatement costs of selected key low-carbon technologies versus today's conventional reference process for 2030

Figure ES.8



Agora Energiewende/Wuppertal Institute, 2020

Note: CO_2 abatement costs depend very much on assumptions about electricity costs. For the calculation of these values, electricity costs of 60 euros per MWh were usually assumed. The estimates here are based on Agora Energiewende/Wuppertal Institut 2019 and represent the lower bound of CO_2 abatement costs in 2030. Higher CO_2 abatement costs are to be expected before 2030 than after 2030 because the technologies must still undergo learning curves for cost reductions.

a viable business case for investment in key low-carbon technologies. The combination of higher carbon prices and border carbon adjustments alone will not create a sufficient investment framework for these key technologies.

4.3 Only a coordinated set of policies across the value chain will enable the necessary investments

To incentivize investment in key low-carbon technologies in the basic materials industry certain basic conditions along the entire industrial value chain need to be met.

- **Upstream:** The industrial sector needs reliable access to clean energy (renewable electricity and clean hydrogen) and raw materials at competitive prices along with the required infrastructure, such as power grids, hydrogen production and transport, CO_2 transport, and CCS. Pan-European solutions will be required to develop, plan, and finance the necessary infrastructure.
- **Midstream**: The industrial sector needs the right economic and financial conditions to develop, implement, and operate investments in key low-carbon technologies. Moreover, policies are needed to address the risks of carbon leakage in a sustained manner.
- **Downstream:** The industrial sector needs demand and scalable markets for decarbonised and circular products, markets that have internalised the higher costs of decarbonised products, and incentives to integrate the circular economy and resource efficiency along the value chain.

If these basic conditions along the value chain are not fulfilled, the industrial sector will not invest in key low-carbon technologies. A cement producer will not invest in the installation of carbon capture technologies unless the government has committed to CO_2 infrastructure (upstream). And even if the cement plant can be connected to a CCS infrastructure, the company will not invest in key low-carbon technologies unless there are mechanisms to cover the significant additional costs of low-carbon cement at the stage of production (midstream) and at the final sale of the product (downstream).

The new European Commission has started to propose policies that, if properly implemented, will address some – though not all – of the industrial sector's specific needs. These policies include the *Hydrogen Strategy*, the *Sustainable Products Policy Initiative*, and the *Circular Economy Strategy*. However, in some key areas such as industrial infrastructure planning for key industrial clusters, implementing instruments to support the high operating costs of low-carbon technologies, or creating new markets for ultra-low carbon products, the European Commission has yet to make concrete proposals. Accordingly, key gaps still need filling.

5 The Clean Industry Package: 11 policy instruments for the entire value chain

Our proposed Clean Industry Package for Europe aims at comprehensively and adequately addressing the basic conditions along the entire industrial value chain. It consists of policies that *both* preserve the business case for existing industry assets until they reach the end of their lifetimes *and* create a framework for new investments compatible with the 2050 climate-neutrality target.

Figure ES.9 provides an overview of the 11 policies. The next section describes them in more detail.

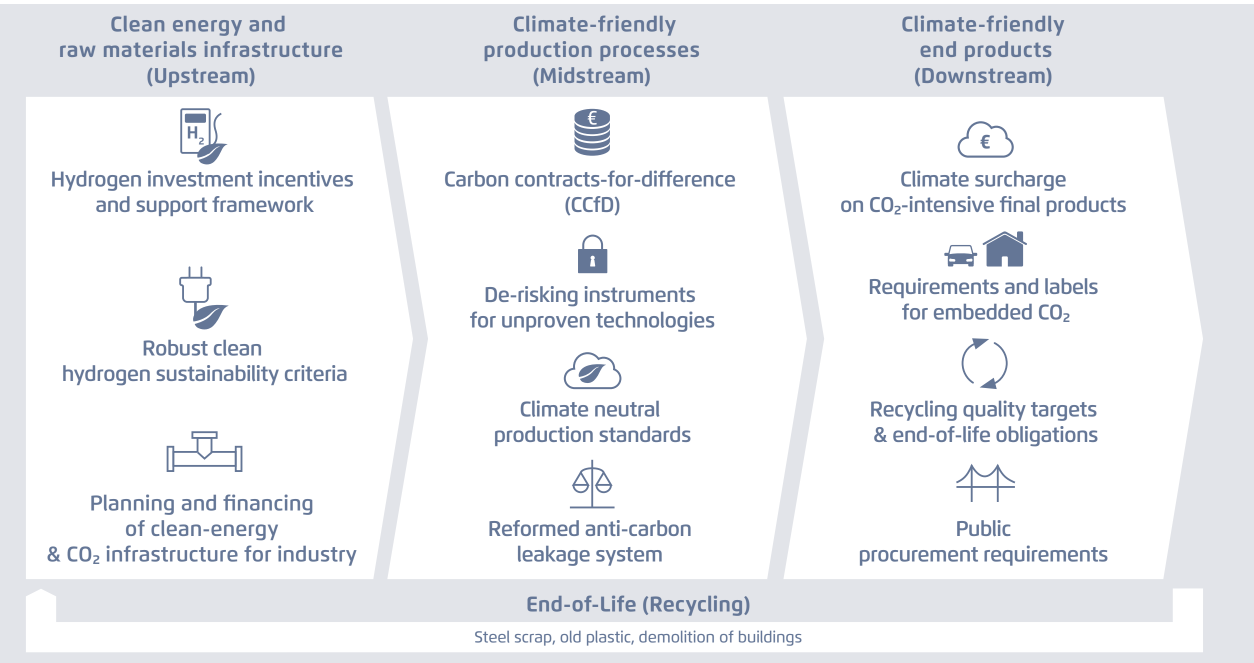
5.1 Upstream policies

1) Support instruments to create a business case for clean hydrogen

To mobilize the required investment in clean hydrogen production and infrastructure, a reliable business case for the production and transport of clean hydrogen must first be established. There are three main options for instruments to establish the required incentives:

→ **A feed-in premium for hydrogen** can close the price gap between the production of clean hydrogen and conventional hydrogen (produced from the steam reforming of natural gas).

Policy needs in the value chain — Figure ES.9



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Such feed in premiums may also be awarded through *hydrogen contracts-for-difference* and possibly be auctioned. They might also be appropriate for supporting early stage investments in greening existing hydrogen production, i.e., the switching from GHG-intensive fuels to clean sources for industrial processes that already use hydrogen. This will encourage the creation of supply for other green hydrogen applications as well.

→ **carbon contracts-for-difference (CCfD)** for the production, transport, and use of clean hydrogen. The additional costs of clean hydrogen can also be covered by financing its use in industrial production applications. This would channel clean hydrogen directly to no-regret-use sectors such as steel (e.g. direct reduction with hydrogen) and chemicals (e.g. low-carbon ammonia).

→ **A clean hydrogen quota** can be applied on sellers of maritime and aviation fuels. In this way, the private sector absorbs the cost of blending a share of renewable fuels in the end product (e.g. airplane tickets). This option may not be appropriate for general industry because the higher cost of hydrogen blending would make it difficult to compete with foreign competitors that do not use renewable hydrogen.

2) A robust sustainability framework for clean hydrogen production and use

To develop clean hydrogen that does not contribute to increasing emissions along the industrial value chain (scope 3 emissions), the EU will need to develop rules that classify hydrogen as "clean" and thus eligible for state aid. These rules could be part of a revised Renewable Energy Directive. Specifically, rules are needed to govern guarantees of origin for clean hydrogen and the "additionality" of renewable or decarbonised energy for clean hydrogen production; to ensure that clean hydrogen is allocated to the most appropriate "no-regret" options (e.g. steel, chemicals, maritime, and aviation); and to govern the safety of hydrogen production, transport, and use.

3) Planning, financing, and regulatory steps to enable clean energy and a CO_2 storage infrastructure

Current infrastructure planning varies greatly from member state to member state. For the development of a pan-European hydrogen, electricity, and CCS infrastructure, future *National Energy and Climate Plans* (NECP) must explicitly include the planning and financing of strategic industrial infrastructure. The plans could then serve as a reference point for other planning and EU financing instruments such as the *Trans-European Networks for Energy regulation* ("TEN-E"), *Regional Just Transition Plans*, *Projects of Common Interests*, and state-aid approval requests.

5.2 Midstream policies

4) An EU policy framework for carbon contracts-for-difference (CCfDs)

By covering the price difference between conventional and key low-carbon technologies, CCfDs can provide a credible business case for investments that are compatible with climate neutrality. Payments to these projects would be calculated based on the difference between the EU ETS carbon price and a pre-agreed strike price (that is, the breakeven carbon price to make this investment viable). Accordingly, CCfDs are critical for covering the cost gap that arises from the expected CO_2 abatement costs of key low-carbon technologies, which in the 2020s will be higher than the projected EU ETS carbon prices. In the medium term, CCfDs could also complement a border carbon adjustment regime to guarantee investors a sufficiently high CO_2 price above the carbon price defined by the border carbon adjustment.

5) De-risking instruments for capital expenditure in first-of-a-kind, large-scale investments

CCfDs can be supplemented by financing instruments that address the capital investment risk that results

from large-scale deployment of new, unproven, and often highly capital-intensive technologies. Funds such as the *EU Innovation Fund and InvestEU* already exist for this purpose. They are relatively small, however. The *EU Innovation Fund* must support all sectors of the entire energy system and the size of *InvestEU* was dramatically lowered during the EU's recent recovery and budget negotiations.
To boost these instruments, the EU must devise additional funding mechanisms. Potential options are an EU-wide climate surcharge on products with large amounts of basic materials that are sold in the EU market or the extraction of new revenues from ETS auctions.

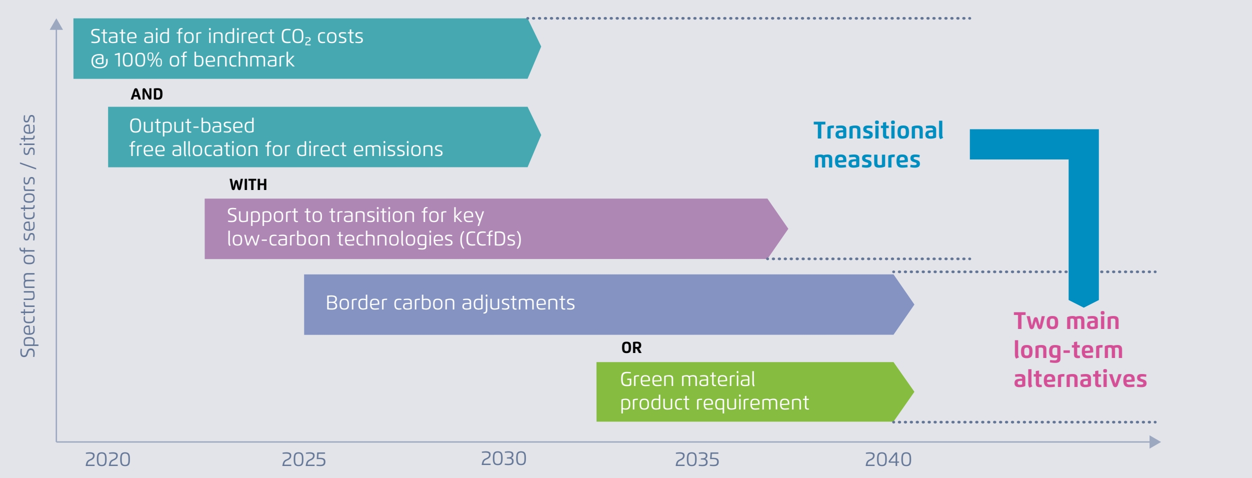
6) Set standards for production processes compatible with climate neutrality

The EU needs standards that dissuade new investment in industrial plants and technologies that are incompatible with achieving climate neutrality by 2050. Appropriate standards can prevent the introduction of more CO_2-intensive conventional technologies and "half-way solutions" that reduce emissions in the short run but lock in technologies with relatively high emissions. They can also clarify eligibility for state aid, identify specific criteria for the use of policy instruments such as CCfDs, and facilitate the creation of lead markets for climate-neutral materials (e.g. through green public procurement).

7) A reformed anti-carbon leakage system, robust to higher carbon prices

Under existing policies, the EU ETS Directive provides two main measures for tackling the risk of "carbon leakage," i.e. when production, jobs, and emissions move to countries with less climate ambition. The first is the free allocation of emissions allowances to sectors at risk of carbon leakage, which include energy-intensive basic materials industries.
The second is the possibility of state-aid payments to compensate for higher electricity prices. But these solutions need to be revised in light of projected increases in carbon prices and decreases in free allowances. In the short run, free allocation must be continued at the full technology benchmark but adjusted based on true output ("output-based allocation"). Moreover, state-aid guidelines should be reformed to enable maximum aid levels for

Short-, medium-, and long-term policy tools for carbon leakage protection — Figure ES.10



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electro-intensive industries once the carbon price rises above 30€/t of CO_2 (full power-price compensation). Border carbon adjustments or carbon product requirements must be prepared carefully and gradually implemented for relevant sectors (see figure ES.10). Depending on the specific design of certain policies further reforms may be needed.

5.3 Downstream policies

8) A climate surcharge on material-intensive final products

Some of the policies at the upstream and midstream levels such as carbon contracts-for-difference require a refinancing option to cover additional funds. One option would be a climate surcharge on certain final products containing large amounts of basic materials (cars, plastic bottles, houses). The climate surcharge would be applied to the final product (e.g. car) regardless of its origin (EU, non-EU) or the production process (conventional steel, low-carbon steel) and would thus be compatible with WTO rules. The additional cost increases in the final product are small (e.g. <1–2 per cent of final product price).

9) Requirements to improve recycled material quality and material efficiency in manufacturing and construction

One of the biggest barriers to boosting the circular economy for basic materials such as steel, non-ferrous metals, and plastics is the degraded quality of secondary scrap and plastic. This limits the share of recycled materials that can be used to replace new virgin materials and a share of energy-intensive primary production processes. One option to incentivise the improvement of material quality would be the introduction of stronger incentives for material conservation and minimum recycled content requirements. A second option would be an EU ban, tax and label products with low recyclability or poor material efficiency. This would ensure that products such as vehicles, machines, and buildings are designed with longevity and ease of disassembly in mind. A third option would be the adoption of minimum requirements for end-of-life dismantling, sorting, and tracing; and of tighter regulations for buildings and construction waste and for vehicle shredding.

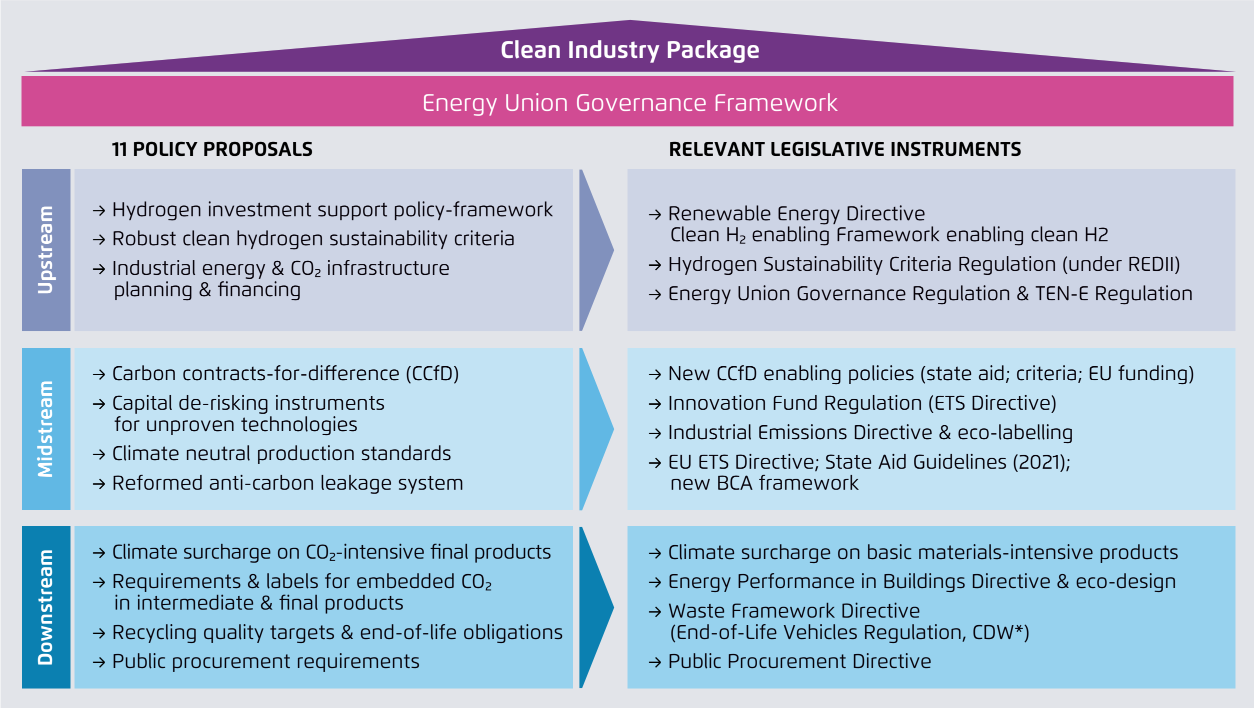
10) Climate-neutral product labelling and eco-design requirements for embedded carbon in final products

Product labelling and eco-design requirements are a prerequisite for the creation of lead markets for low-carbon basic materials. One option is to create an EU-wide low-CO_2 product label for basic materials to allow end customers to distinguish between green and conventional products. For example, a "climate-neutrality compatibility label" for low-carbon steel could be used by car manufacturers and other leading private-sector purchasers who wish to advertise their green credentials. Another option are specific design requirements for final products via minimum requirements for embedded carbon in final products. This can help tackle the overestimation of material requirements in construction and inefficient manufacturing processes.

11) Green public procurement requirements for basic materials

EU public procurement legislation from 2014 already permits – but does not require – environmental criteria to be used in public procurement for the domestic market. One potential reform option is to set declining maximum CO_2 limits on specific materials that are eligible for use in public projects. A second option is to introduce mandatory life-cycle CO_2 performance criteria for assessing projects that are based on harmonised European methodology.

Policies and legislative instruments to implement the Clean Industry Package — Figure ES.11



Agora Energiewende, 2020

Note: CDW stands for Construction and Demolition Waste period.

Figure ES.11 summarises the eleven policy recommendations and maps them onto existing EU-level legislative instruments. The figure shows that, apart from legislation for carbon contracts-for-difference and border carbon adjustment legislation, nearly all the proposed instruments can be attained with reforms to existing legislative tools.

The continuation of existing policies is not an option if EU industry is to be part of an EU Green Deal that spurs innovation and green investment while securing future-proof industrial jobs in a resilient economy. Moreover, border carbon adjustments alone will not suffice, because CO_2 prices for EU ETS are not expected to be high enough to make key low-carbon technologies economically viable. With a good deal of industrial capacity slated for replacement or refurbishment in the 2020s, European industry needs policymakers to make a strong commitment to preserving industrial production in Europe, despite higher climate ambition for 2030. This entails maintaining a business case for existing conventional assets until they reach the end of their lifetimes (see instrument 7 on carbon leakage) as well as the introduction of a framework for investment in key low-carbon technologies. The protection of existing assets will ensure that companies have the financial vitality to handle transformational challenges, while the investment framework will need to create instruments (such as carbon contracts-for-difference) as well as new product standards and markets that can support the higher operating costs of key low-carbon technologies. Together, these measures will be crucial for kick-starting industrial transformation under the EU Green Deal. In tandem with other elements of the Clean Industry Package, they will help to spur necessary investment during the coming investment cycle and beyond.

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197/01-Z-2020/EN

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Agora Energiewende is a joint initiative of the Mercator Foundation and the European Climate Foundation.