Climate-Neutral Industry

Key Technologies and Policy Options for Steel, Chemicals and Cement

EXECUTIVE SUMMARY

Agora Energiewende

IKEM BECKER BÜTTNER HELD NAVIGANT Wuppertal Institut

Climate-Neutral Industry

IMPRINT

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Key Technologies and Policy Options
for Steel, Chemicals and Cement

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Preface

Dear readers,

The basic materials industry is a cornerstone of Germany's economic prosperity. In addition to making a major contribution to GDP, it provides over 550,000 high-quality jobs. While this sector of the economy has improved its energy efficiency in recent years, there is an urgent need for far greater emissions cuts, given national and international climate protection targets. But how can the basic materials industry become climate neutral by 2050 without jeopardising its strong competitive position in the global marketplace? This is a pressing question.

Agora Energiewende and the Wuppertal Institute recently explored this issue in a series of workshops held with industry associations, trade unions, government ministries and civil society representatives. The study, which outlines various technology and regulatory design options, is the outcome of this dialogue process. These workshops underscored that industry is ready to proactively tackle the challenge of climate protection.

However, the absence of a conducive regulatory environment in tandem with an insufficient willingness on the part of policymakers to implement innovative policy instruments prevents industry from striking out and taking the lead. It's high time that changes. Ultimately, every new industrial facility that is constructed in coming years must be compatible with the goal of zero net emissions – as new facilities have lifespans lasting well beyond 2050. The aim of this publication is to encourage industrial investment that aids rather than hinders the attainment of our climate protection goals.

We hope you enjoy reading the study.

Dr. Patrick Graichen
Director, Agora Energiewende

Prof. Dr.-Ing. Manfred Fischedick
Vice President, Wuppertal Institute

Key findings at a glance:

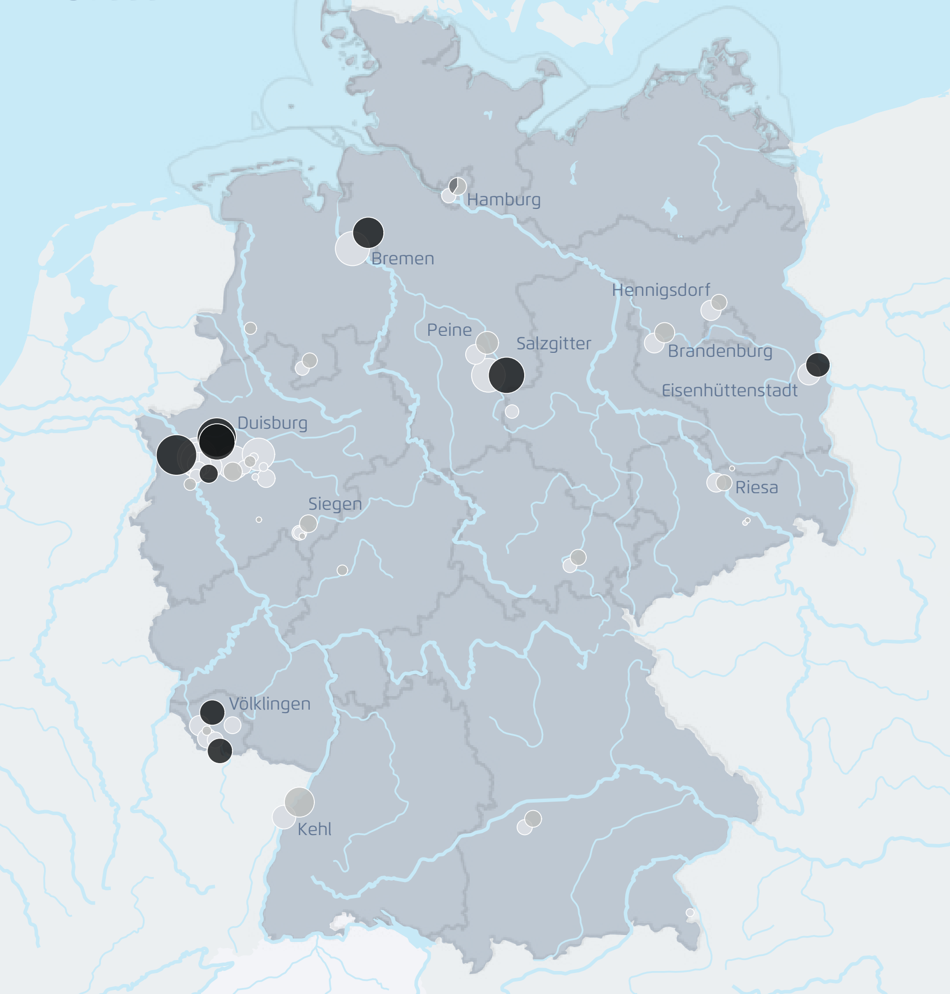
1. **The basic materials industry is facing a major challenge: it must make a 25% reduction in emissions by 2030 and achieve near zero emissions by 2050 – but emission levels have remained constant over the last ten years.** Breakthrough innovations are thus needed to enable the climate-neutral production of steel, chemicals and cement. Gradual efficiency improvements remain important, but they are no longer sufficient.

2. **The technologies needed for climate-neutral industry are already available – or are close to market readiness.** Green hydrogen will play a central role in achieving carbon neutrality in the steel and chemical industries. Particularly in the chemicals industry, the closing of material loops will be a core strategy. In the cement industry, new binders and carbon capture and storage (CCS) will be key technologies.

3. **Industry needs a new regulatory framework over the short term, as a major reinvestment phase will occur between 2020 and 2030. Promising political instruments include *Carbon Contracts for Difference* (CfD), a *green hydrogen quota*, and a *green public procurement* commitment by the federal government.** With the right mix of policy instruments, the German government can ensure reliable conditions for investment while also incentivising behaviour at various levels of the supply chain: *upstream, midstream* and *downstream*. By contrast, continued investment into conventional technologies risks *stranded assets*, as new industrial plants have lifespans well beyond 2050.

4. **The future of German industry must be climate-neutral. Germany now has the opportunity to become a technology leader in key low-carbon technologies with a significant potential upside.** By ushering in climate-neutral industry at home, Germany could help to demonstrate the viability of a climate-neutral industry and thereby help to foster a global market for low-carbon technologies worth billions.

PRODUCTION SITES AND CAPACITIES STEEL



Direct CO_2 emissions of the steel industry 2017
around 57 Mt CO_2

Steel production 2017
42.1 Mt of crude steel (of which: exports of 21.7 Mt of rolled steel in semi-finished products)

Steel demand 2017
41.0 Mt of rolled steel (of which: imports of 22.4 Mt of rolled steel in semi-finished products)

LEGEND

Production capacity crude steel (kt/a)

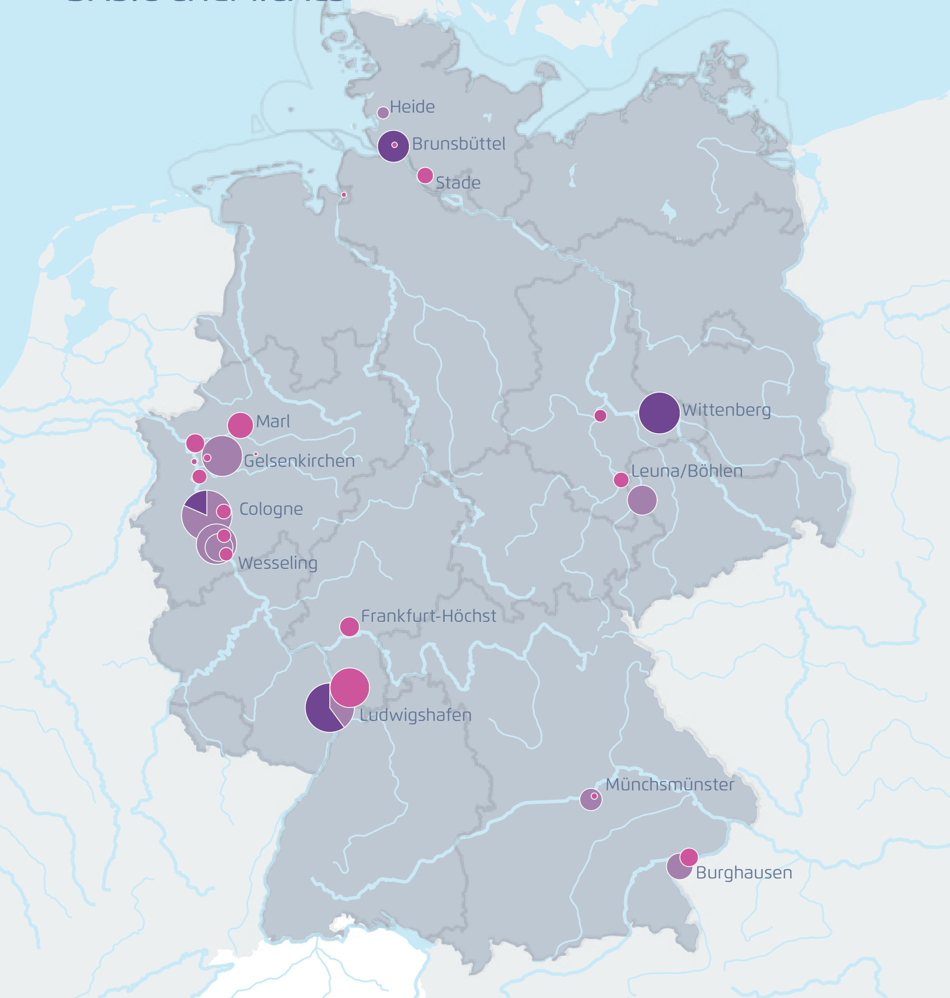
- Integrated blast furnace route (BF-BOF)
- Direct reduction with natural gas (DRI)
- Electric arc furnace with steel scrap

Production capacity rolled steel (kt/a)

- Hot rolling

2,000
4,000
6,000

PRODUCTION SITES AND CAPACITIES BASIC CHEMICALS



Direct CO_2 emissions of the basic chemicals industry 2017
37.2 Mt CO_2

Chemicals production 2017
12.3 Mt of high value chemicals (HVC)
(of which: exports of 2.8 Mt of HVC)

Chemicals demand 2017
11.9 Mt HVC (of which: imports of 2.5 Mt of HVC)

LEGEND

Production capacity basic chemicals

- Ammonia (kt/a)
- Steam crackers (kt of ethylene/a)
- Combined heat and power plants of the chemical industry (MW_{el})

200
600
1,000

PRODUCTION SITES AND CAPACITIES CEMENT

Direct CO_2 emissions of the cement industry 2017
20.5 Mt CO_2

Cement production 2017
34 Mt cement
(of which: exports of 6.2 Mt cement)

Cement demand 2017
28.8 Mt cement
(of which: imports of 1.6 Mt cement)

LEGEND

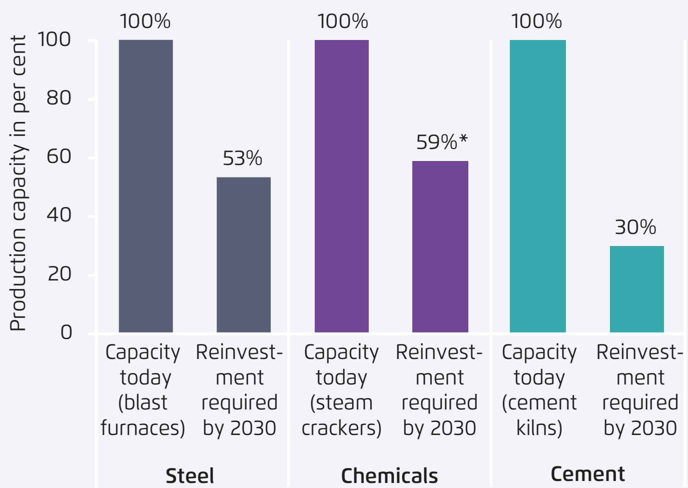
Production capacity cement

- Cement clinker (kt/a)
- Cement mills (kt/a)

200
600
1,000

REINVESTMENT REQUIREMENTS AND EMPLOYMENT IN 2017

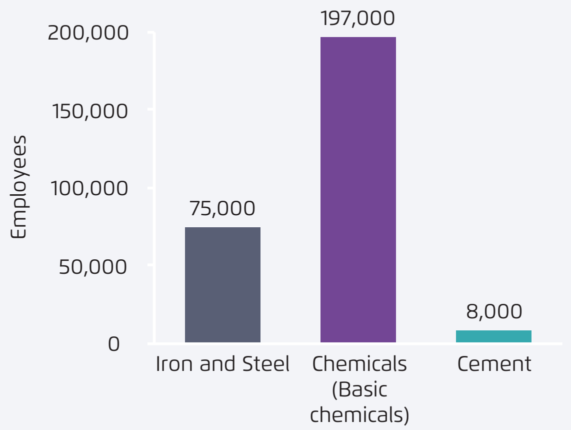
REINVESTMENT REQUIREMENT OF PRIMARY PRODUCTION CAPACITIES IN GERMANY BY 2030



Wuppertal Institute, 2019

* Steam crackers are normally maintained and modernised continuously so that they are not completely replaced at one time. However, the need for reinvestment gives a rough impression of the need to modernise existing facilities.

DIRECT EMPLOYMENT IN THE INDUSTRIAL SECTORS UNDER CONSIDERATION IN 2017



Destatis, 2018

Source: Agora Energiewende / Wuppertal Institute, 2019

Contents

Roadmap for sustainable industry in Germany (Executive Summary)

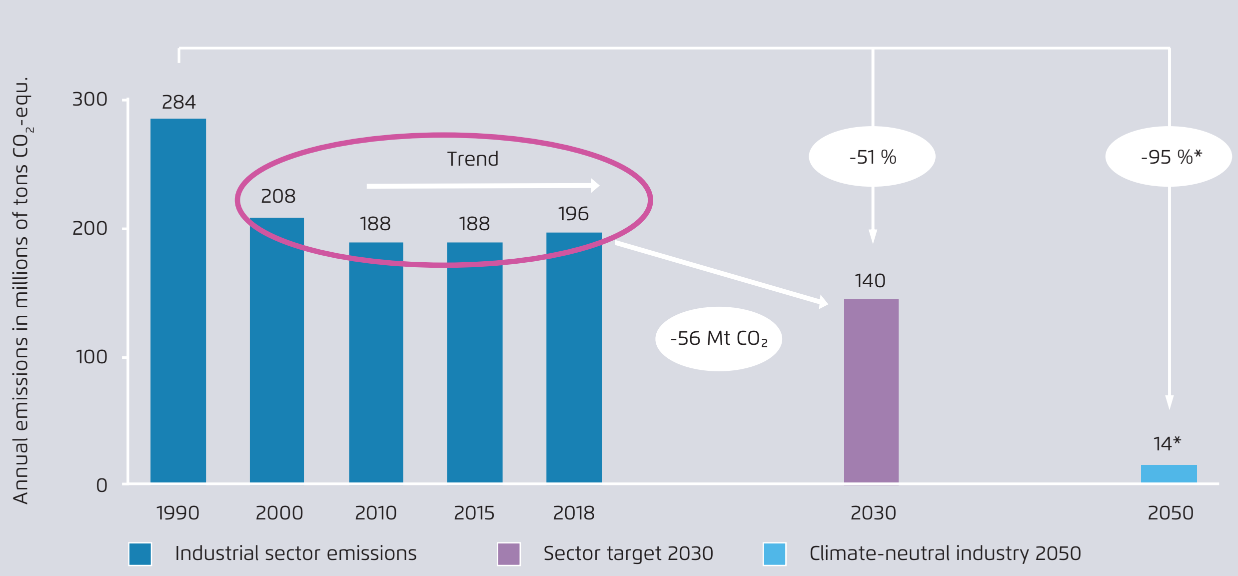
The energy-intensive basic materials industry is a cornerstone of Germany's economic prosperity. In addition to making a major contribution to GDP, it provides over 550,000 high-quality jobs, often in structurally weak regions. Internationally, *Made in Germany* is a seal that stands for products of the highest quality and innovation. Understandably, there exists a political consensus that efforts should be made to preserve the competitiveness of the basic materials industry in order to prevent market share from being lost to other parts of the world. Against this backdrop, and the imperatives of the energy transition, there is a pressing need to encourage fundamental technological innovation in the basic materials industry that not only ensures competitiveness, but also places the sector on the path to zero net emissions by 2050. Ultimately, German companies should seek to become world leaders in the production of climate-neutral basic materials, and thus usher in a new chapter in Germany's economic success story.

1 The climate protection challenge for industry

By 2030 Germany aims to reduce greenhouse gas emissions by 55 per cent below 1990 levels. Against this backdrop, the industrial sector has committed to reducing emissions by around 56 million tonnes (around 29 per cent) by 2030 (compared to 2018 levels). The overarching political goal is to make

Emissions of the industrial sector 1990-2018 (sector definition based on German Climate Protection Plan) and sector targets 2030/2050 of the industrial sector

Figure ES.1



UBA, 2019a; BMU, 2016; Sector target 2030 according to government draft Federal Climate Protection Act; sector target 2050 according to climate protection plan 2050
* remaining emissions in 2050 must be offset for climate neutrality

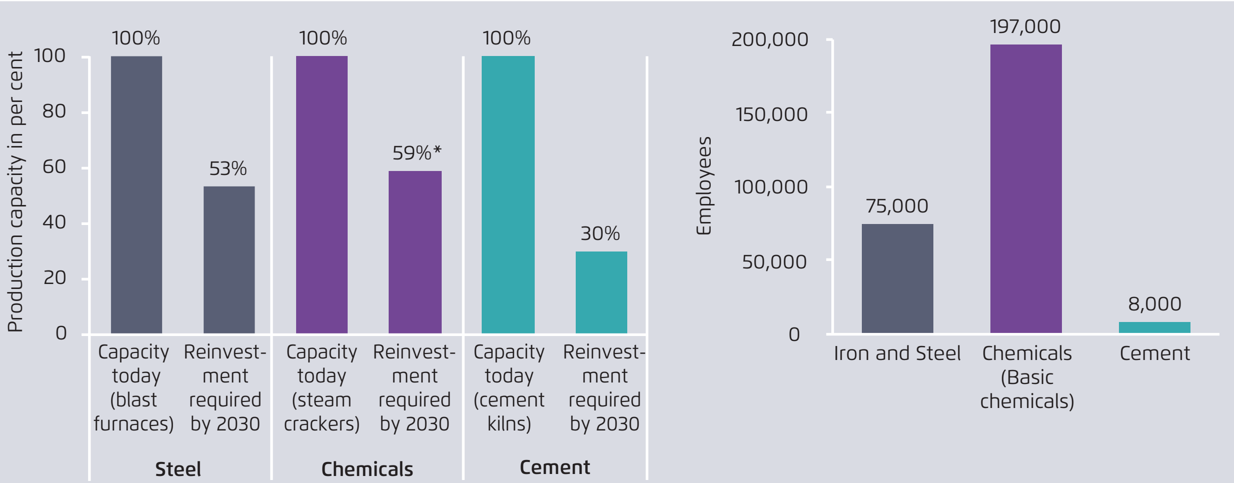
Germany – and, by extension, German industry – climate-neutral by 2050. However, there is a glaring impediment to achieving this goal: Over the last ten years, the industrial sector has increased its efficiency, but without achieving a corresponding reduction in emissions. Achieving the 2030 target now appears unlikely. Clearly, simply replacing older factories with more efficient ones that use conventional technologies is not compatible with the goal of a climate-neutral industrial sector by 2050.

Capital-intensive production plants have long operational lifespans (often with depreciation periods of 50 to 70 years). This poses a particular hurdle to achieving climate neutrality, especially in the basic materials industry. By way of comparison, a passenger car is replaced every 10 to 15 years on average. Another special feature of this sector is that about one-third of emissions take the form of process emissions, which cannot be avoided using conventional production techniques due to the raw materials used and associated chemical reactions.

This means that in order to achieve climate neutrality by 2050, all investment moving forward must be climate-neutral or at least provide for the possibility of retrofitting to emissions-free production. In the coming investment cycle, renewed investment in conventional technologies could lead to stranded assets, i.e. to the early decommissioning of assets that have not yet been fully depreciated, and the associated economic losses incurred.

The situation faced by the basic materials industry in Germany is alarming in this respect. In order to maintain current production levels, massive reinvestments into production plants will have to be made in the coming years: By 2030, around 53 per cent of the blast furnaces in the steel industry, around 59 per cent of the steam crackers in the basic chemical industry and roughly 30 per cent of the cement kilns in the cement industry will need a reinvestment. This could affect up to 158,000 employees when accounting for the directly integrated downstream value stages, too.

Reinvestment requirement by 2030 of primary production capacities in Germany in the steel, chemical and cement sectors as well as direct employees in the industrial sectors under consideration 2017 — Figure ES.2



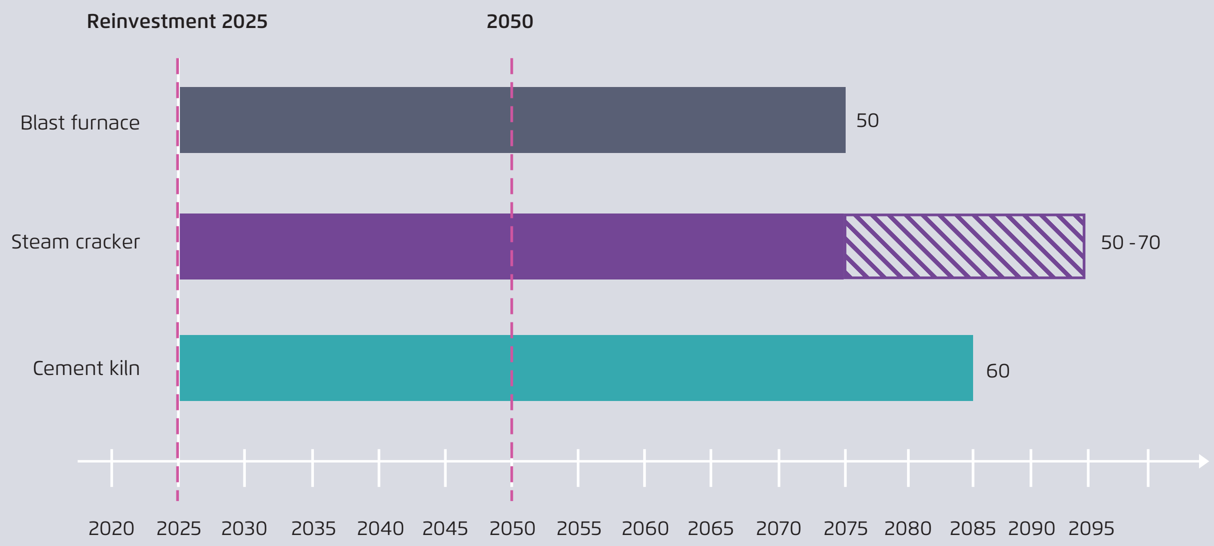
Wuppertal Institute, 2019

Destatis, 2018

* Steam crackers are normally maintained and modernised continuously so that they are not completely replaced at one time. However, the need for reinvestment gives a rough impression of the need to modernise existing facilities.

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

Figure ES.3



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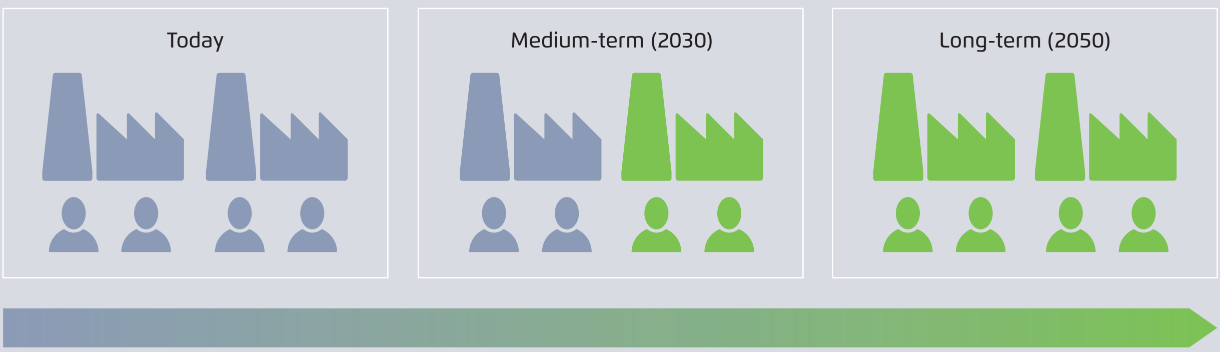
Companies will not make the necessary replacement investments if the long-term economic and regulatory conditions are uncertain. In light of increasing demands for climate protection, reinvesting in conventional, emission-intensive technologies faces a greater likelihood of being decommissioned early, increasing the risk associated with such endeavours.

From the standpoint of companies as a rational economic actor, there are only two options: to invest in climate-neutral technologies in the next investment cycle, or to close down existing production plants at the end of their service lives and, if necessary, make new investments abroad. The consequence of this second decision would be to disrupt

The transformation of a basic industrial company on the road to climate-neutral production (stylised depiction)

Figure ES.4



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local economies and integrated value chains. The relocation of associated industries could potentially occur as a knock-on effect, triggering massive job losses. Yet relocation abroad is not a foregone conclusion. German industry has a clear opportunity to take bold steps now and to lay the foundation for sustainable, well-paid jobs, as well as continued technological leadership.

2 Technological solutions on the verge of breakthrough

Technological potentials that could be harnessed to make the energy-intensive basic materials industry almost completely climate-neutral already exist today. Some solutions, such as the production of hydrogen through water electrolysis, are already close to market readiness or can be brought to market readiness in a few years. Examples of low-emission technologies include: the direct reduction of iron ore with hydrogen (instead of conventional processing in a blast furnace) in the steel industry; the chemical recycling of plastics (instead of thermal recycling) in the chemical industry; and carbon capture in the cement industry.

These technologies and production processes are still significantly more expensive today than conventional manufacturing processes. Furthermore, the additional costs cannot be passed on to customers because of fierce international competition. To

Overview of possible key technologies for a predominantly carbon-neutral basic industry — Table ES.1

Steel	Key technology	Earliest possible market readiness
	Direct reduction with hydrogen and smelting in the electric arc furnace	2025 – 2030 (phase-in with natural gas)
	Alcaline iron electrolysis	likely after 2050
	HIsarna® process in combination with CO_2 capture and storage	2035 – 2040
	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	2035 – 2045
	Green hydrogen from renewable energies	2025 – 2035
	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	2030 – 2035
	Alternative binders	2020 – 2030 (depending on product)

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stimulate investment in these leapfrogging innovations now, industry actors need political signals that the government will actively support this transformation.
In this study, 13 key technologies that can significantly reduce greenhouse gas emissions in the steel, chemical and cement industries are described in more detail (see Table ES.1). In addition to providing an overview of each industrial sector, including current emissions levels, production data, employees and reinvestment requirements, the study concisely summarises each of the 13 key technologies. For each low-emission technology, you will find information on pilot and demonstration projects, CO_2 reduction potentials, CO_2 avoidance costs, a technology comparison with the conventional technology, and the central assumptions on which the calculations are based. Finally, the study discusses the possible CO_2 reduction potentials in the steel, chemical and cement sectors up to 2030. The technology summaries were drafted following in-depth discussions with select industry associations and firms.

3 Prerequisites for successful decarbonisation

To maintain competitiveness and enable companies to make necessary investments, the shift to low-carbon production processes requires a comprehensive new regulatory framework:

- → Industry actors need long-term, cross-party assurance that Germany will ensure **internationally competitive energy prices** for its energy-intensive basic material industries.
- → The **new version of the EU state aid guidelines** must be geared towards climate neutrality. National policy instruments to promote low-carbon technologies should not require individual approval from the Commission, thus ensuring that the supplemental investment and operation costs associated with such technologies can be financed over the long term.
- → **Necessary infrastructure**, including power lines, hydrogen pipelines and carbon capture and storage infrastructure (pipelines and ports as well as safe CO_2 storage facilities) must be reliably available in good time. To this end, planning approval must be granted quickly; this will require adjusting permitting rules and associated appeal procedures.

While the above regulatory provisions are important prerequisites, by themselves they cannot ensure the success of the transformation. After all, providing the necessary energy and infrastructure does not provide a business case for investment in innovative technologies per se. In this regard, additional political measures are needed to encourage the shift to low-carbon production process, as discussed in the following.

4 Policy instruments for climate-neutral industry: what can be done

Against this backdrop, Agora Energiewende has developed **ten policy instruments** that intend to make low-carbon technologies available on a large scale as quickly as possible while also enabling German companies to become global pioneers in the market for these technologies. The analysis that was undertaken for this report devoted particular attention to understanding divergent industry conditions, the current stage of technological development, potential interdependencies with other regulatory provisions, and legal and policy implementation issues. Specifically, the study considered traditional carbon pricing instruments, subsidy mechanisms, mechanisms to create markets for green products, and other regulatory options.

The following ten instruments were examined:

1. **Carbon price floor with border carbon adjustment:** This option foresees introducing an increasing carbon price floor price to the EU ETS, in order to furnish a predictable price incentive.

In addition, a carbon tax would be levied on imports, and exports to regions without carbon prices would receive tax credit equal to CO_2 costs.

2. **Carbon Contract for Difference (CfD):** Under this policy instrument, when investing in key low-carbon technologies, companies would receive project-related subsidy payments based on avoided CO_2 emissions, thereby reducing project risks for industry actors. The amount of subsidy funding would be determined through an auction. Over the long term, the ability to participate in the auction should be available to all companies.

3. **Green financing instruments:** This instrument foresees reducing financing costs for investment in low-carbon technologies, either by offering below-market interest rates or indemnifying creditors for potential losses when projects are at the final stages of technology development.

4. **Climate surcharge on end products:** To help refinance other policy instruments mentioned here, a special charge would be levied on selected materials (steel, plastic, aluminium and cement), irrespective of emissions associated with their production.

5. **Carbon price on end products:** When products are sold to the end consumer, a charge would be levied based on the carbon content of the materials, thus offsetting the cost disadvantage of low-carbon products. This charge revenue could then be used to finance other instruments.

6. **Green public procurement:** Public-sector entities would be required to fulfil sustainability requirements when developing infrastructure (e.g. buildings, bridges and railways) and procuring vehicles. This would create reliable demand for sustainably produced basic materials and end products (especially steel, cement and vehicles).

7. **Quota for low-carbon materials:** Producers of consumer goods would be obliged to use fixed shares of low-carbon materials in their end products, thus guaranteeing demand for low-carbon materials.

8. **Green hydrogen quota:** Natural gas providers would be required to sell a certain share of green hydrogen, thus ensuring the expansion of power-to-x technologies on the road to long-term decarbonisation.

9. **Changes in construction and product standards:** Regulations and standards would be fundamentally revised and continuously adapted in order to simplify material efficiency and substitution and the use of new building materials in construction (e.g. cement based on alternative binders).

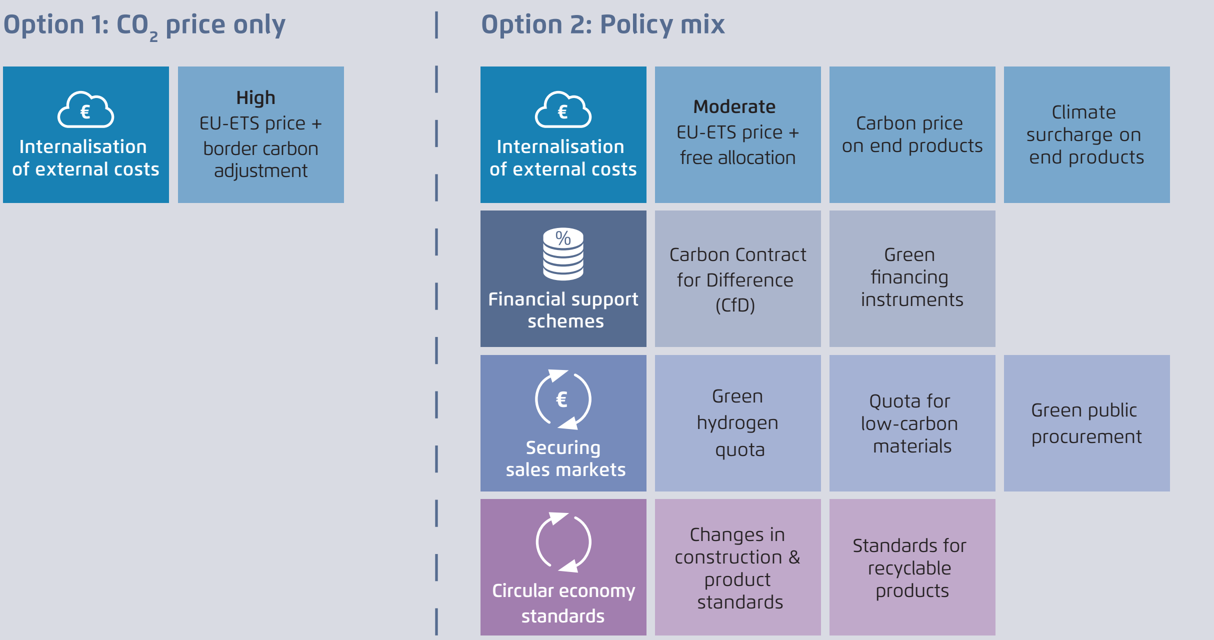
10. **Standards for recyclable products:** Manufacturers would be obliged to design products so that recycling is simplified in order to close material loops and to reduce carbon-intensive primary production.

As a result of this analysis, two basic options for climate-friendly industrial policy were identified:

Option I: High carbon price in the EU ETS, coupled with a border carbon adjustment

A high carbon price in the EU ETS, coupled with a border carbon adjustment, would be the most efficient instrument from an economic standpoint while also guaranteeing a level playing field for industry. Due to the very high CO_2 abatement costs of many of the low-carbon technologies, a very high carbon price in the EU ETS would be required. Furthermore, the carbon price would have to increase reliably over time in order to give companies the security that their investments will not become depreciated. To ensure the proper function of this instrument and the accurate calculation of the border carbon adjustment, however, it would be necessary to transparently record and validate the specific CO_2 content of

Two different options for a possible climate and industrial policy framework — Figure ES.5



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materials and end products. This raises a number of fundamental methodological questions: When evaluating electricity for industrial production, for example, should the electricity mix of the respective country be used to calculate emissions – or would it also possible for an energy-intensive company to declare the purchased electricity as carbon-free using renewable certificates or proofs of origin? The answer to this question will be of decisive importance to countries with a high share of coal-fired generation. Questions also arise concerning appropriate CO_2 pricing when products cross the border from an industrialised or developing country. The border carbon adjustment could potentially be abused to serve special interests. In such a case, international trading partners would be likely to view the border carbon adjustment as a trade barrier, and react with countermeasures. Trade policy and commercial disputes would therefore be inevitable. Despite the aforementioned, this instrument plays a role in the discussion because it is favoured by important actors (including the French government). The new EU Commission intends to examine the feasibility of a border carbon adjustment.

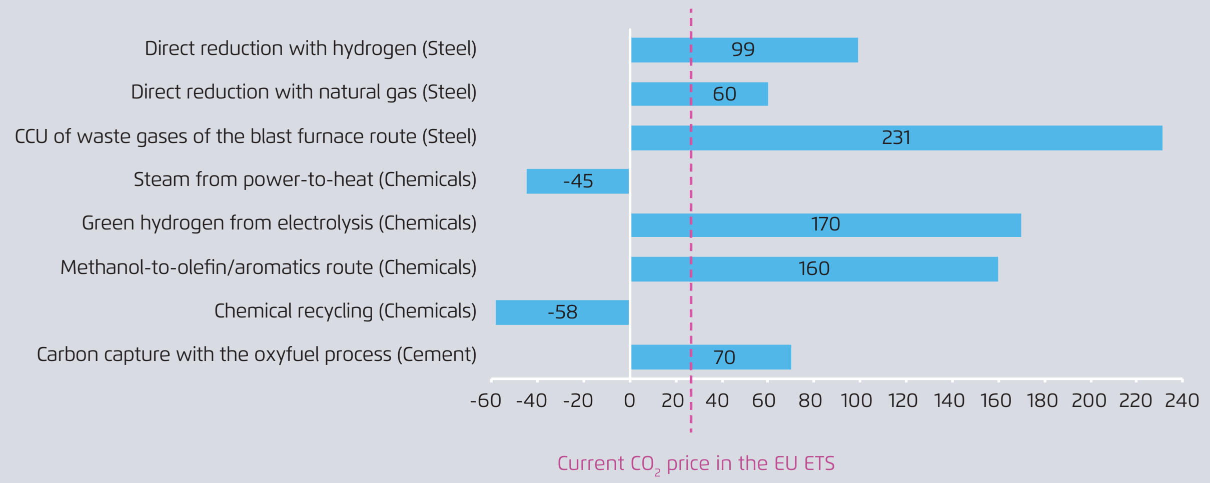
Option II: Policy mix

The policy mix approach combines various instruments that address different levels of the economic value chain: upstream instruments focus on secure access to energy and raw materials at competitive prices; midstream instruments take the form of incentives and direct subsidies for changing production processes; and downstream instruments focus on ensuring reliable demand and regulatory requirements.

Within the scope of a policy mix, the following combination of instruments appears to be the most promising:

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

Figure ES.6



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The CO_2 abatement costs are strongly dependent on assumptions about electricity costs; for the calculation of these values, usually electricity costs of 60 euros per MWh were assumed. In the study, ranges were calculated; the values presented here represent the optimistic scenario. Higher CO_2 abatement costs are to be expected before 2030, as the technologies still have to go through learning curves for cost reductions. For six other technologies that were analysed in this study, an industrial-scale application by 2030 is not to be expected, as they are still in the early stages of technological development. For these technologies, no CO_2 abatement costs were estimated for the year 2030 due to the high uncertainties.

a) Upstream policy instruments

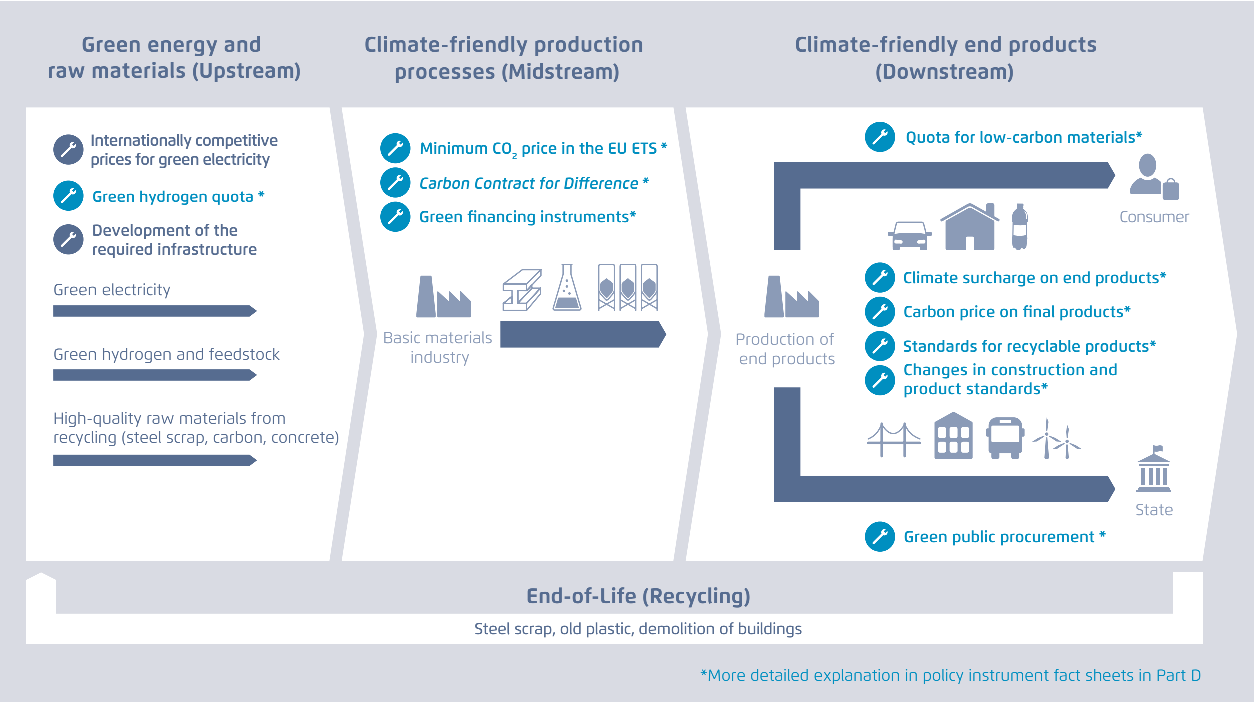
In order to ensure international competitiveness, industrial actors require **internationally competitive energy prices** (for electricity, natural gas, and hydrogen) over the long term. The cost of energy should be kept predictably within a narrow price band that is oriented towards international benchmarks. On this matter, it must be assured that price intervention of this nature is permissible over the long term under EU state aid law.

The availability of hydrogen at low cost will be of particular importance to the climate neutrality of many energy-intensive production processes. The introduction of a **green hydrogen quota** would ensure access to large quantities of hydrogen produced through low-carbon production processes. A target of at least ten gigawatts of electrolyser capacity in Germany by 2030 would significantly reduce hardware costs and could also establish German companies as global technology leaders. In terms of policy implementation, natural gas traders could be obliged to sell a certain share of green hydrogen. Under such an arrangement, deliveries to 100% hydrogen networks would count towards quota fulfilment, as we can assume that industrial processes and heavy freight transport will primarily rely on pure hydrogen. It is imperative that the electricity required for the production of green hydrogen comes from additional renewable energy plants. In addition, **necessary infrastructure**, including that required for hydrogen production and transport, carbon capture and storage (CCS) or the transport of large quantities of electricity, must be made available to industry in good time.

b) Midstream policy instruments

The following instruments could be used to encourage firms to adopt new production processes:

Policy instruments at the different levels of the value chain — Figure ES.7



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As one part of a multifaceted policy mix, the **EU Emissions Trading Scheme** (EU ETS) could be further developed to provide incentives for ongoing efficiency improvements and the adoption of new fuel sources. The free allocation of allowances on the basis of product benchmarks should be maintained. In order to provide sufficient incentives for green production processes, the EU ETS Directive should be revised. It must be ensured, on the one hand, that low-carbon production plants receive free certificates for a limited period of time based on the avoided level of emissions, and, on the other hand, that these plants are excluded from the calculation of the product benchmarks used to determine emission avoidance.

To finance risky technologies that have not been tested at scale and which have CO_2 abatement costs well above the foreseeable EU ETS price, companies should receive project-related operating subsidies for a fixed period (e.g. 20 years) via a **Carbon Contract for Difference (CfD)**. These operating grants should be determined based on the difference between the CO_2 price in the EU ETS and the price determined by the auction (usually the actual CO_2 abatement costs for the green basic material). The amount of CfD funding provided will be determined through an auction, although over the long term, it should be possible for any company to participate. As a first step, technology-specific tenders could be carried out in the steel, chemical and cement sectors. Companies would have reliable long-term conditions for investment thanks to guaranteed government support for potential differences between the EU ETS price and the level of remuneration determined by auction. A second revenue stream would be created for companies by the free allocation of EU ETS certificates for new production facilities on the basis of EU ETS benchmarks (e.g. 1.6 EUAs per tonne of steel). Since no (or very little) CO_2 emissions are emitted during production, companies would be able to sell the freely allocated certificates on the market. The CfD could be financed through the EU Innovation Fund, federal funds (e.g. the Environmental Innovation Programme) or new financing instruments such as a **climate surcharge on end products**. The funding of operating grants must also be assured under EU state aid law in such a way that no individual approvals from the EU Commission are required or, alternatively, the aid approval is granted without lengthy individual review if certain minimum requirements are met. **Green financing instruments** (e.g. through the European Investment Bank), which would provide government indemnification for the risks of technological innovations in the final stages of development, would be an appropriate supplementary measure.

c) *Downstream policy approaches*

Policy costs could be recovered though a **climate surcharge on end products** and/or through disbursements from an EU Innovation Fund. The climate surcharge on end products would be levied at the end of the value chain (i.e. at the point of sale to the consumer) on products with carbon-intensive manufacturing, such as steel, plastic, aluminium and cement. The additional costs for consumers would be limited: A small car with a CO_2 price of 30 euros per tonne would be 90 euros more expensive. This surcharge has the advantage that it would be levied on all products sold in Germany (including imports), while exports would be excluded. Accordingly, this instrument does not pose the risk of increased carbon leakage (i.e. displacement of emissions to other countries).

For investors, reliable outlet markets are crucial for the planning of production plants, which have long operating lifecycles. To this end, a **quota for low-carbon materials in end products**, which would initially apply to a select range of goods, would be an appropriate instrument. Manufacturers of certain products (e.g. vehicles) would be obliged to purchase a fixed percentage of used materials (e.g. steel and plastics) from green production plants in order to sell the products in the EU (or Germany). The additional costs could be passed on to consumers. The quota could be designed to increase continuously over time. During a transitional period, a certificate system could be introduced in order to avoid discriminating against manufacturers (including foreign firms) who do not have access to green materials.

The government (and public-sector companies) are a large consumer of basic materials through construction activities (especially for infrastructure development). Mandatory **green public procurement** could create reliable outlet markets for sustainably produced materials (e.g. steel, cement and wood) and sustainably manufactured consumer products (e.g. vehicles). **Standards for recyclable products** could be introduced to address areas that fail to respond adequately to economic incentives. Many products in the basic materials industry have a very low recycling rate. There are various underlying causes of this, including impurities (e.g. copper in the case of steel) or a high proportion of composites (in the case of plastics). Most plastic products are incinerated, and impure steel can only be downcycled (i.e. steel limited to certain applications). Over the long term, we must aim to close material loops and create extensive circular economies. The EU Eco-Design Directive is the right place to enshrine standards in this regard.

It is clear that the current regulatory framework, which consists of the EU ETS and numerous small-scale funding programmes, is not sufficient to get the necessary investments off the ground. Moving forward, in-depth deliberation must take place between policymakers, business leaders, trade unions and civil society on various issues, including the future mix of instruments that will best enable climate-neutral industry, the question of implementation at the national or European level, and the expected effects on jobs. The present study seeks to establish a foundation for such a discussion to take place.

5 Seven cornerstones of an immediate action programme to promote climate-neutral industry

Following our analysis of low-carbon technologies and possible policy instruments, we propose the adoption of an immediate action programme to demonstrate a strong political commitment to climate-neutral industry. This programme should contain the following provisions:

1. The German government will soon present a draft law for **the process by which companies will bid for Carbon Contracts for Difference (CfD)**, which aim to promote low-carbon technologies as part of the government's Environmental Innovation Programme. As a first step, technology-specific tenders should be launched in the steel, chemical and cement sectors. After evaluating this pilot phase, tenders that are open to all types of technology should be launched for all energy-intensive sectors.

2. In order to cover costs associated with the CfD, the German government should present a law that **introduces a climate surcharge on end products**. This surcharge should apply to selected emission-intensive basic materials (steel, cement, aluminium and plastics). Initially, this surcharge should only apply to select products in order to keep complexity low and provide an opportunity to gain experience with the instrument.

3. The German government should commit itself over the near term to adopting **green public procurement** standards for building materials that are required in major federal construction projects, provided such materials are available in sufficient quantities. This would create a reliable outlet market for climate-friendly materials, including in particular steel and cement. Obligatory sustainability criteria should also be introduced promptly for vehicles procured by the federal government. On the one hand, the introduction of a ceiling for government fleet emission averages is conceivable. On the other hand, the CO_2 intensity of the material inputs to vehicles purchased by the federal government and/or to buses and trains purchased for public transport networks could be considered, given sufficiently reliable data and calculation methods.

4. Over the near term, the German government should introduce a **green hydrogen quota** that obliges natural gas traders to ensure that at least 0.5 per cent of their energy sales take the form of CO_2-neutral hydrogen. This quota could be gradually increased to 10 per cent by 2030, with at least half of the required share taking the form of green hydrogen and the remainder taking the form of blue hydrogen. Imports from foreign countries to Germany and feed-in to 100% hydrogen networks should count toward meeting this quota. Exceptions should be made for industry in order to preserve its international competitiveness. It should also be ensured that the electricity required for the production of green hydrogen comes from additional renewable energy plants.

5. The EU Eco-Design Directive must be expanded to encourage **circular economies** in which material loops are closed over the long term. To this end, standards for recyclable products should be introduced in order to significantly increase recycling rates for metal, concrete and plastics to equivalent quality grades while also reducing thermal recovery in the mid-term.

6. As part of the planned **EU climate and industrial strategy**, which the new EU Commission will present in 2020, the German government should strive to ensure that the instruments set forth under points 1 to 5 are also introduced at European level.

7. Within the framework of the United Nations and the G20, the German government should continue

to advocate for a global carbon price. The instruments introduced at the national and EU levels could then, in due course, be transformed into a global set of instruments that encompasses all key competitors.

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