Technology and policy options for a climate-neutral energy-intensive industry

Options for the steel, cement and chemical industries

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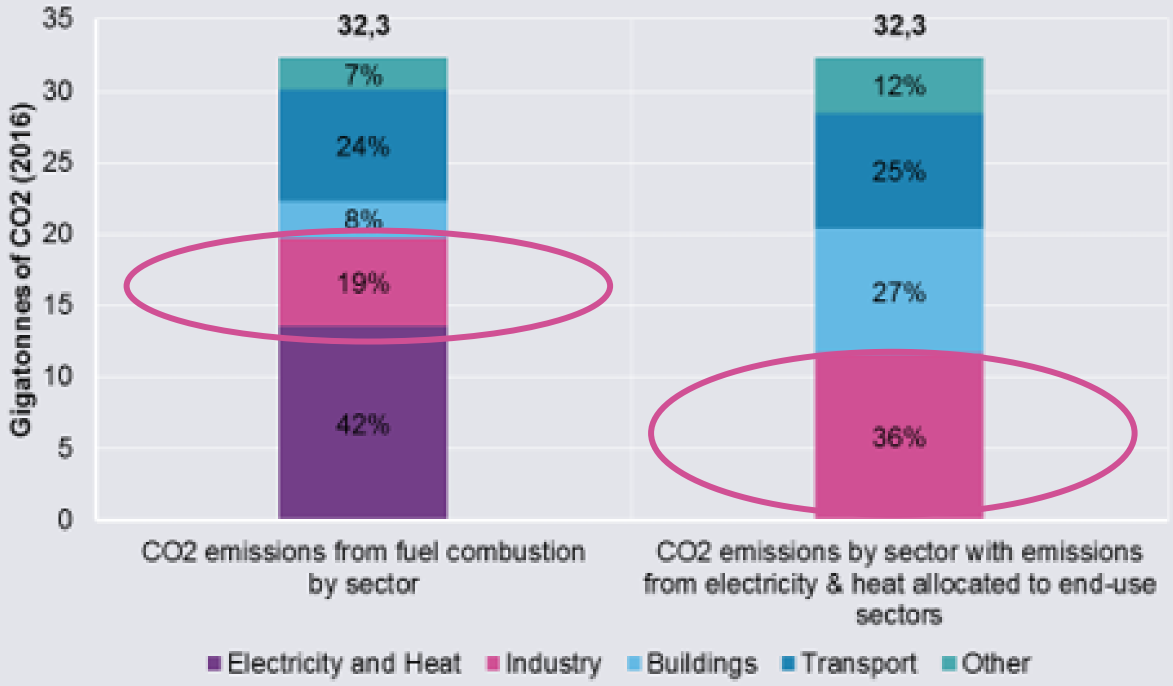
When it comes to decarbonization efforts, the industry sector has long been left out of the discussion… but industry is critical to reach the goals of the Paris Agreement

Global fossil fuel emissions by production (left) and end-use (right)



Agora Energiewende based on IEA 2018; McKinsey 2018

Different emission allocation methods

If the emissions by the electricity and heat sector are allocated to the end-use sector, industry is by far the largest CO_2 emitting sector

Hard-to-Abate Sectors (Steel, Cement, Chem.)

Most climate mitigation efforts focused on low-hanging fruits (coal phase-out, buildings, transport)

Rising global demand for basic materials

Yearly production in 2050 compared to 2015:

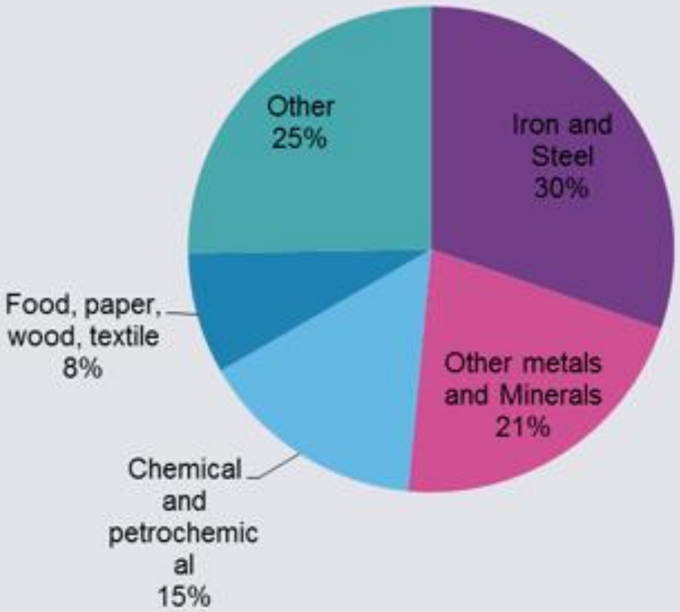
Steel (+30%); cement (+25%); ammonia (+65%)

Avoiding process emissions is key

Due to the long life-times of industrial plants, future reinvestments should be into the new technologies

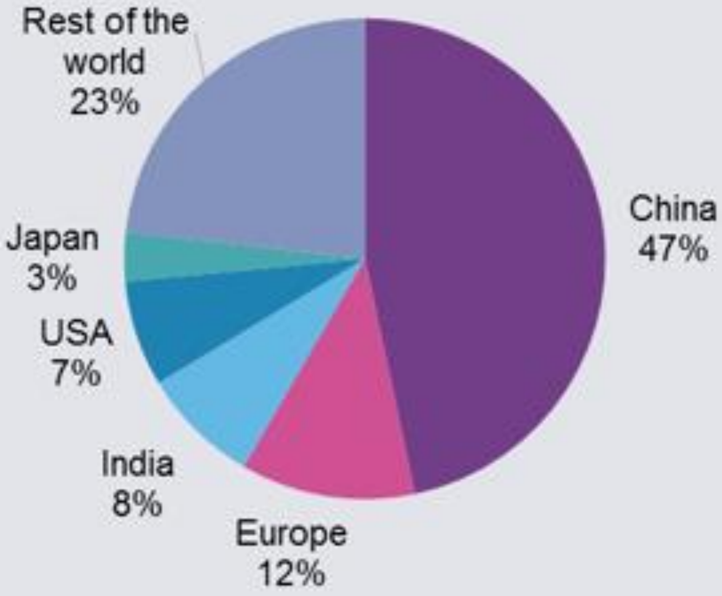
3 sectors account for 66 percent of the emissions in the industry sector – steel, cement, fertilizers and plastics are the most CO_2-intensive products

Industry global CO_2 emissions (2016): the share of key branches



Agora Energiewende based on IEA 2018

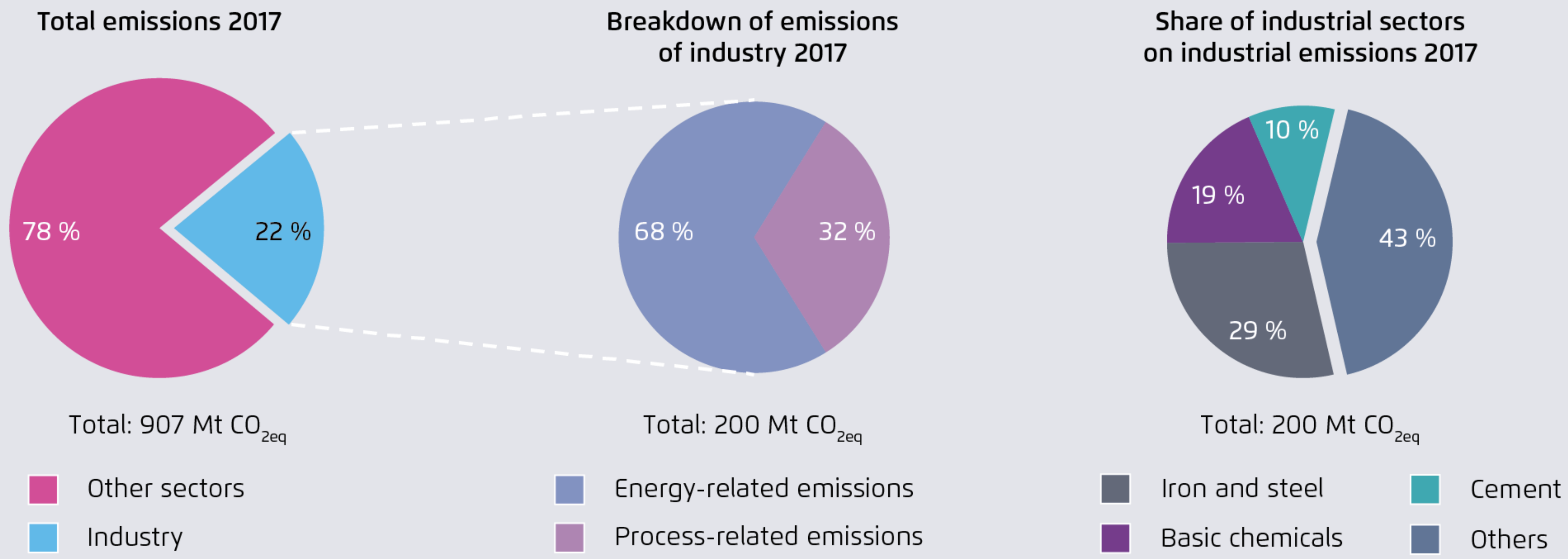
CO_2 emissions of industry (2016): Where do they come from?



Agora Energiewende based on IEA 2018

Germany: Industry is responsible for about one fifth of total emissions – about 60 percent of which is accounted for by the steel, chemical and cement industries

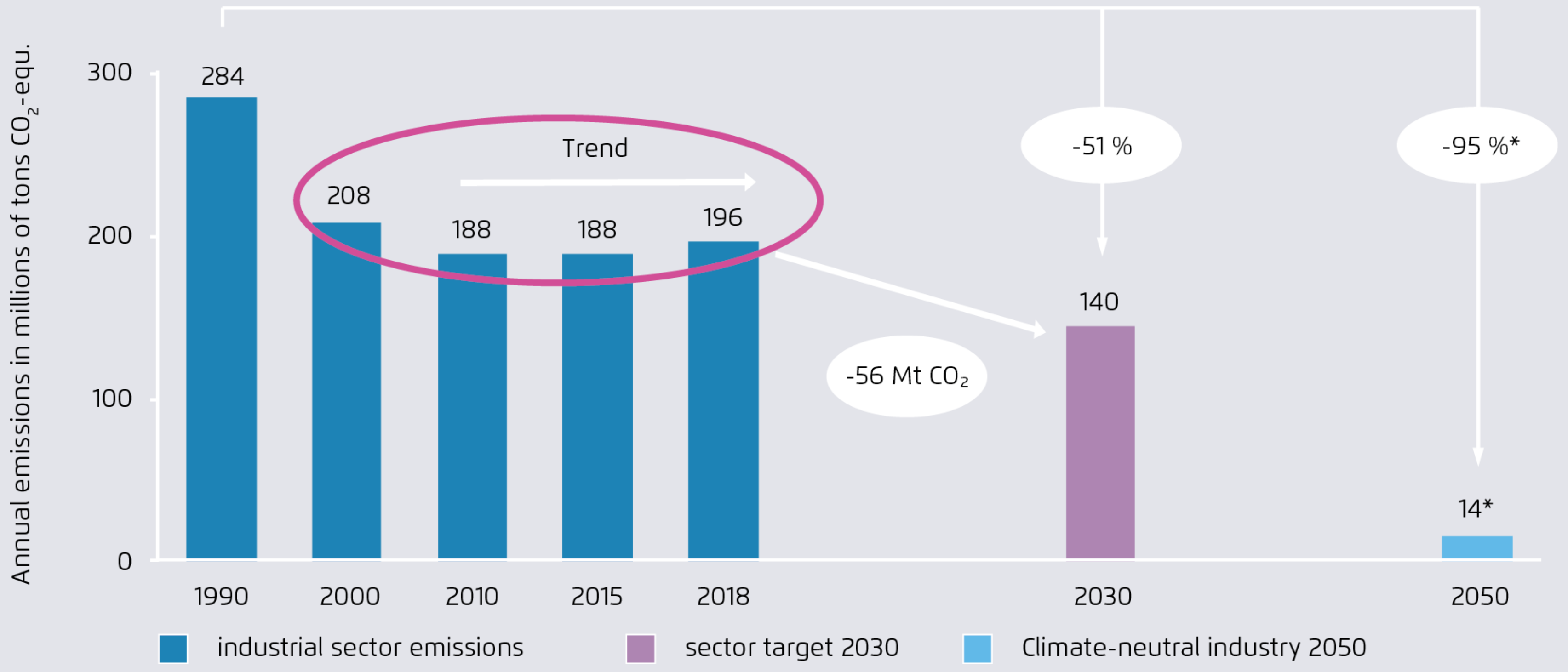
German industrial sector emissions in 2017 in Mt CO_{2eq} (by source balance)



Sources: UBA, 2019a; WV Stahl, 2018; VDZ, 2018; Wuppertal Institute, 2019

Industrial emissions in Germany have remained constant since 2010 – energy efficiency compensated for parts of production growth, but are not sufficient for a climate-neutral industry

Emissions in the German industrial sector 1990 - 2018 (according to Germany's climate protection plan) as well as German sector targets for 2030/2050 for the industrial sector



Sources: UBA, 2019a; BMU, 2016; * Residual emissions 2050 must be offset

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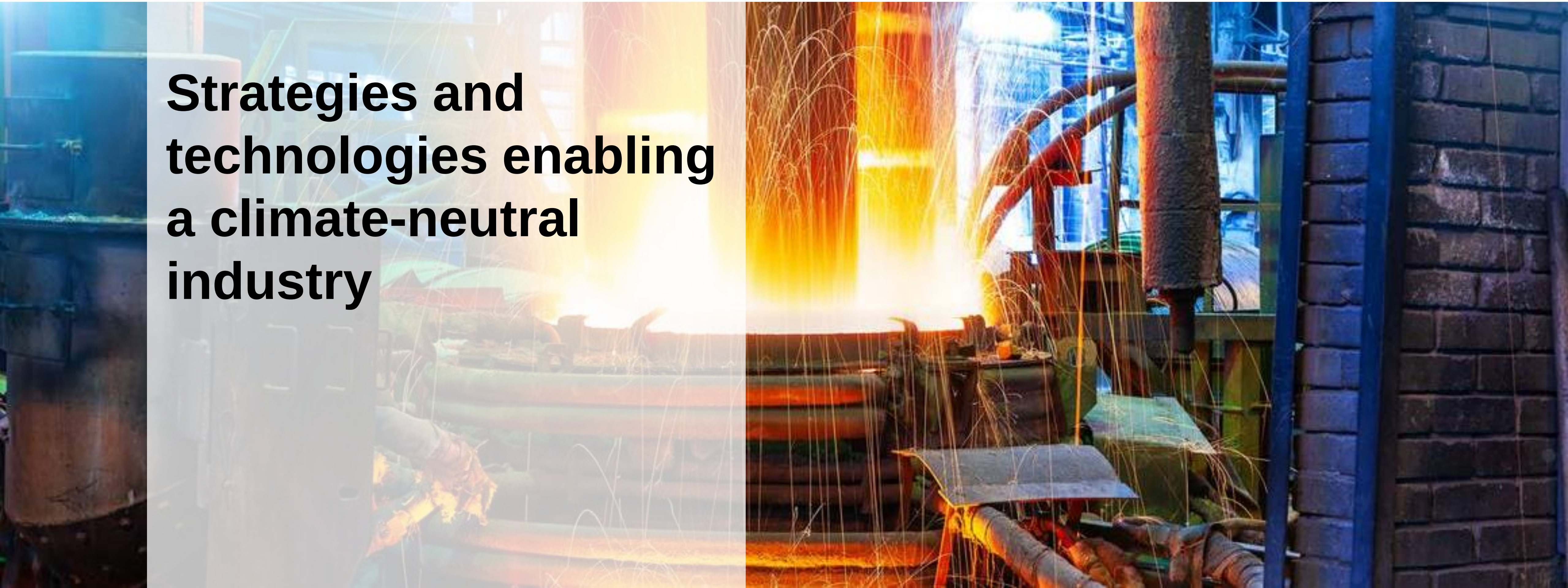
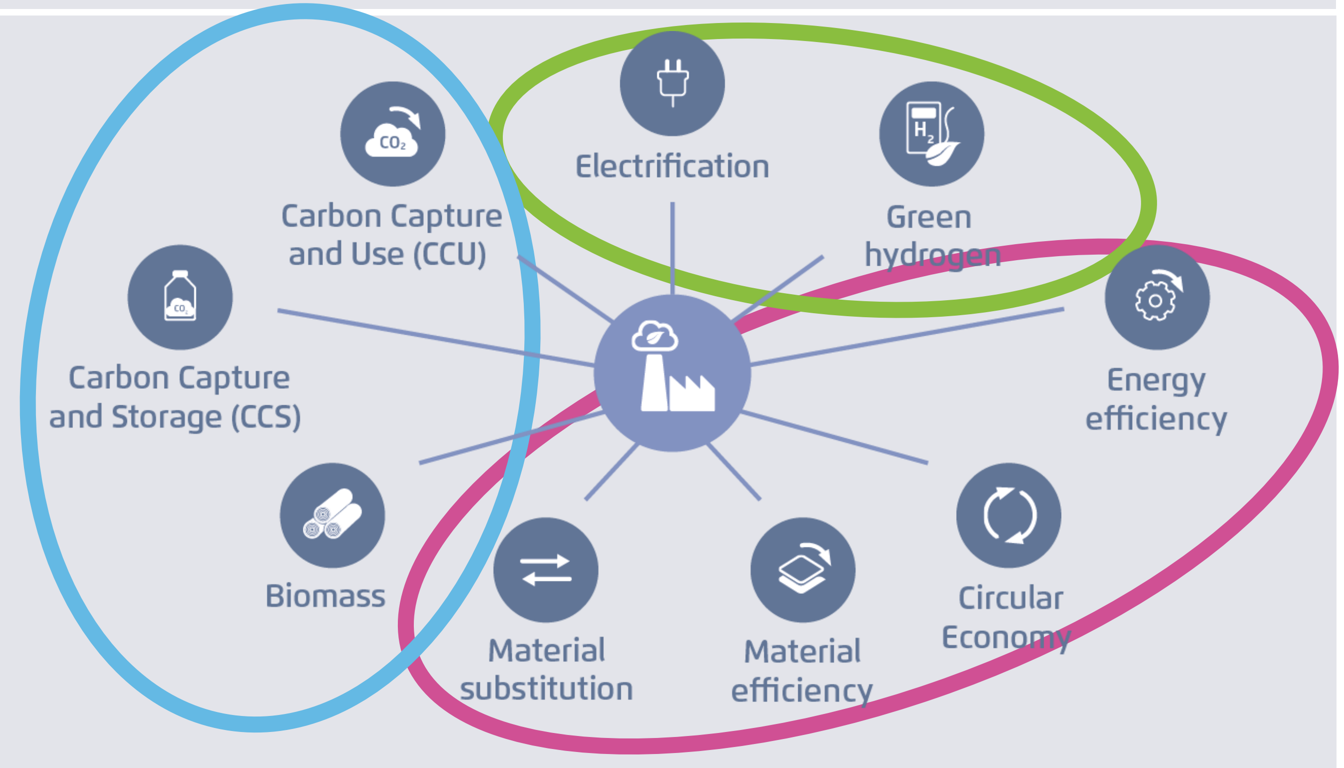
Strategies and technologies enabling a climate-neutral industry



A combination of different strategies enables a climate-neutral industry – the less emphasis is placed on electrification, the more ‘circular economy’ and CCS are required

Strategies that enable a climate-neutral industry



Source: Agora Energiewende, 2019

1. **Strategy: Direct and indirect use of renewable electricity**
   - → Direct use of green electricity
   - → Indirect use of green electricity through green hydrogen
2. **Strategy: Resource efficiency and the circular economy (‘Kreislaufwirtschaft’)**
   - → Circular Economy
   - → Energy efficiency
   - → Material efficiency
   - → Material substitution
3. **Strategy: Closing the carbon cycle**
   - → Carbon Capture and Storage (CCS)
   - → Carbon Capture and Use (CCU)
   - → Biomass

Key technologies for basic chemicals: There are promising technologies to reduce emissions and close material cycles

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Overview of possible key technologies for a (largely) greenhouse gas-neutral chemical sector

Chemicals	Key technology	Earliest possible market readiness	
	Heat and steam generation from power-to-heat	From 2020	Direct and indirect use of green electricity
	CO_2 capture at combined heat and power plants	2035 – 2045	Closing the carbon cycle
	Green hydrogen from renewable energies	2025 – 2035	Direct and indirect use of green electricity
	Methanol-to-olefin/-aromatics-route	2025 – 2030	Direct and indirect use of green electricity; Closing the carbon cycle
	Chemical recycling	2025 – 2030	Direct and indirect use of green electricity; Resource efficiency and Circular Economy
	Electric steam crackers	2035 – 2045	Direct and indirect use of green electricity

- Direct and indirect use of green electricity
- Closing the carbon cycle
- Resource efficiency and Circular Economy

Sources: Agora Energiewende/Wuppertal Institut, 2019

Key technologies for steel: Hydrogen will play a central role
Key technologies for cement: Alternative binders and CCS are needed

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Overview of possible key technologies for a (largely) greenhouse gas neutral steel and cement sector

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 utilization of waste gases from integrated blast furnaces	2025 – 2030

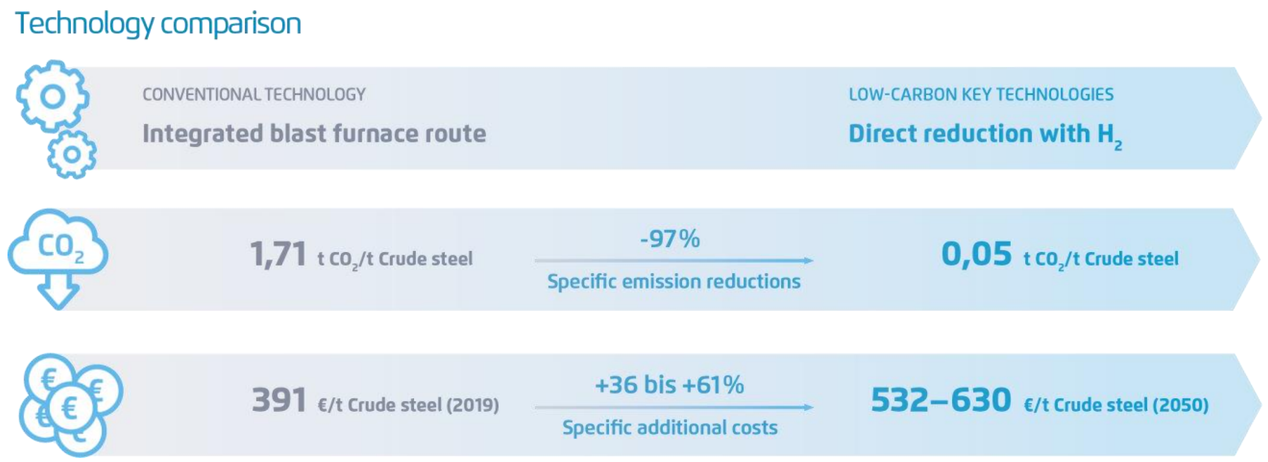
Cement	Key technology	Earliest possible market readiness
	CO_2 capture with oxyfuel process (CCS)	2025 – 2030
	CO_2 capture in combination with electrification of the high temperature heat at the calciner	2030 – 2035
	Alternative binders	2020 – 2030 (depending on product)

- Direct and indirect use of green electricity
- Closing the carbon cycle
- Resource efficiency and Circular Economy

Sources: Agora Energiewende/Wuppertal Institut, 2019

The promising low- and zero-carbon technologies identified in the study have different CO_2 reduction potentials, costs and technological maturity levels

Comparison of direct reduction with hydrogen with the blast furnace route

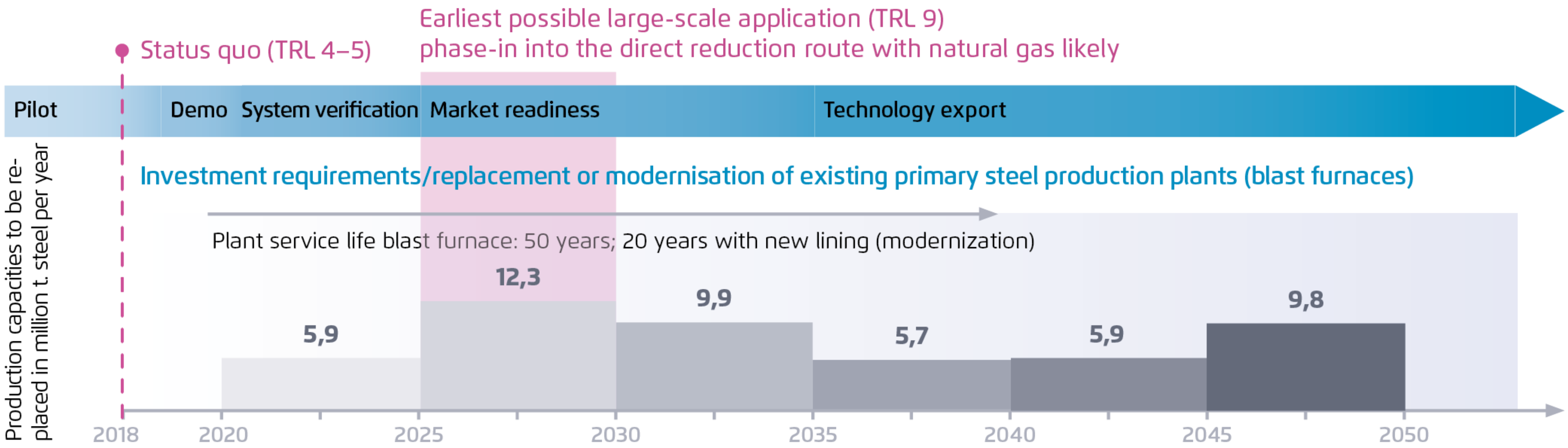


Source: Wuppertal Institut, 2019

- Agora Energiewende and the Wuppertal Institute have developed brief fact sheets for 13 promising key technologies in the fields of steel, chemistry and cement that are potentially CO_2-free/low CO_2
- Information provided in the fact sheets includes: CO_2 abatement costs, CO_2 abatement potential, technology-specific additional costs, existing pilot projects, reinvestment cycles and technology readiness.
- Interim results were provided to and consulted with industry associations and companies

Steel: High reinvestment needs until 2030 – climate-neutral technologies must be scaled up as quickly as possible – a multistep phase-in beginning with natural gas is possible

Reinvestment requirement and possible market readiness of direct reduction with hydrogen



Sources: Wuppertal Institute/Agora Energiewende, 2019

German industry is working on numerous pilot projects – but the framework conditions needed to enable large-scale commercialization and deployment are still missing

Pilot projects of the energy-intensive industry in Germany

Source: Fotolia, 2019

Salzgitter AG, ArcelorMittal

→ *H2-DRI*: Steel production by direct reduction with hydrogen

ThyssenKrupp, BASF, Linde, Covestro, Evonik

→ *Carbon2Chem*: Use of waste gases e.g. CO_2 from blast furnace process for chemical production

BASF, Remondis, Plastics Energy and others

→ *ChemCycling*: Chemical recycling of plastic waste for reuse

HeidelbergCement and others

→ *CEMCAP*: Oxyfuel-CCS (Clinker cooling)

→ *LEILAC*: Electrification of cement kiln and CCS

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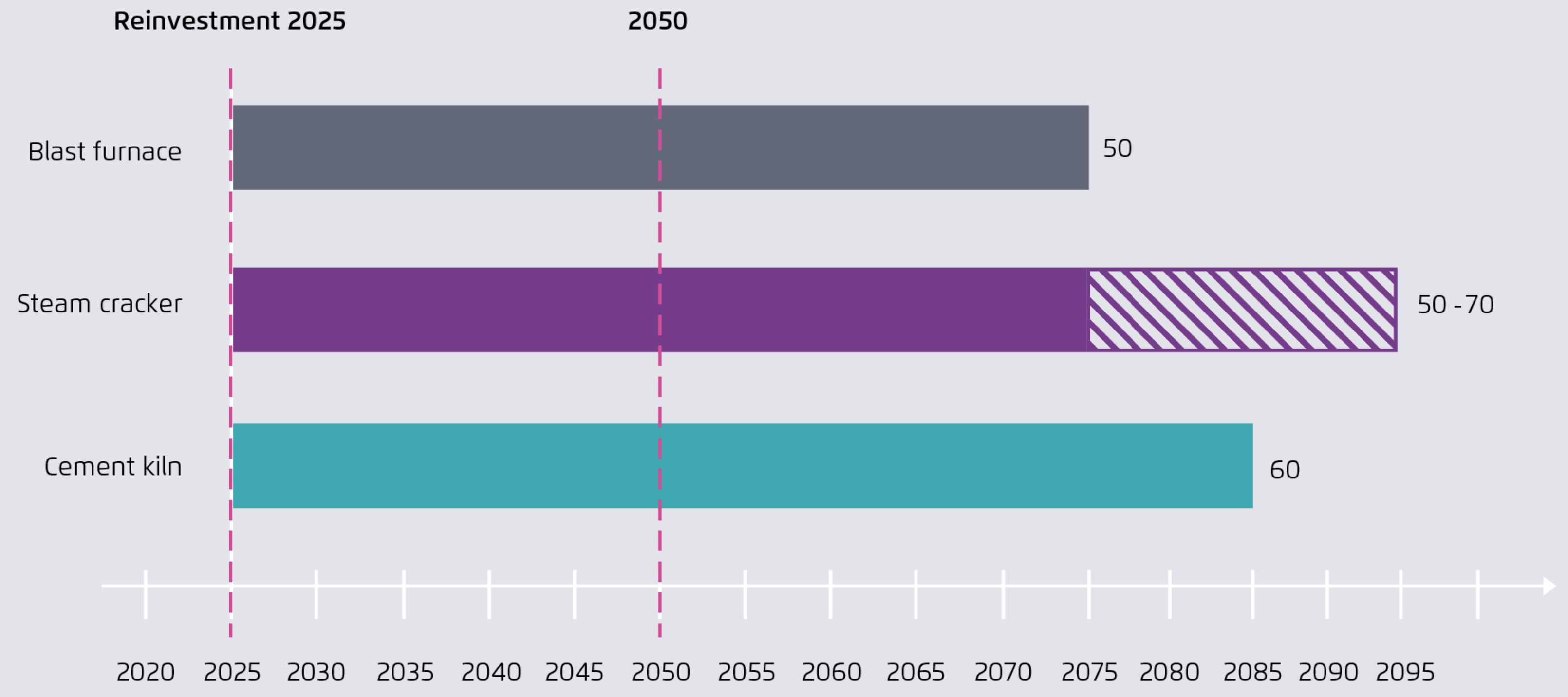
Policy instruments for enabling a climate-neutral industry

All plants built today will still exist in 2050 – any future investment must therefore be climate-neutral

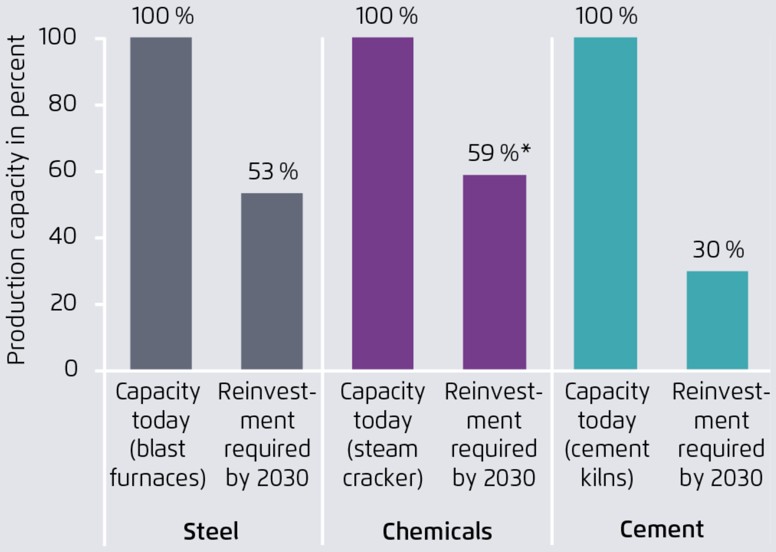
Technical lifetime of primary production plants in the steel, chemical and cement sectors with reinvestment in 2025



Sources: Agora Energiewende/Wuppertal Institute, 2019

The reinvestment needs in Germany’s energy-intensive industry until 2030 are high – many jobs are affected

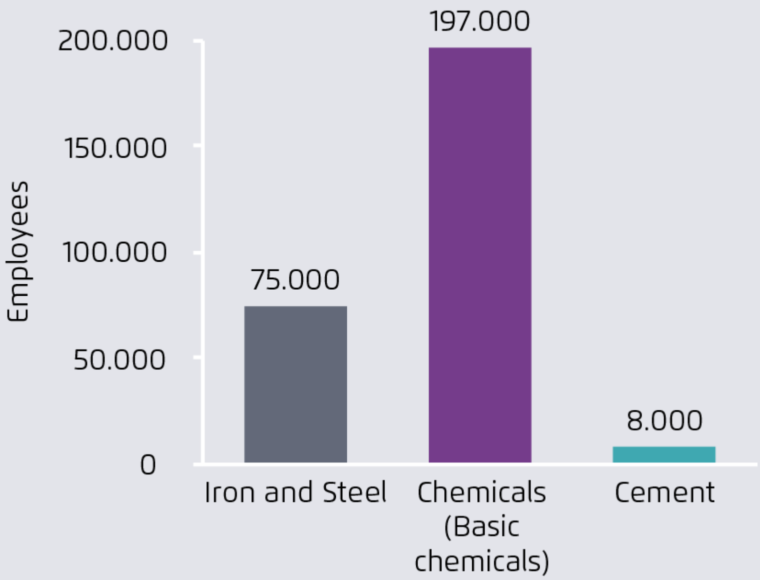
Reinvestment needs in German Industry until 2030 (primary production capacity)



* 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.

Source: Wuppertal Institute, 2019

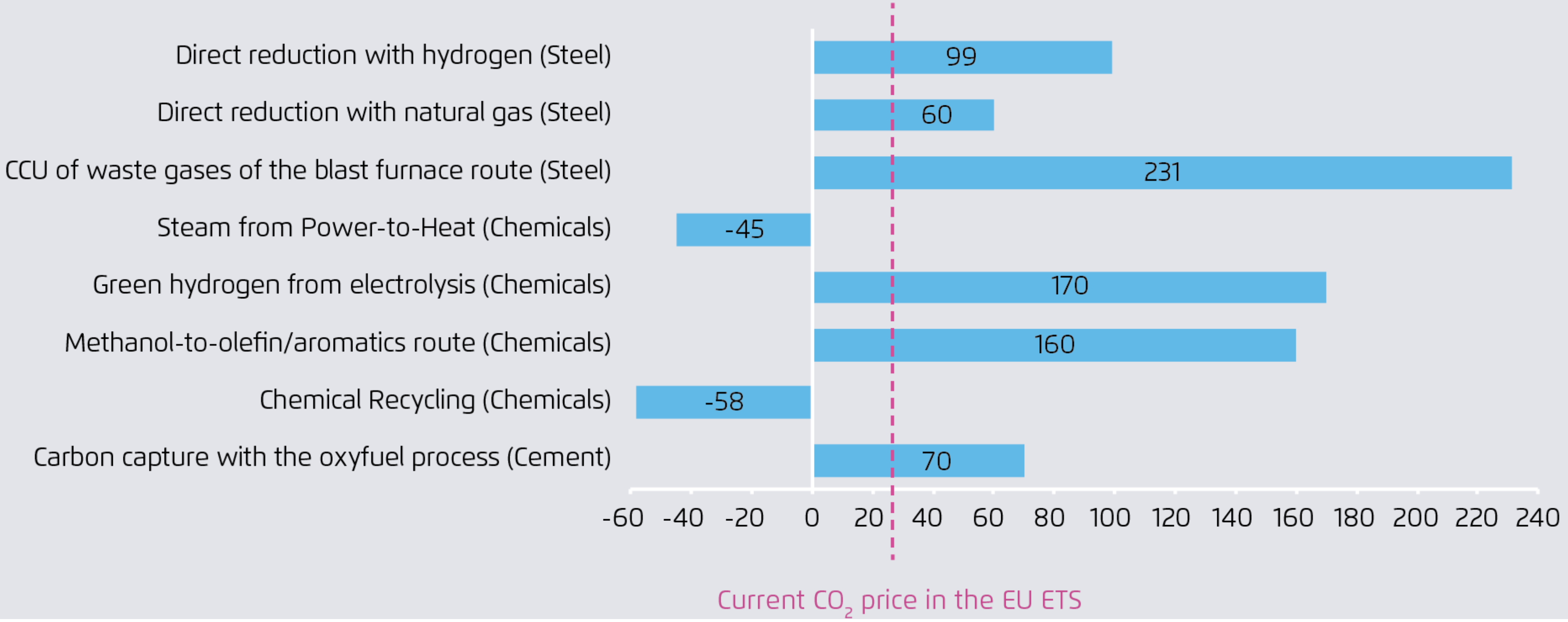
Direct employment of relevant industries in Germany 2018



Source: Statistisches Bundesamt, 2018

The marginal abatement costs of breakthrough innovations are in most cases significantly higher than current and anticipated EU ETS-prices

Marginal abatement costs of new technologies in industry 2030, lower range, in Euro/t CO_2



Sources: Wuppertal Institute/Agora, 2019

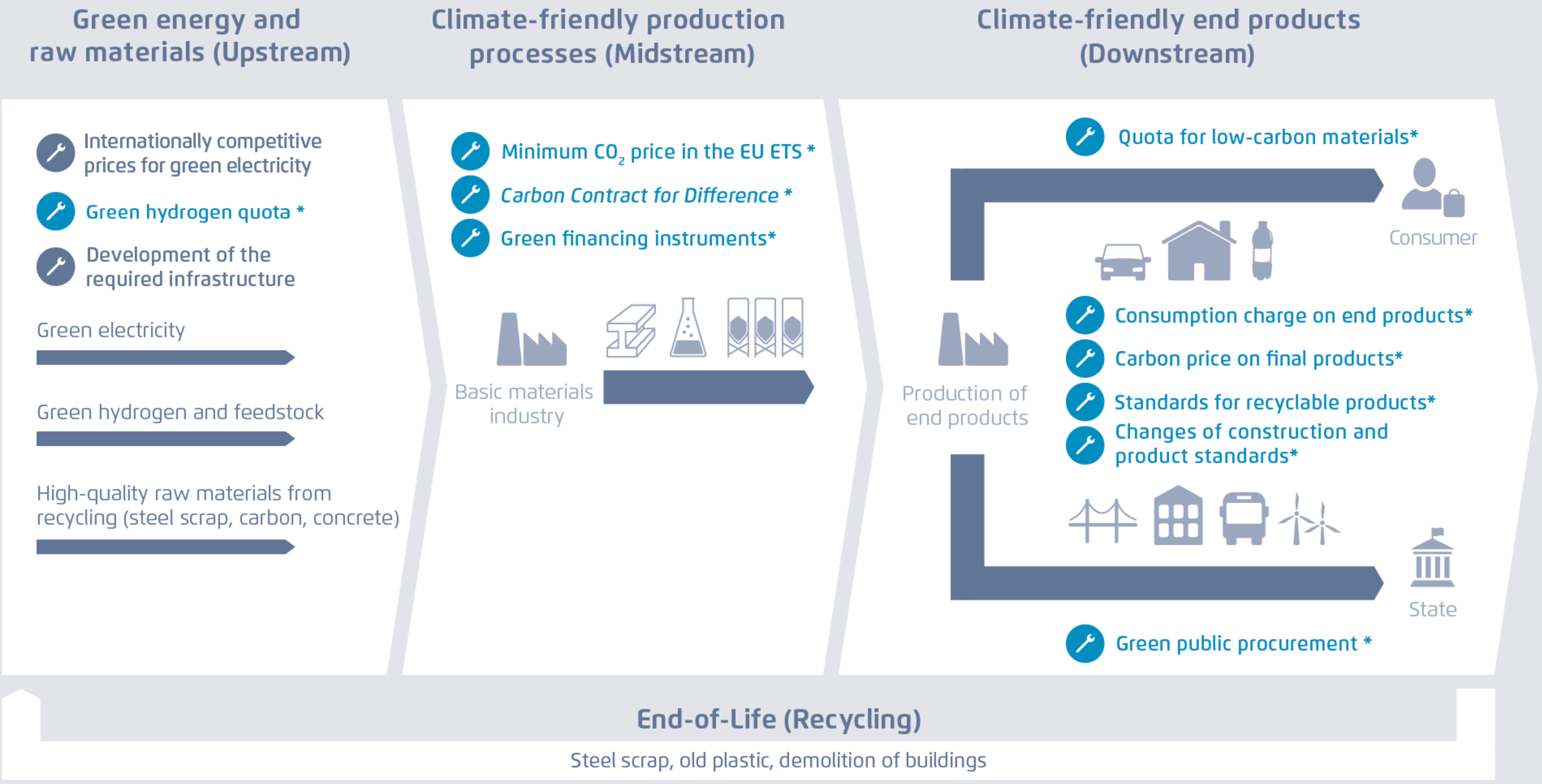
In principal there are two options:
Option I: A very high CO_2 price with a border adjustment regime
Option II: A policy mix of various instruments

Option 1: CO_2 price only

Internalisation of external costs	**high** EU-ETS price + border carbon adjustment

Option 2: Policy mix

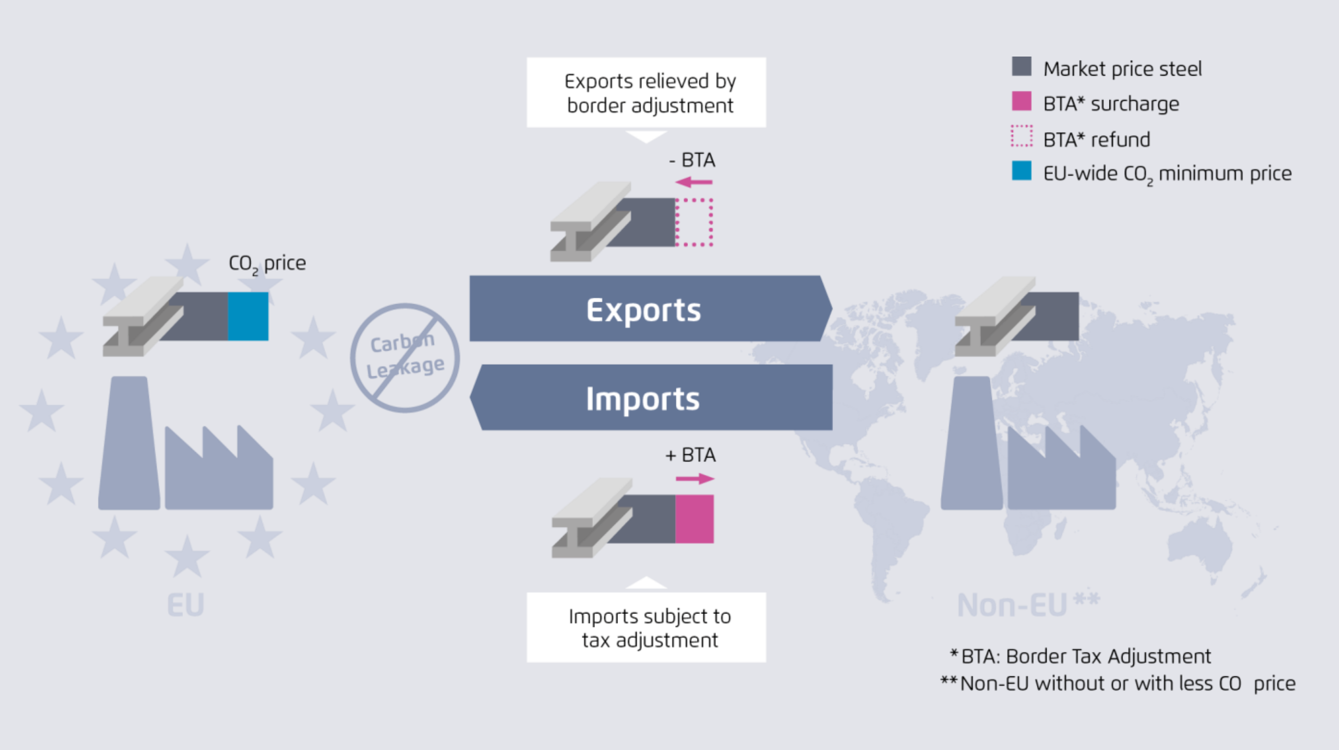
Internalisation of external costs	**moderate** EU-ETS price + free allocation	Carbon price on end products	Consumption charge on end products
Financial support schemes	Carbon Contract for Difference (CfD)	Green financing instruments	
Securing sales markets	Green hydrogen quota	Quota for low-carbon materials	Green public procurement
Circular economy standards	Changes in building & product standards	Standards for recyclable products	



*More detailed explanation in policy instrument fact sheets in Part D

Option I: A high CO_2 price in the EU-ETS, coupled with a border adjustment mechanism, is theoretically optimal – but comes with high practical hurdles and may fuel trade conflicts

High CO_2 price in EU-ETS with border adjustment regime

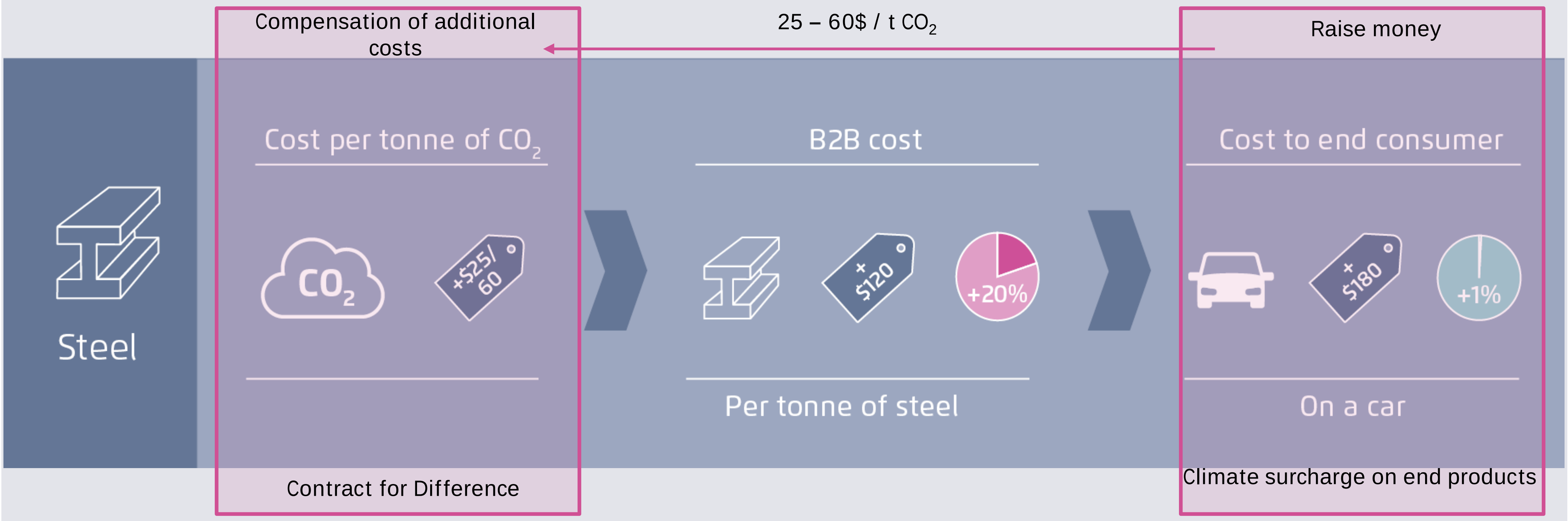


Source: Agora Energiewende, 2019

- → A high CO_2 price with a border adjustment mechanism is the most economically efficient solution and guarantees a level playing field
- → A border adjustment regime is currently being discussed in the EU Commission and is called for by the French government
- → Technically and administratively ensuring the transparency and validity of emissions data is difficult.
- → The introduction of a border adjustment regime (above all for exports) is associated with high hurdles under international trade law
- → Even if administrative and legal issues can be resolved, the political risk remains that trading partners will regard a border adjustment regime as a non-tariff barrier and react with countermeasures; fueling trade conflicts

Option II: A Carbon Contract for Difference for low carbon key technologies, financed by a climate surcharge on end products

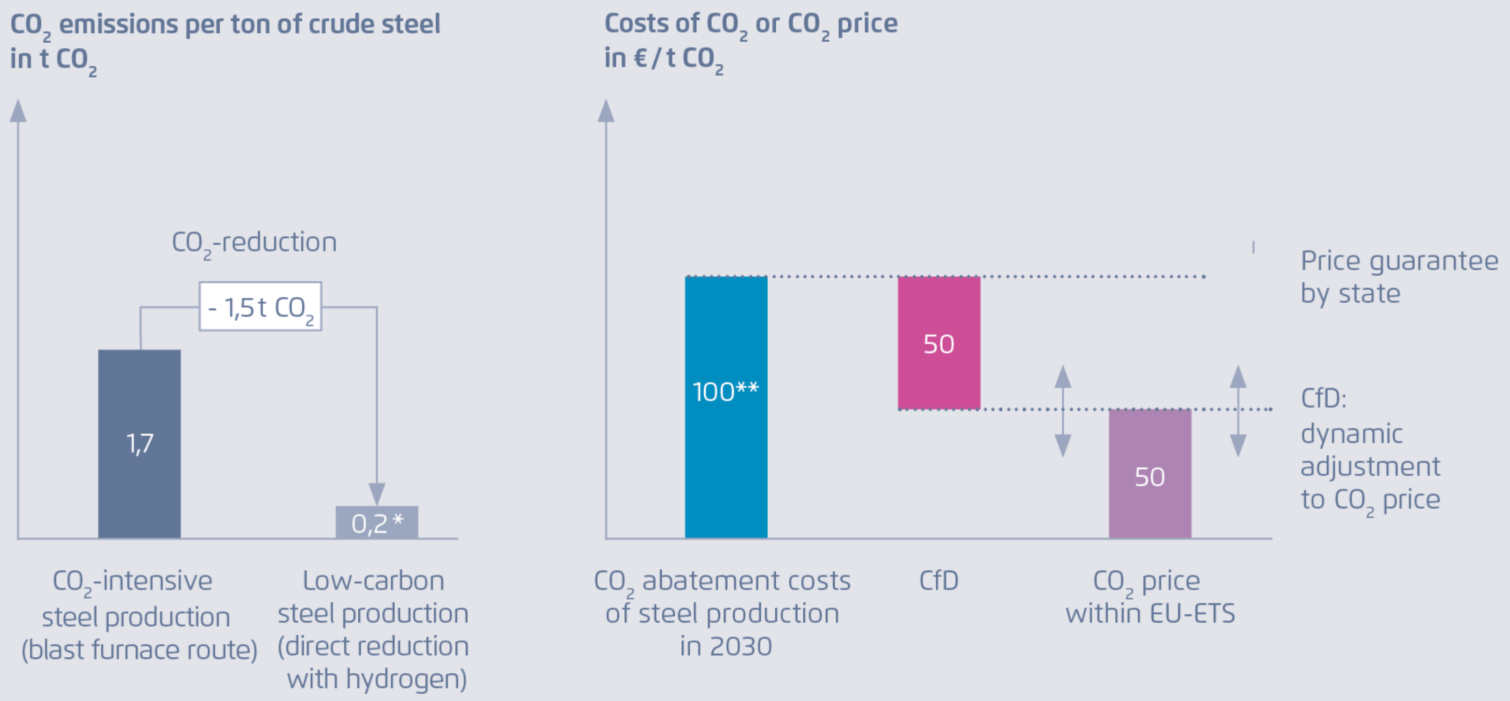
Policy mechanism to compensate for additional costs of green steel production through CfD along on the steel value chain



Source: ETC, 2018

Illustration:
How a Carbon Contract for Difference could help finance new low-carbon key technologies

Illustration of the policy mechanism of the Carbon Contract for Difference



Source: Agora Energiewende, 2019

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Conclusion and questions for Q&A session

- The 2030 sector target for German industry is ambitious – given continued economic growth, it will be difficult to achieve the targets through efficiency improvements alone. Fundamentally new processes and production methods are also needed to achieve climate-neutrality in industry.
- The available strategies and technologies for a climate-neutral, energy-intensive industry are well known. Anticipating the need to achieve climate-neutrality by 2050, it is critical that upcoming re-investments until 2030 go into future-proof technologies.
- Research and innovation funding is helping to bring technologies into the pilot and demonstration phase. However, appropriate policy instruments and framework conditions to enable commercialization and industrial-scale investment are still needed.

Questions for the Q&A session:

- Which policy instruments are best suited to a climate-neutral industry?
- What should be the relationship between the EU-ETS and potential new instruments?
- What is the likely timeframe for the introduction of new instruments?

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