PATHWAYS TO DEEP DECARBONISATION OF THE GERMAN INDUSTRY SECTOR UNTIL 2045

WIFO Research Seminar (Online), 8th September 2021

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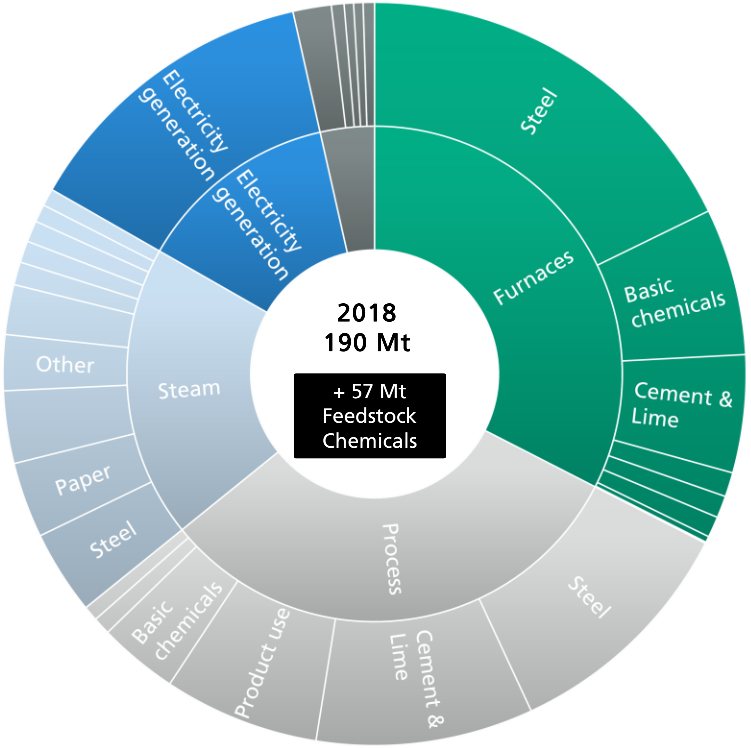

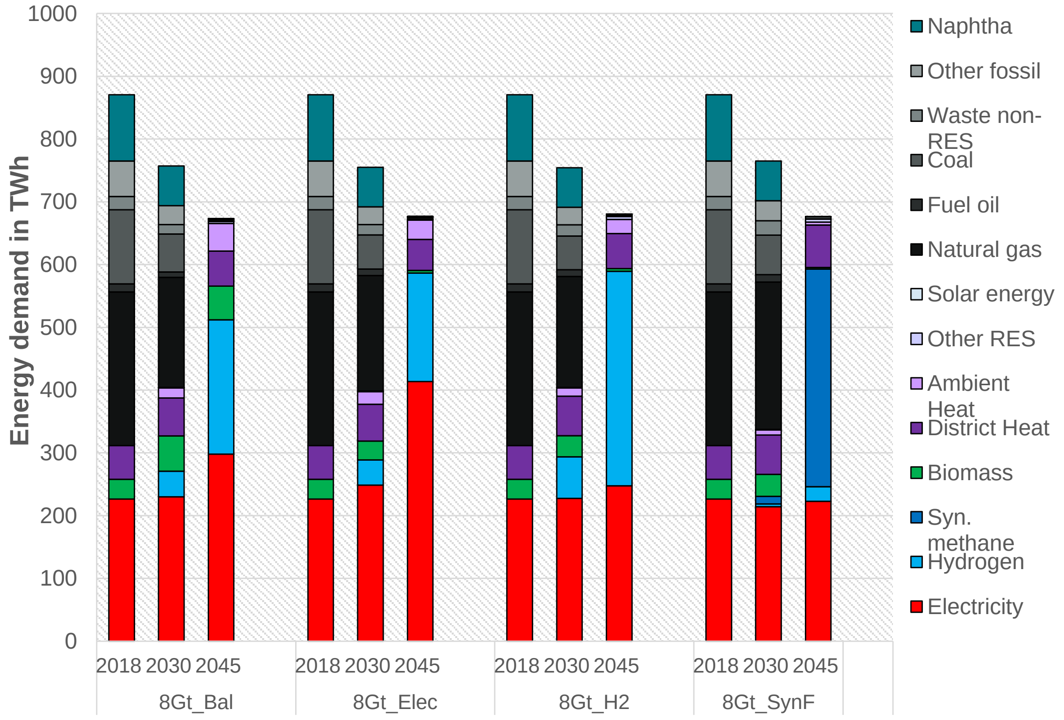

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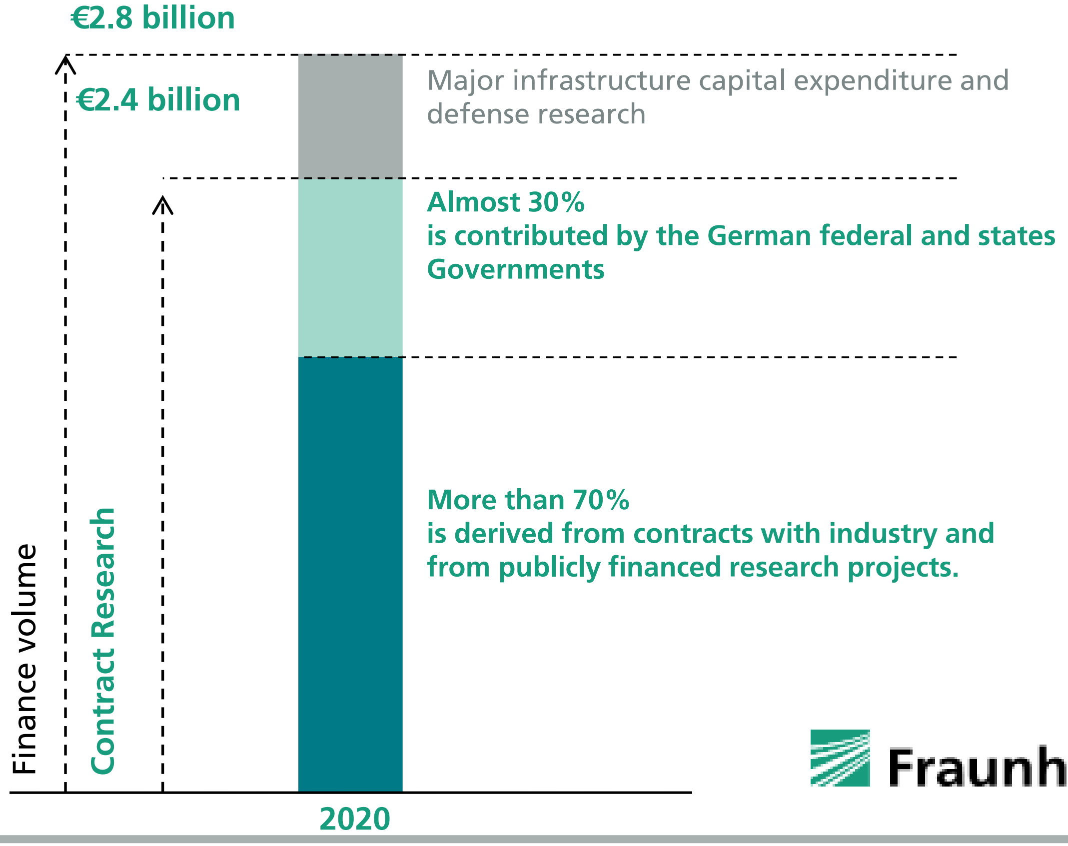

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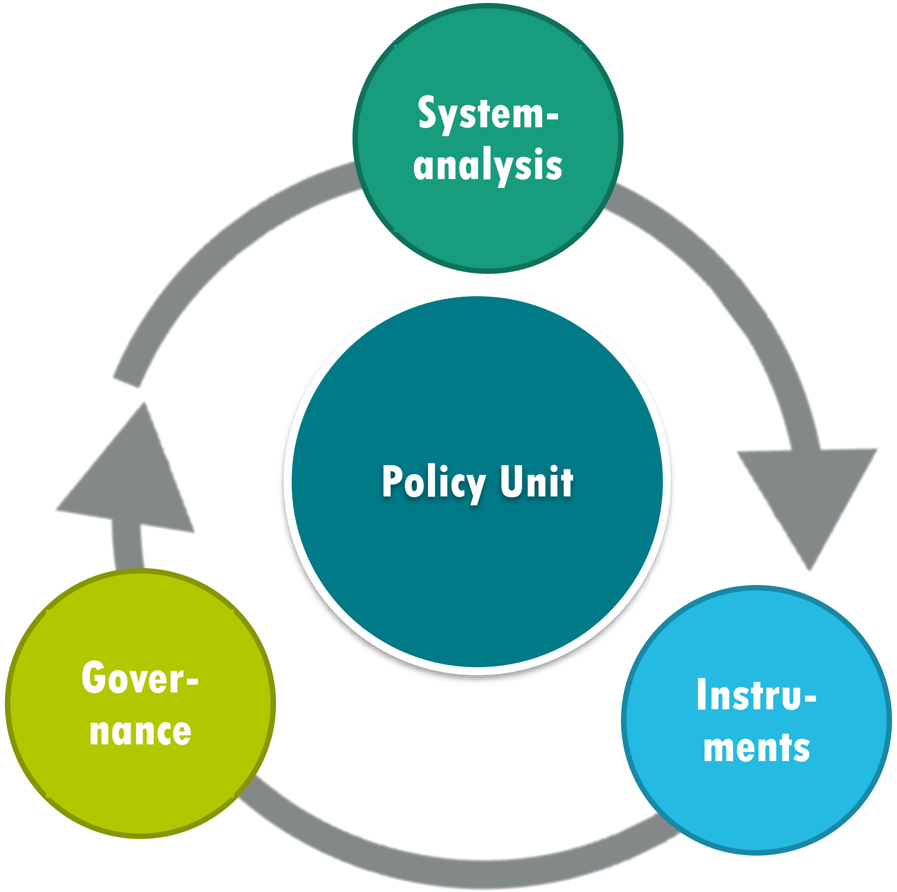
Project Context - Copernicus Project ARIADNE 2020 - 2023

Ariadne analyses how policy measures work in a joint learning process between science and society - from individual sectors to the big picture

Joint learning process of science, politics, business and society via participation formats

Governance and institutions for an effective policy process



Energy transition strategies and their systemic effects and sectoral interactions

Policy instruments to achieve the goals in an efficient and socially balanced way

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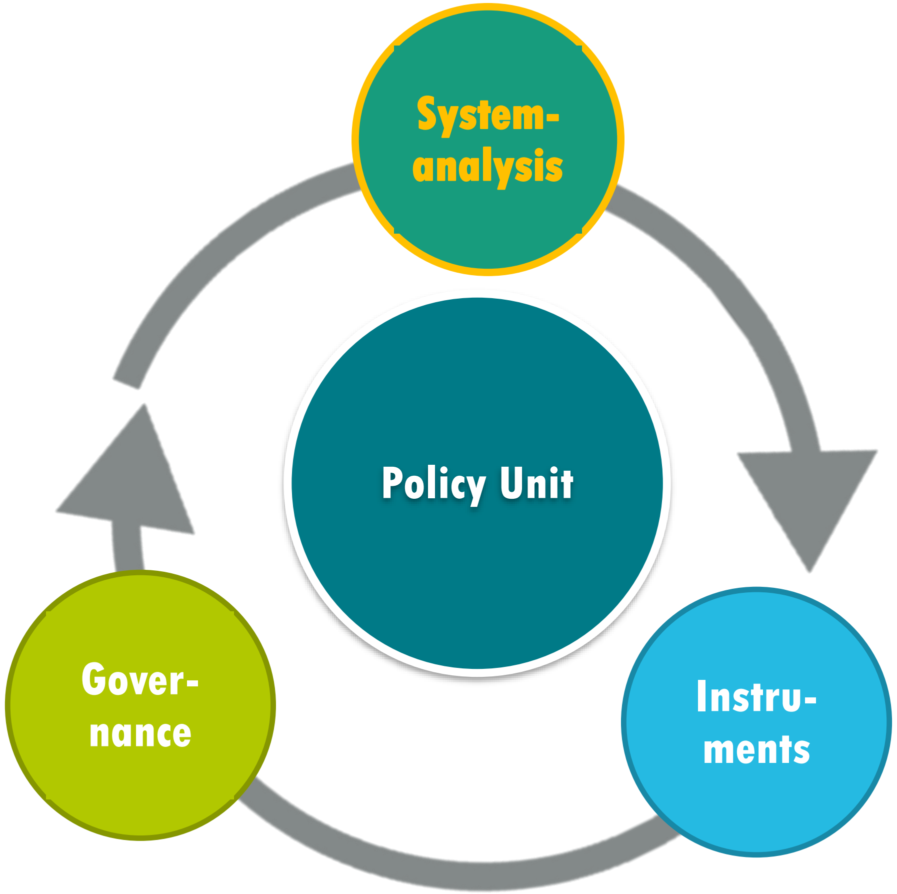

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OUTLINE

- **Introduction**
- Methodology
- Pathways
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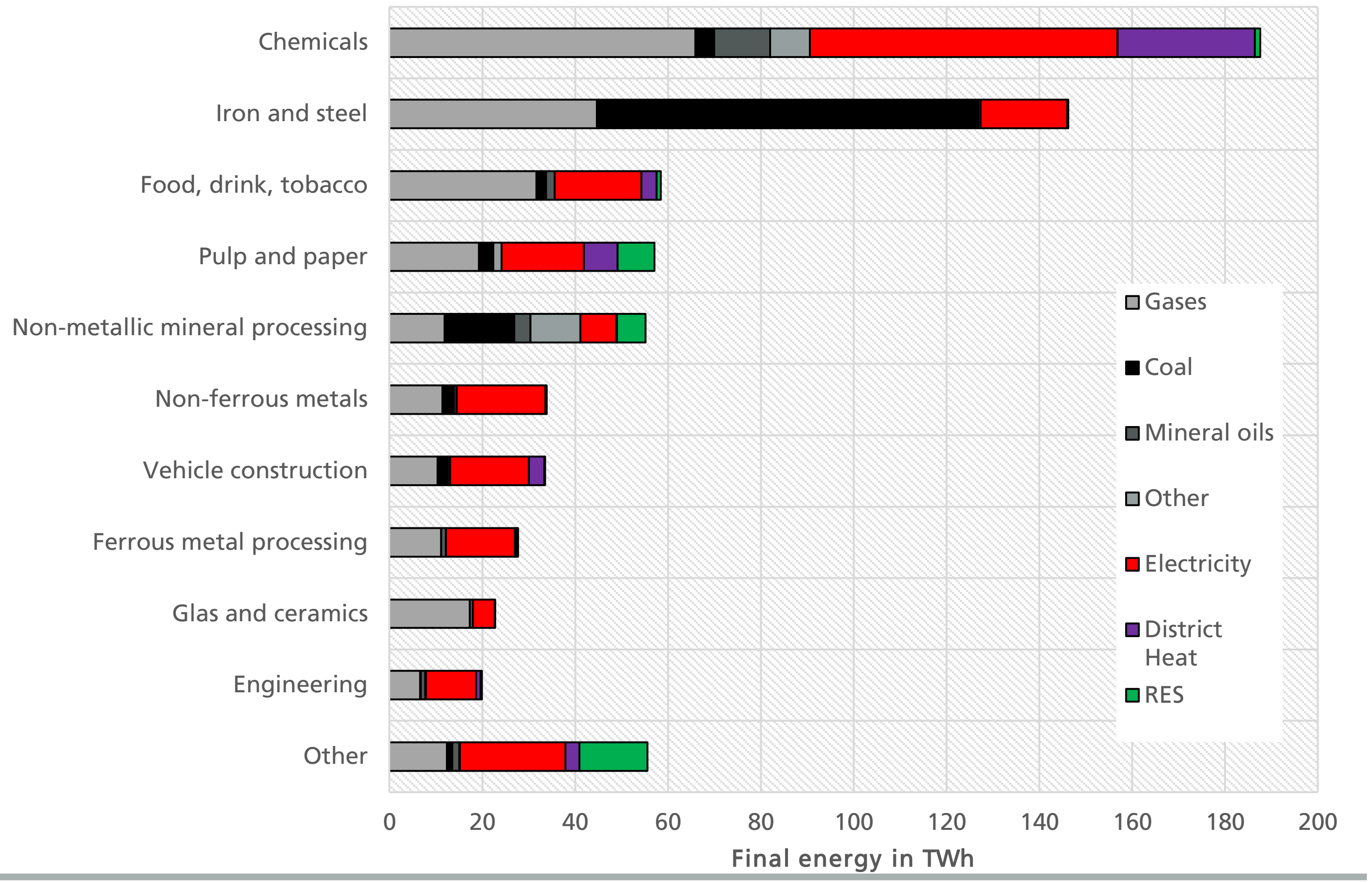
The industrial sector is responsible for about 23% of GHG emissions in Germany

- About **70 % of industrial energy demand** is generated by companies in **energy-intensive industries** (e.g. iron & steel, cement, basic chemicals)
- To achieve long-term GHG neutrality, industrial emissions must also **trend towards zero** in the long term
- **Interim target for the industrial sector 2030:** **118 Mt = 57%** emission reduction by 2030 compared to 1990
- **Unclear** which **technology path** industry will take towards decarbonisation

Industrial final energy consumption by economic sector



Quelle: AGEB

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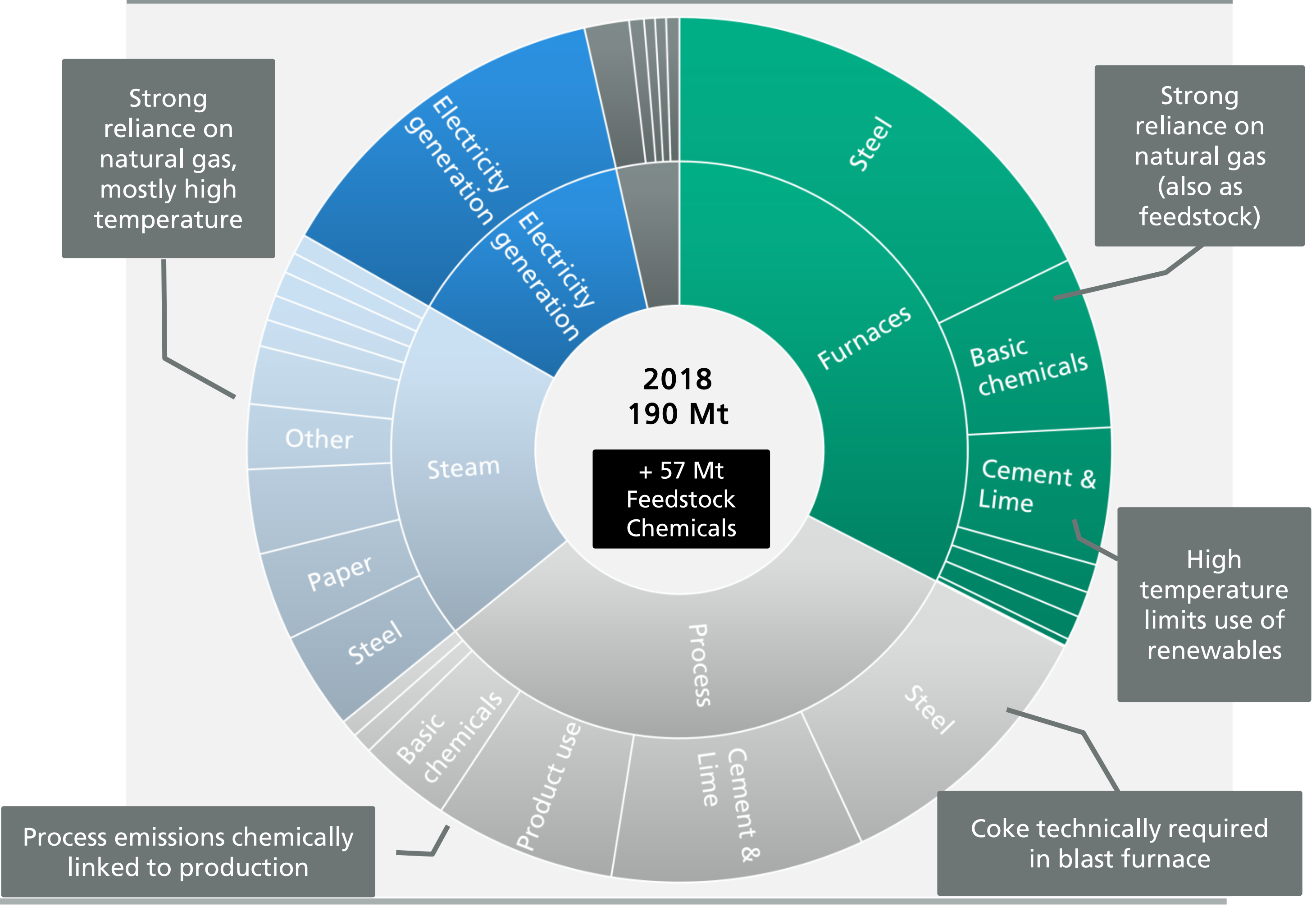
The transformation of the industrial sector still faces very major challenges

- **Many options** such as energy efficiency, biomass, electrification, green hydrogen, power to gas (PtG), circular economy, material efficiency, process change and CCU/S are on the table

- **Tension field:**
  - Individual **contributions are hotly debated**
  - CO2-neutral processes differ in **maturity and distance to market**
  - Transformation cannot succeed without an **appropriate political framework**
  - Preservation of international **competitiveness** of industry
  - Availability of **resources & infrastructure**

Direct industrial emissions by end-use category and sector*



* Excluding refineries; Source: Fraunhofer ISI

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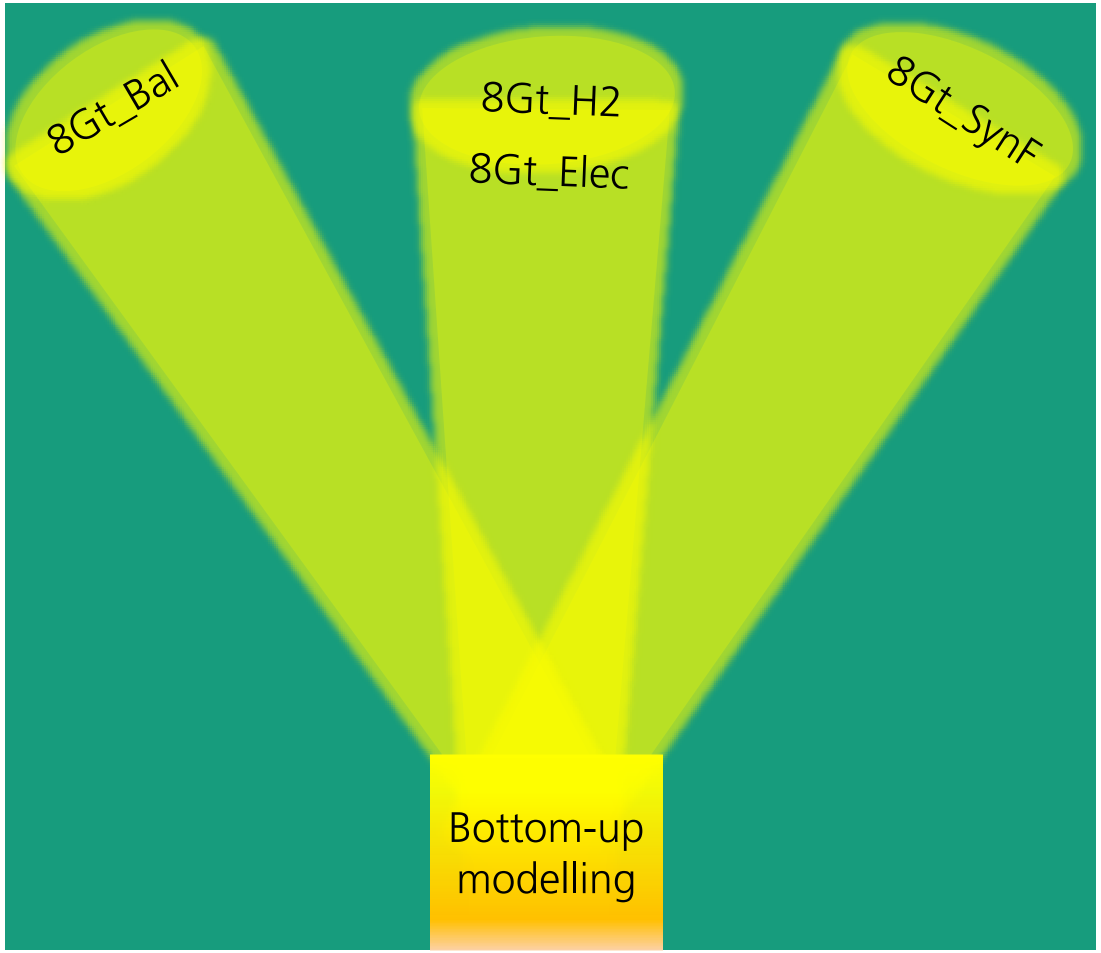
Gaining knowledge through comparison instead of a single "lead scenario"



Central questions

- How could different (technology) pathways to a near-climate neutral industry by 2045 look like?
- What role does the use of electricity and hydrogen play in the different scenarios?

Approach

- Comparison of the decarbonisation of the energy system through
  - a balanced technology approach (scenario 8Gt_Bal)
  - very high use of electricity (scenario 8Gt_Elec)
  - very high use of hydrogen (scenario 8Gt_H2)
  - very high use of synthetic hydrocarbons (8Gt_SynF)
- Modelling of the transformation pathways until 2045 with a detailed bottom-up model

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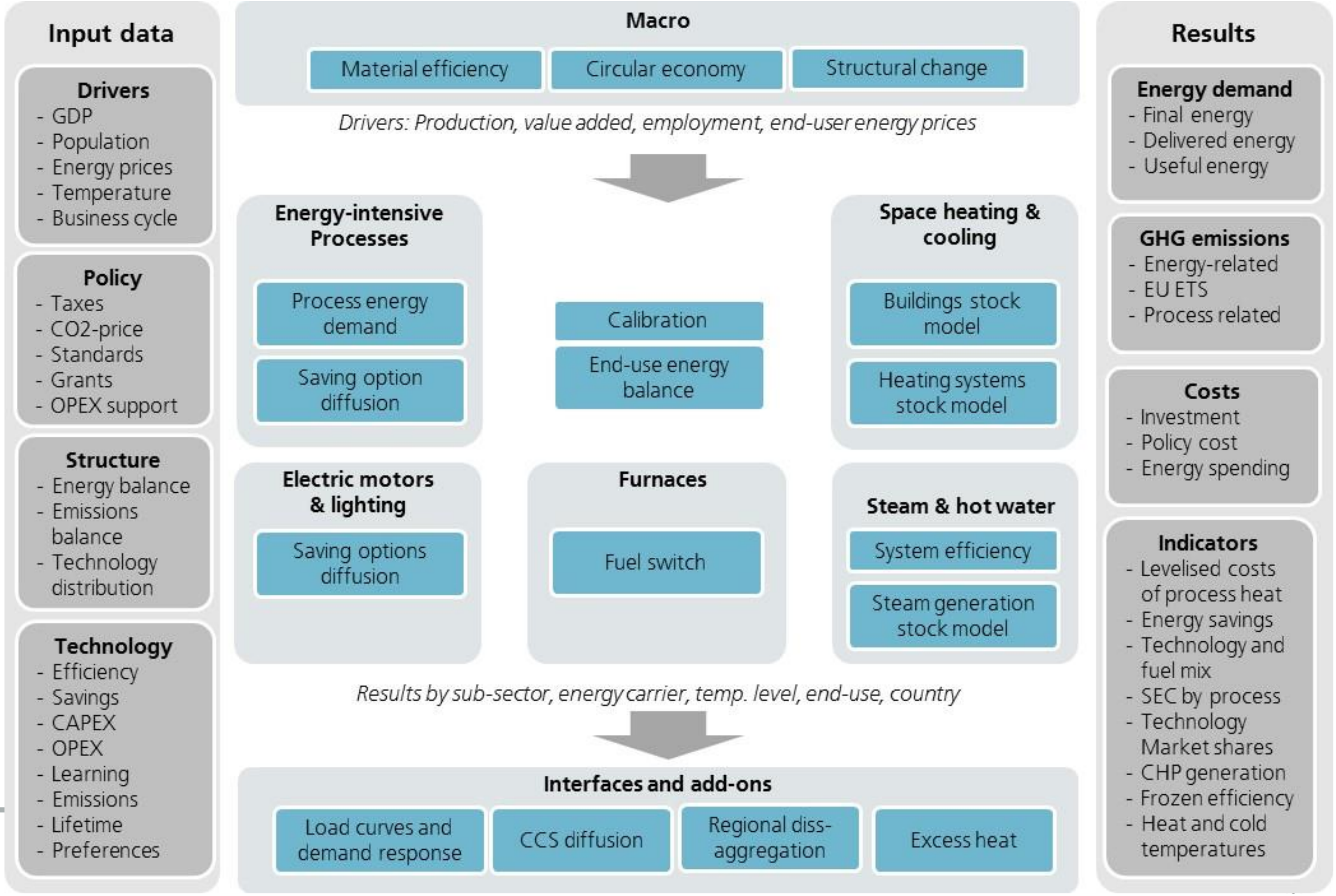
Bottom-up simulation model FORECAST

- Bottom-up simulation
- High technology resolution
- All important abatement levers
- Complete energy and GHG balance

https://www.forecast-model.eu

FORECAST
FORecasting Energy Consumption Analysis and Simulation Tool



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The scenarios show alternative paths to almost CO2-neutral industrial production by 2045

All GHG-neutral Scenarios

- GHG reduction in the industrial sector >95%.
- Economic development (+1% p.a.)
- Ambitious energy and material efficiency + high shares of secondary production
- Avoid use of biomass in focus scenarios
- Avoid CCS

8Gt_Bal

- No clear technology focus

8Gt_Elec

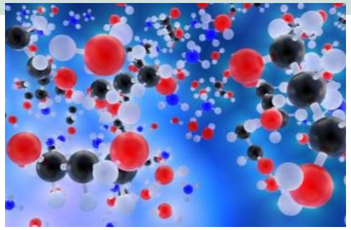
- Direct electric solutions preferred
- Hydrogen as feedstock

8Gt_H2

- Hydrogen widely available
- Use preferred in terms of energy and feedstock

8Gt_SynF

- Synthetic methane widely available
- Preferred for energy and feedstock



The scenarios show alternative paths to almost CO2-neutral industrial production by 2045

		8Gt_Bal	8Gt_Elec	8Gt_H2	8Gt_SynF
CCS	Steel, Chemicals, Cement and lime	no			CCS for cement
CCU	Cement and lime	Cement and lime as CO2-source			no
Process switch to low-carbon primary processes	Steel	H2-DRI			PtG-DRI
	Cement	Low carbon cement + waste, clinker factor	Electric clinker and lime kilns	Low carbon cement + H2-bburner	Low carbon cement + Gas
	Chemicals	MtO, H2 methanol, H2 elektrolysis ammonia			MtO + PtG methanol, H2 elektrolysis ammonia
	Glass	H2 Glass melting	Electric melter	H2 Glass melting	Glass melting (status-quo)
Fuel switch	Industrial furnaces	H2, Electricity, Waste	Electricity dominant	H2-burner furnacces and steam	Gas dominant
	Steam and hot water	Mix	Electricity dominant	H2-burner furnacces and steam	Gas dominant

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Technology overview: H2 and electricity

Subsektor	Prozess/ Produkt	Konventionelle Technologie	H2-Alternative	TRL	Elektrische Alternative	TRL
Rohstoffliche Verwendung						
Grundstoff-chemie	Ammoniak	Dampfreformierung	Synthesegasbereitstellung aus H2	8-9	-	
	Methanol	Dampfreformierung	Synthesegasbereitstellung aus H2 und CO2	8-9	-	
	Olefine (HVC)	Steam Cracker	Methanol-to Olefins	8-9	Elektr. Cracker	5-6
Raffinerien	Rohölverarbeitung	Dampfreformierung	H2 aus Elektrolyse	8-9	-	
Bereitstellung von Prozesswärme						
Metalle	Rohstahl	Hochofen	Eisenerz-Direktreduktion (H_2-DRI)	5-7	Elektrolyse	4
	Nicht-Eisen Metalle Gießerei Walzen / Weiterverarbeitung	Erdgas-befeuerter Ofen (Teilweise bereits elektrische Öfen)	H2-befeuerter Ofen	4-5	Elektr. Ofen	5-7
Glas	Behälterglas Flachglas	Erdgas-befeuerte Glasschmelzwanne	H2-befeuerte Glasschmelzwanne	4-5	Elektr. Glasschmelzwanne	6-8
Zement und Kalk	Zement Kalk	Erdgas-befeuerter Ofen	H2-befeuerter Ofen	4-5	Elektr. Ofen	4-5
Alle	Dampferzeugung	Erdgas-betriebener Dampferzeuger	H2-betriebener Dampferzeuger	9	Elektr. Dampferzeuger (<500°C)	9
					Elektr. Wärmepumpe (<150°)	8

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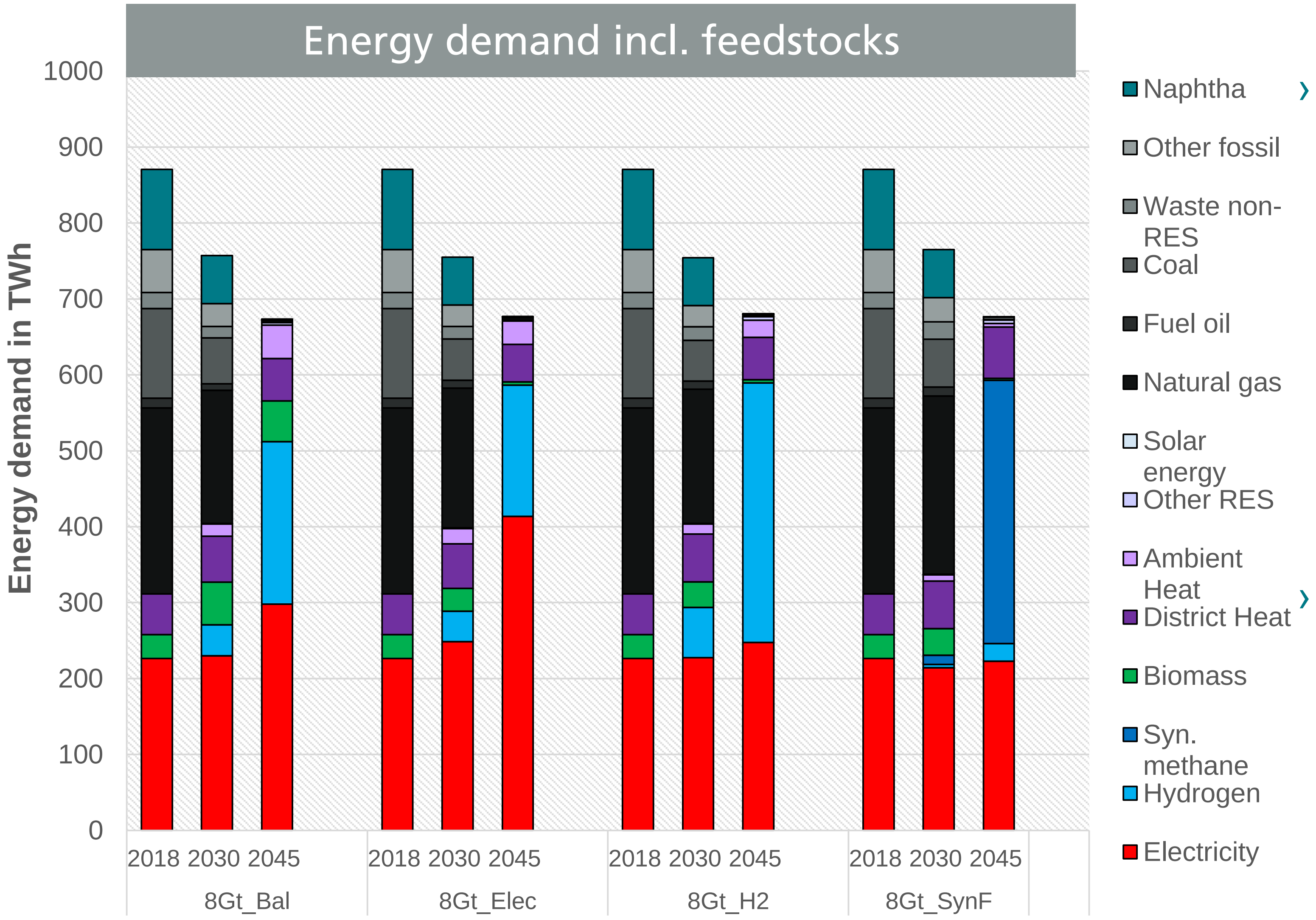
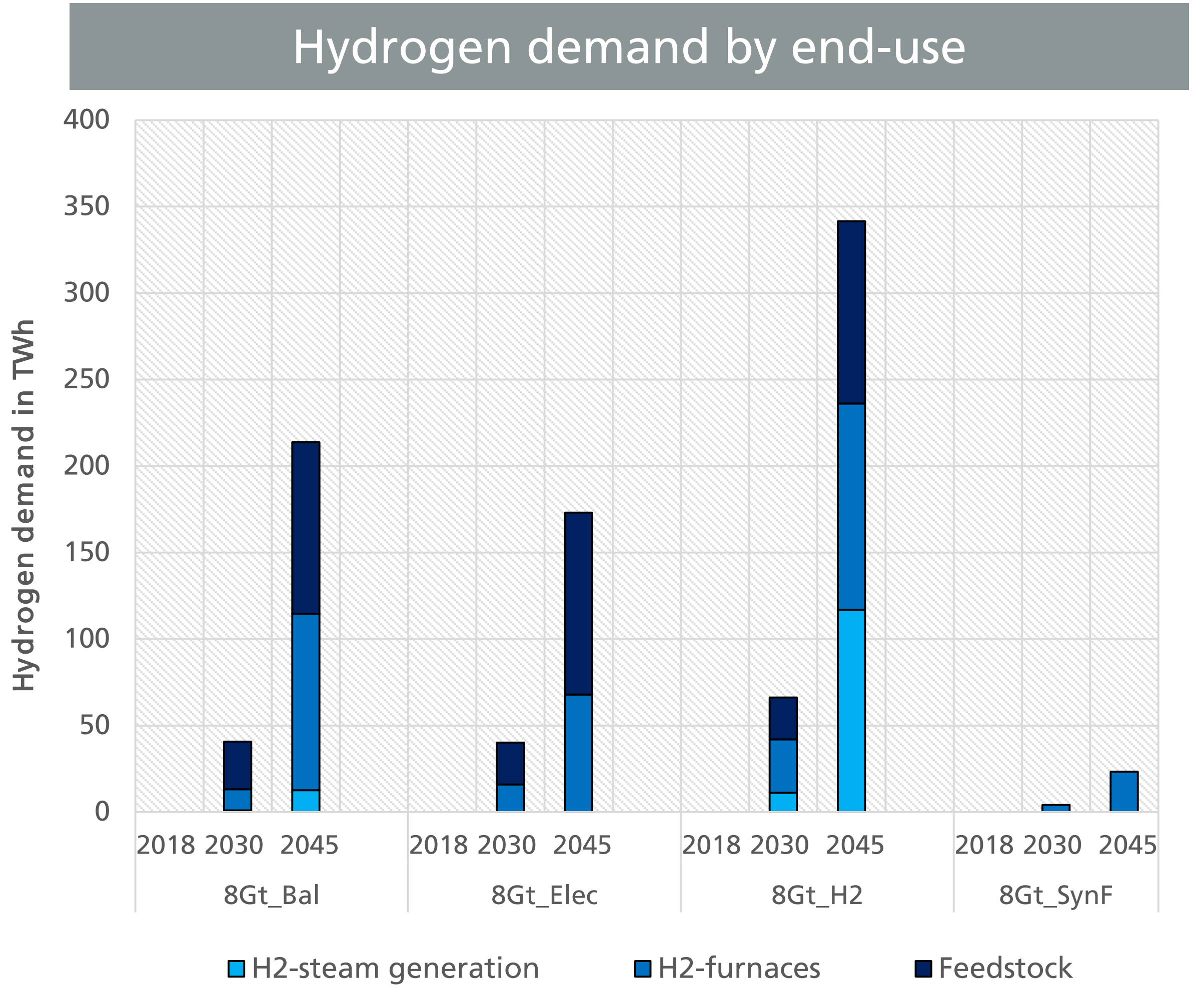
In all scenarios, high amounts of CO2-neutral secondary energy sources are used



› **Decrease in energy consumption** in all scenarios ~ **20%**, through
- › Energy efficiency
- › Material efficiency and circular economy
- › More efficient new processes
- › System boundary effect: H2 production now outside the industrial sector

› **2045:**
- › No fossil fuels used
- › Very distinct technology pathways: electricity, H2, PtG
- › Biomass only in Balance Scenario

Robust hydrogen demand especially in the steel and chemical industry



- **Hydrogen demand** for **steel** and **chemicals** (ammonia, methanol/olefins): **~170 TWh in 2045**
- This demand is distributed among **few industrial locations** (about 20 sites)
- **8Gt_H2 Scenario:**
  - Large-scale use of hydrogen for **process heat** generation in all industries **+ 169 TWh = 342 TWh in 2045**
  - Additional demand is distributed over a **high number of locations** and requires a large-scale expansion of the **distribution grids**

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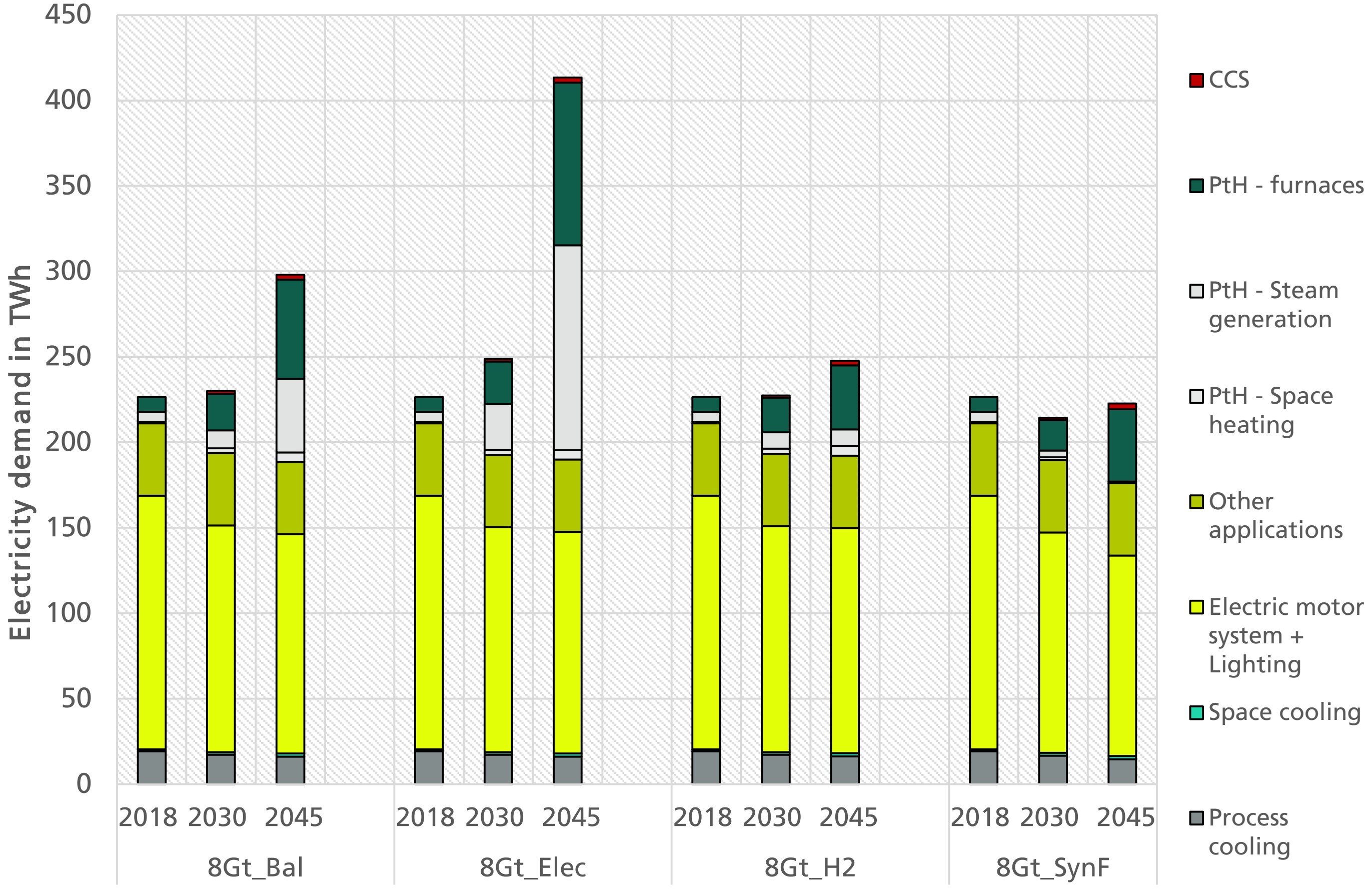
Conventional electricity consumers decline slightly due to efficiency gains in all scenarios

Electricity demand by end-use



- **Conventional electricity consumers:** process cooling, space cooling, electric motor systems, others
- **8Gt_Elec Scenario:**
  - Electrification of steam generation and industrial furnaces drives electricity demand –> **+215 TWh in 2045**
- **8Gt_H2 & 8Gt_SynF:**
  - Efficiency gains and electrification roughly balance each other out

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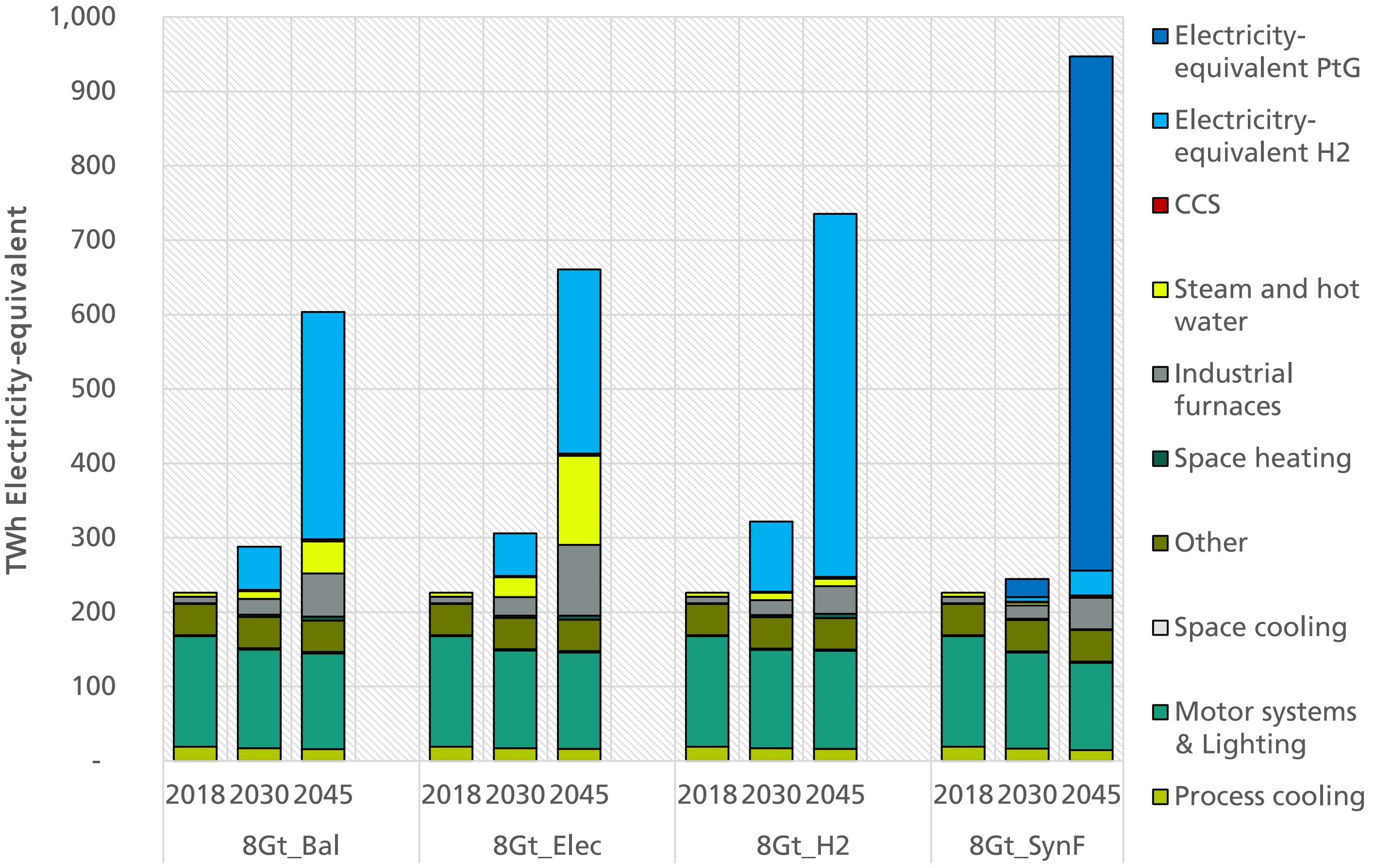
Electricity equivalents for H2 and PtG generation change the picture completely

Electricity demand by application incl. H2 and PtG



- Hydrogen and PtG are produced in a **CO2-neutral** way via electrolysis
- Very high **electricity demand**
  - Today 200 TWh
  - **600 to 950 TWh until 2045**
- Outside the system boundary used by the industrial sector
- **Provision** of CO2-neutral secondary energy sources of central importance
- Significant quantities **already required by 2030**
- **Bi-valent demands** as a starting point?

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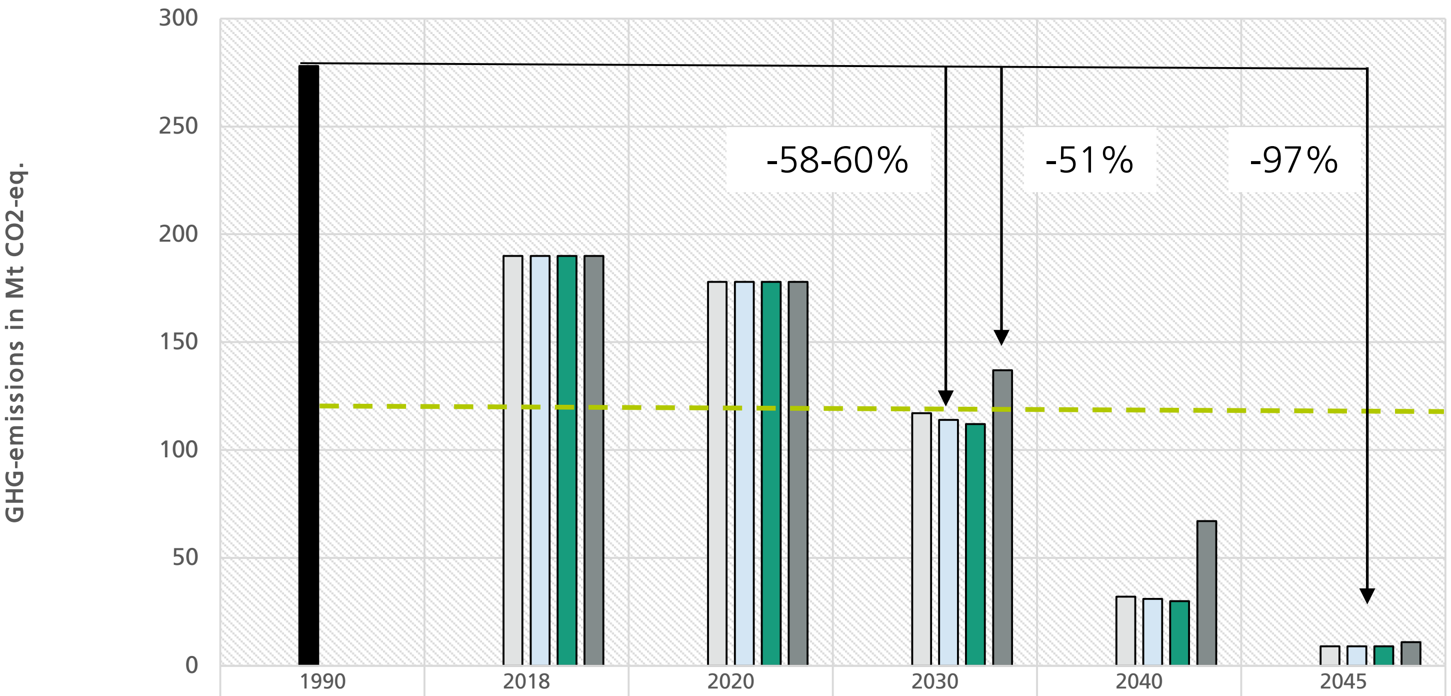
Near GHG-neutrality in 2045 is achieved in all scenarios



	1990	2018	2020	2030	2040	2045
Sector target old				140		
Sector target new				118		
8Gt_Bal	278	190	178	117	32	9
8Gt_Elec		190	178	114	31	9
8Gt_H2		190	178	112	30	9
8Gt_SynF		190	178	137	67	11

- **2030:**
  - Achieved reduction **-51 to 60%**
  - The new sector target (-57%) for industry is overachieved in 3 of 4 scenarios
  - Slower decline in SynFuel Scenario due to blending of PtG in gas grid
- **2045:**
  - Achieved reduction **-96 to 97%**
  - Almost no more fossil GHG emissions
  - Only a few Mt of **process emissions** distributed among about 20 smaller source types (e.g. ceramics)

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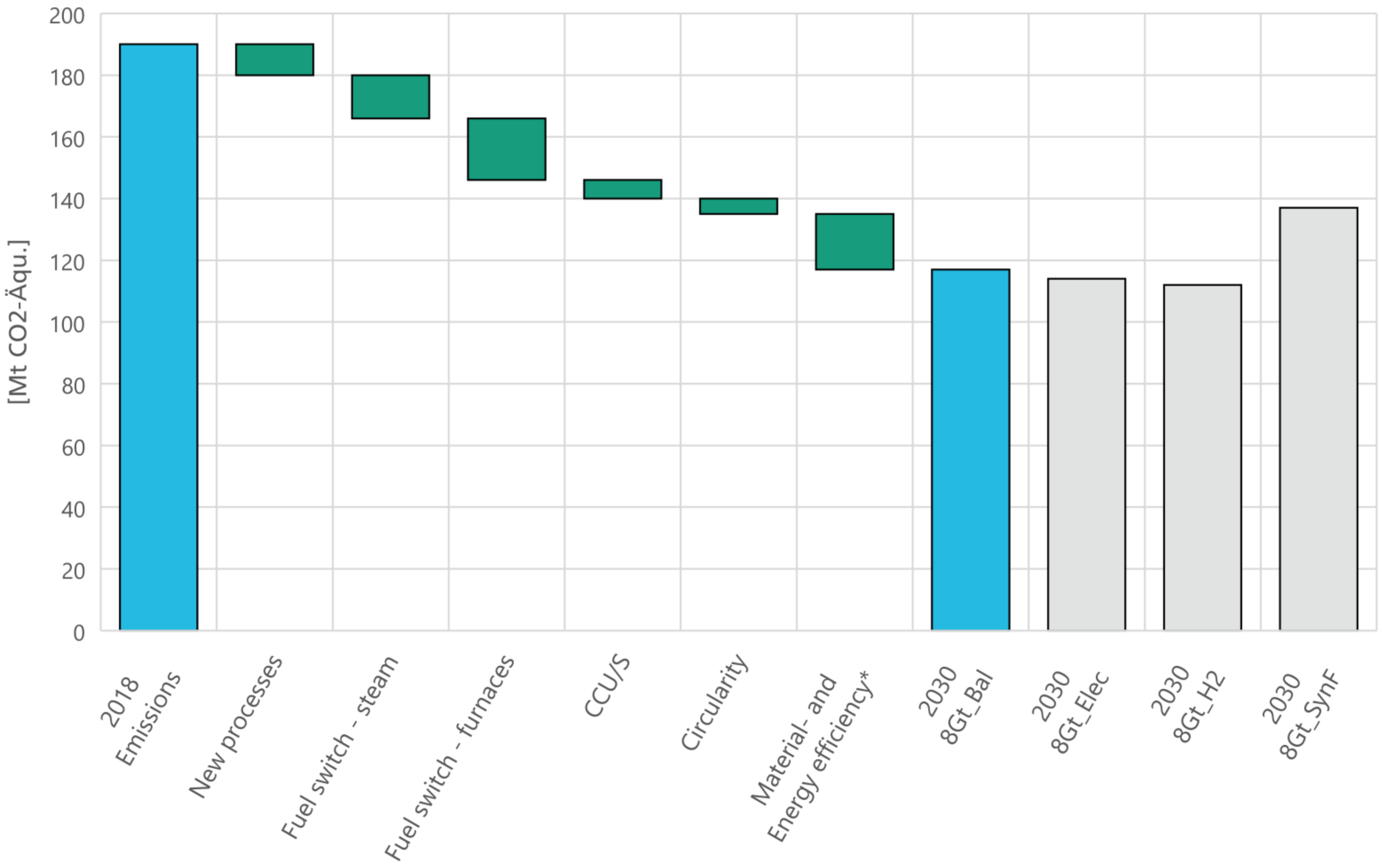
The time horizon until 2030 is crucial to achieve climate neutrality by 2045

Contribution of individual abatement options to emission reductions by 2030 compared to 2018 in the scenario 8Gt_Bal

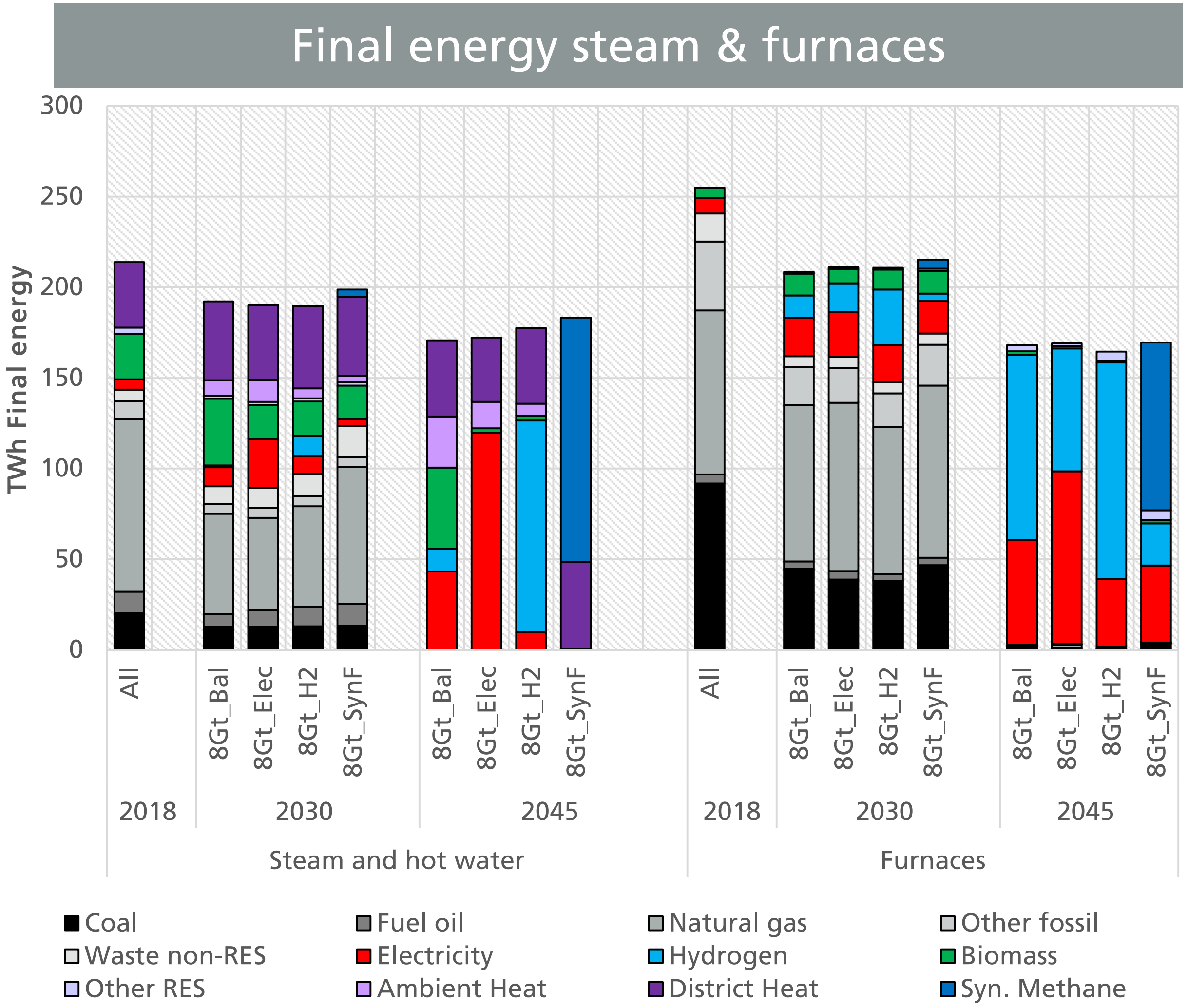


- **Highest reduction** of **>30 Mt CO2-eq.** is due to **fuel switching**
  - Conversion to electricity, hydrogen and gas for process heat generation
- **Material and energy efficiency** contribute **about 20 Mt CO2-eq.**
  - Additionally offsetting the emission-increasing impulses of economic growth
  - Gross reduction of this field of action would be even higher
- **New processes and CCU/S** with **about 15 Mt CO2-eq.** reduction make a significant contribution

Central basis of the transformation scenarios is the conversion of individual production processes in the basic materials industry...

- ... to **technologies** that allow (almost) **CO2-neutral operation** (e.g. crude steel, cement clinker, olefins, ammonia and methanol)
- Assumption: First plants will come into operation **from 2025 onward** and take **significant market share by 2030** (e.g. H2-DRI 5 Mt in 2030, ~20% of primary production)
- This conversion is associated with **investments:** In many areas, **new plants or extensive modernisation** of the existing stock are necessary
- The **age structure of the stock accommodates this** -> 20 to 50% of relevant plants will reach the end of their calculated lifetime
- BUT there is a **risk of re-investment in fossil plants:** windows of opportunity arising from the existing modernisation cycles should be used for the conversion to CO2-neutral production
- In most cases, conversion also involves **switching to expensive CO2-neutral secondary energy sources**
- **Reliable perspective for the economic operation** of these plants is needed for substantial expansion of production capacities by 2030

CO2-neutral process heat supply is a key strategy for decarbonising industry



- **~470 TWh** final energy demand for process heat in 2018 - mostly **natural gas** and **coal**
- **Possible reduction** of **30 Mt CO2-eq. until 2030**
- **Steam and hot water:**
  - High-temperature heat pumps, biomass, electric boilers and hydrogen
  - **Economic viability** depends on the **price difference** between energy sources
  - Investments only account for a small share of the total costs
  - **Multivalent steam generation central for starting the transformation of the plant stock**

Energy and material efficiency as the backbone of CO_2-neutral industrial production

- An **ambitious increase in energy and material efficiency in all applications and sectors** is a prerequisite for CO_2-neutral industrial production in the scenarios examined
  - Reduces the final energy demand
  - Lowers the costs for the expansion of renewable energies and grid expansion
  - and the import of secondary energy sources
- **8Gt_Bal scenario:**
  - Final energy demand (excluding feedstock) decreases from 730 TWh (2018) to 637 TWh (2030)
  - Final energy intensity in relation to gross value added falls from 1.37 kWh/euro in 2018 to 1.07 in 2030 (average annual efficiency progress of about 2%)
  - E.g. secondary route from recycled steel scrap in crude steel production increases from 30% (2018, 13 Mt) to 39% (2030, 16 Mt)
- **Prerequisite:** Effective instruments to increase EE
- Still **major challenges** concerning expansion of **circular economy & mateff/matsub** (e.g. technologies, instruments, behavioural change)

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CO_2 capture, use and storage of process-related emissions

About **one third of the GHG emissions of the industrial sector** are **process-related** which stem from chemical reactions within the production process

Cement and lime production:

- Process emissions cannot be avoided with conventional measures (responsible for 2/3 of emissions)
- Increasing the use of additives or low-CO_2 binders is not sufficient
- CO_2 capture and use or storage (**CCU**/S) is necessary in all scenarios
- By 2030, **30% of the production volume** of these two products in the scenarios is equipped with CCU/S:
  - avoiding 6 Mt of the remaining CO_2 emissions

Prerequisites:

- Implementation of appropriate **legal framework conditions**
- Development of **infrastructure for the transport** of production plants to storage sites and demanders in the chemical industry
- **Socio-political consensus** that CO_2 capture and use/storage of process-related emissions is necessary

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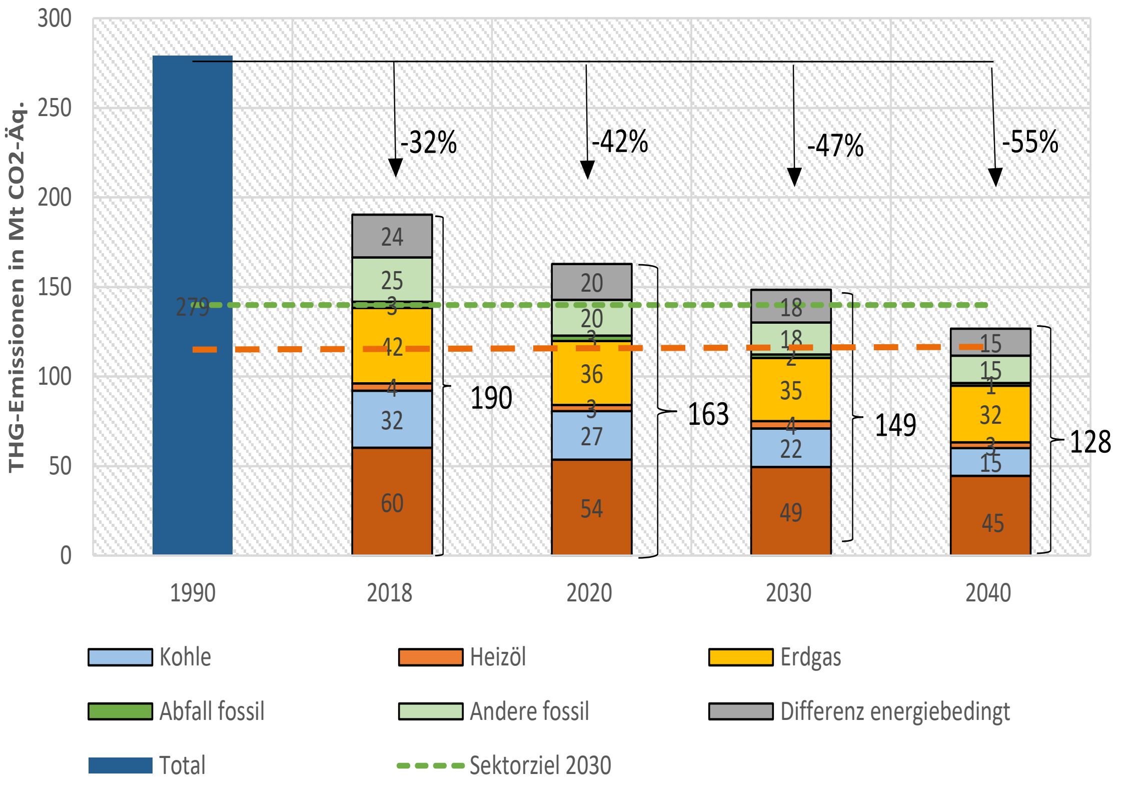
Industry is not on the path towards GHG neutrality with existing instruments

- **All types of instruments are available and all important abatement levers are basically addressed***

- **Nevertheless the 2030 target will be missed by ~30 Mt CO2-eq.**
  - **CO2 price increase is not enough** to make CO2-neutral secondary energy sources competitive
  - Large residual **process emissions** (e.g. cement)
  - Hardly any additional progress in **circular economy**: instruments are not geared towards decarbonisation
  - No efficient **use of materials** in consumption sectors: no CO2 steering effect
  - **Still high uncertainty for investors**



*status August 2020

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Six elements of a potential instrument mix in particular are worth mentioning here:

Carbon Contracts for Difference

- Closing the profitability gap
- Support market introduction of CO2-neutral processes
- Long-term phasing out
- Accompanying: expansion of existing R&I promotion; guarantees, sureties, green bond

Green Lead Markets

- Accelerate market introduction & upscaling
- e.g. quotas, product labelling, public procurement

EU-ETS Minimum Price Path

- Providing long-term clarity and certainty for investors
- Increase the incentive effect of emissions trading

Infrastructure development

- High uncertainty concerning (local) availability & costs/prices of CO2-neutral energy sources
- Hydrogen Backbone Grid
- CO2-Transport Grid
- Clear milestones provide planning security

Policies targting CE & MatEff

- Strong CO2 price can provide incentives
- CO2 price will not be sufficient on its own
- Markets for recycled products
- Uniform product standards (EU & national level)

CBAM & global climate regime

- Border tax/notional ETS
- Consumption or climate levy
- Needs accompanying instruments

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Summary

- The scenarios show alternative paths to **almost CO2-neutral industrial production by 2045**. They involve **ambitious changes to the entire industrial production system** and assume a profound transformation in many sectors and value chains
- In all scenarios, in addition to improvements in **material and energy efficiency**, high quantities of **CO2-neutral secondary energy sources** are used
- **Time horizon until 2030 is crucial** - Until then, it must be possible to **scale up CO2-neutral processes** from pilot and demonstration scale to industrial level and **make them economically viable**.
- High investments in new plants are necessary and **solutions for the provision of CO2-neutral hydrogen and electricity** must be implemented.
- Accordingly, the regulatory framework must offer a clear perspective for CO2-neutral production. This particularly concerns the **availability** and role of **CO2-neutral hydrogen, gas and electricity**.
- **Targeted subsidies** for operating and investment costs are necessary as long as the CO2 price alone does not enable competitive investment. **Green lead markets** can also accelerate the transformation. Beyond the basic industry, **CO2 price signals down to the consumption sectors** are crucial to align value chains with the goal of CO2 neutrality.

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Thank you for your attention

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