

The background of the slide is a photograph of a large, modern building with a prominent triangular pediment and several tall, narrow windows. The building is light-colored, possibly beige or tan. There are green trees and bushes in front of the building. The sky is blue with some light clouds. A horizontal bar with a yellow segment on the left and a grey segment on the right is positioned below the building image.

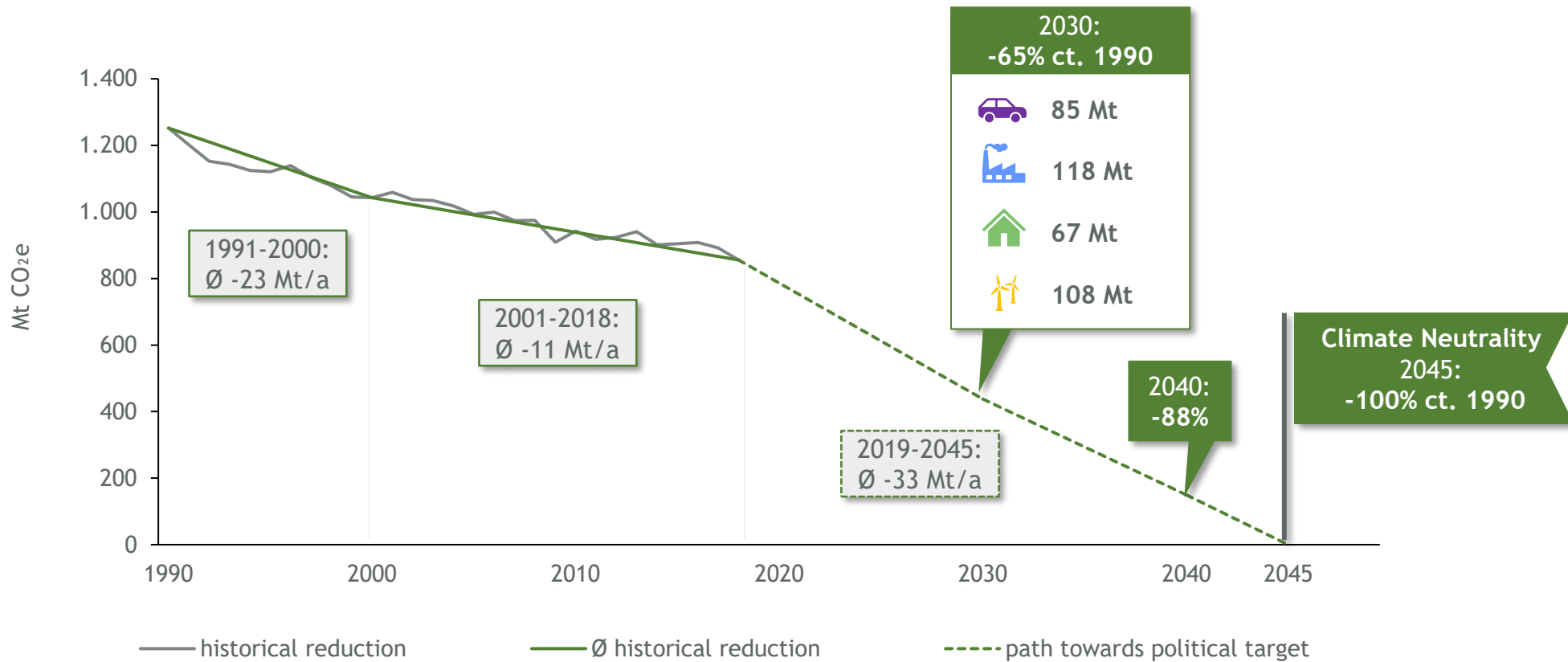
DENA PILOT STUDY: CLIMATE NEUTRALITY 2045

Transformation of the consumption sectors and the energy system

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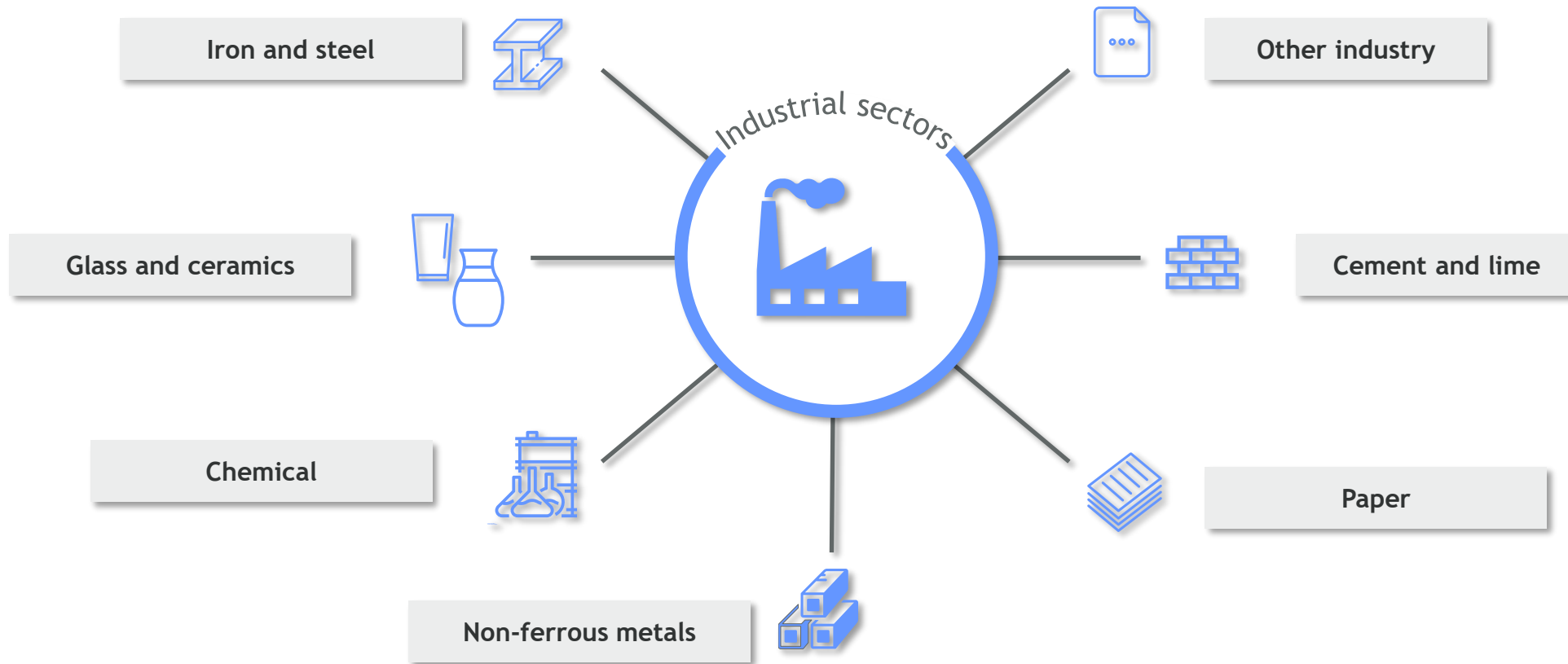
Institute of Energy Economics at the University of Cologne (EWI) gGmbH | 07.12.2021

The scenario “Climate Neutrality 100” (CN100) shows how the sector targets can be achieved in 2030 and climate neutrality in 2045.



Transformation of the consumption sectors

The industry transformation scenario is based on a detailed energy accounting for different industrial sectors.



Final energy demand decreases as efficiency is raised and fossils are substituted by electricity and hydrogen.

Iron and steel

- 2030** 1/3 of the conventional steel production is converted to hydrogen-based direct reduction processes
- 32 TWh** hydrogen demand for energy use in 2045
- +41 %** electricity demand in 2045 compared to 2018 (+14 TWh)

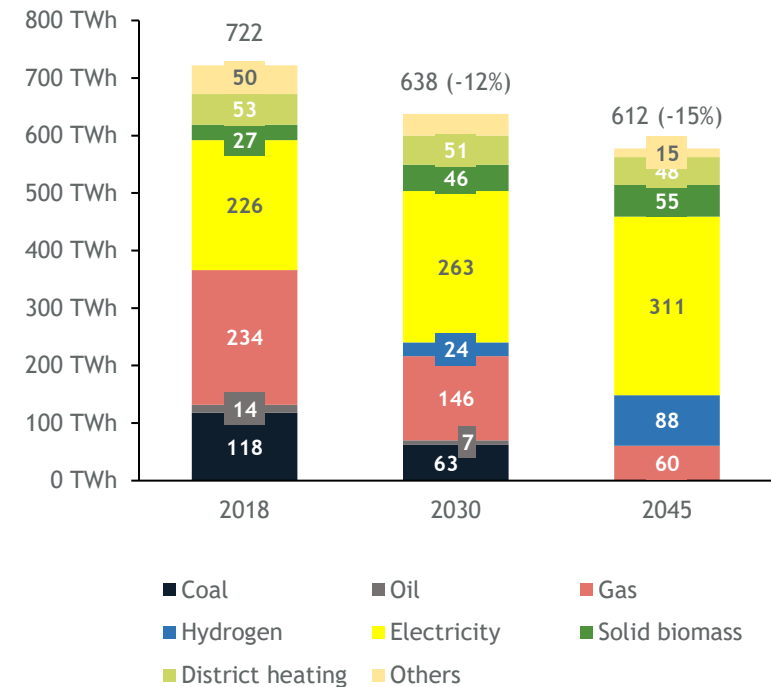
Chemical

- 2030** biomass and hydrogen start substituting natural gas especially in high-temperature processes
- 23 TWh** hydrogen demand for energy use in 2045
- +50 %** electricity demand in 2045 compared to 2018 (+27 TWh)

Cement and lime

- 14 %** production due to material-saving construction methods and the use of resource-efficient concretes
- 11 TWh** hydrogen demand for energy use in 2045 mainly due to substitution of coal and natural gas in the lime industry

Final energy demand of the industrial sector (only energy use)



Options for decarbonization include changes in fuel consumption as well as behaviour.



Final energy demand from transport sector decreases as fossil fuels are substituted and behavioural changes affect modes of transport.

Passenger cars

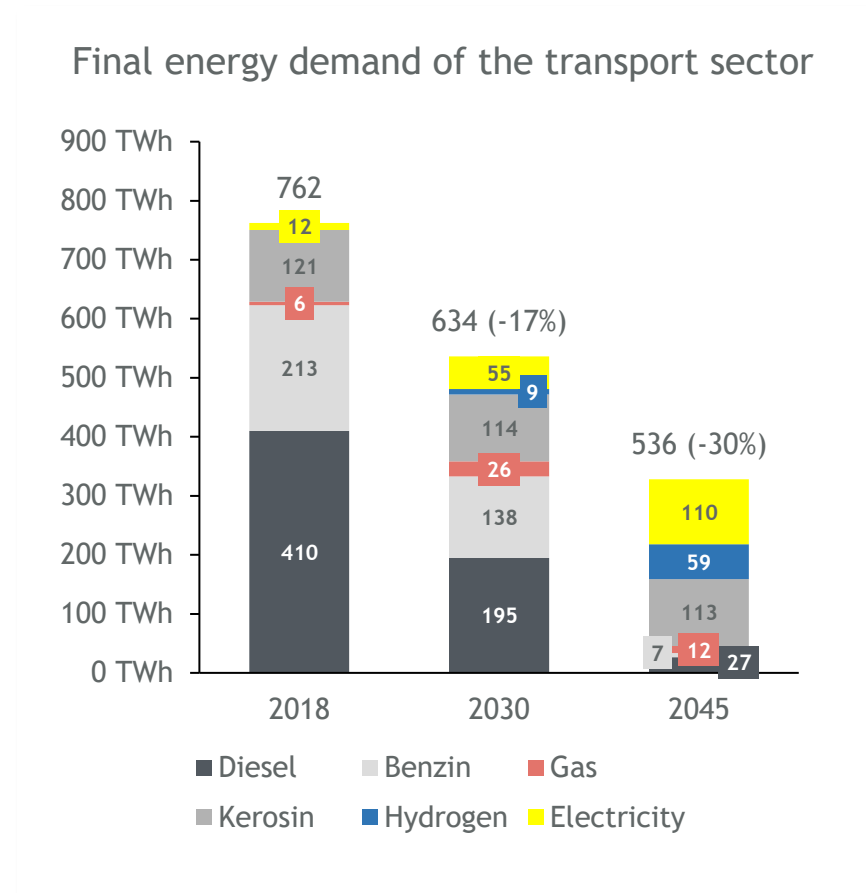
- 18 % passenger cars in 2045 compared to 2018 because of a partial shift to rail
- 32m battery-electric cars in 2045 (9m in 2030)
- 2m fuel cell electric vehicles powered by hydrogen in 2045

Freight transport

- +23 % freight transport in 2045 compared to 2018 because of economic growth
- 37 % of all trucks are electrified in 2045, mainly light vehicles and short-distance routes
- 41 % of all trucks in 2045 are powered by hydrogen, mainly for long-distance routes

Other modes of transport

- >93 % of the trains in 2045 are electrified
- 2030 first hydrogen-powered aircrafts are used in passenger aviation



Decarbonization of the building sector means an extensive transformation of the building stock.

Improvement of the building envelope

Refurbishment of existing building envelope to reduce energy demand

Energy Efficiency standards of new buildings



Expanding the use of renewable energy resources

Use of synthetic and biogenic energy sources



Replacement of heating system

Use of efficient and new heating technologies

E.g. expansion of heating networks and heat pumps



Final energy demand from buildings decreases as buildings are refurbished and inefficient heating systems are substituted.

Residential buildings

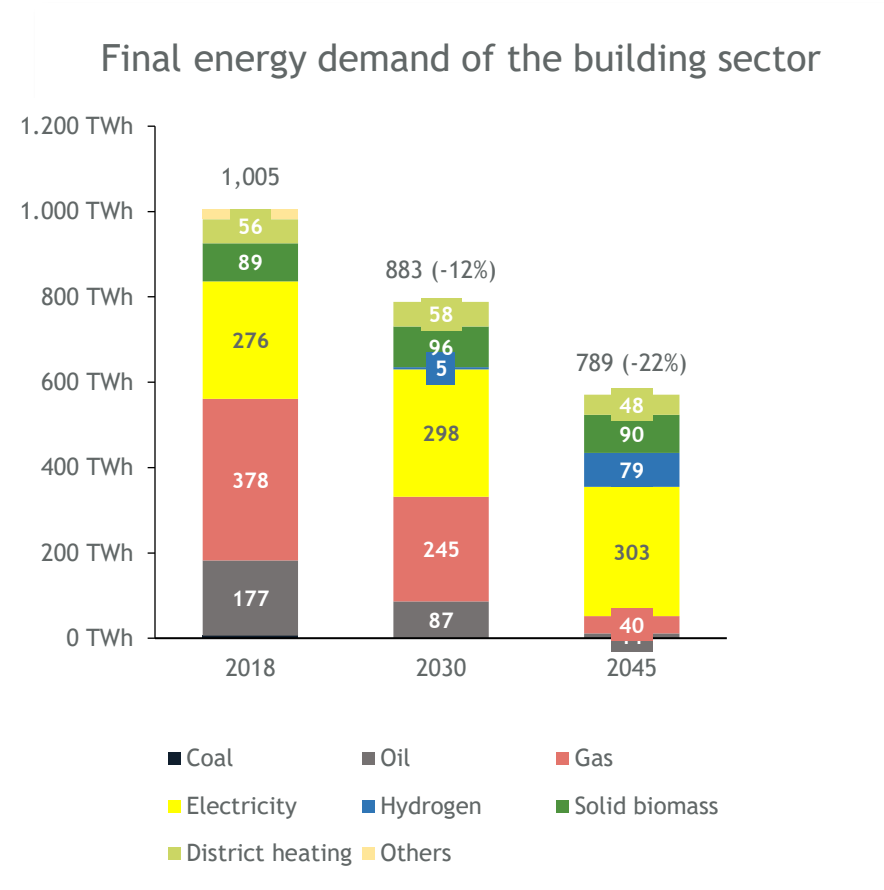
- +1,7m** residential building in 2045 compared to 2020
- 1,9 %/a** refurbishment rate in 2045
- 9m** electric heat pumps in 2045 (4,1m in 2030)
- +40 %** buildings connected to district heating network in 2045 compared to 2020

Non-residential Buildings

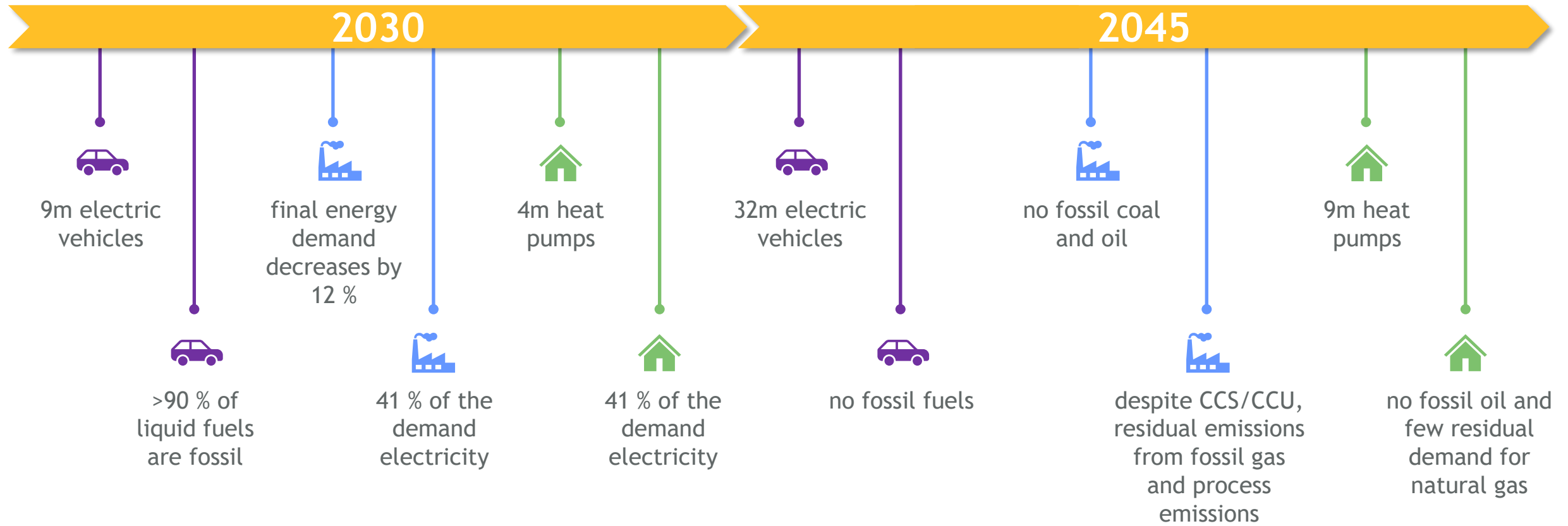
- 30 %** final energy demand in 2045 compared to 2020
- 70 %** of the final energy demand in 2030 is electricity

Entire building sector

- >2024** newly installed gas heating systems are H₂-ready or easily convertible
- 45 TWh** demand for hydrogen in 2045
- 90 %** demand for gas in 2045 compared to 2018



Key issues in all consumer sectors are the substitution of fossil fuels and extensive electrification.



Transformation of the energy sector

Total final energy demand drops by 41% until 2045. Fossil fuels are subsequently substituted by electricity and green hydrogen.

Natural gas, coal and oil

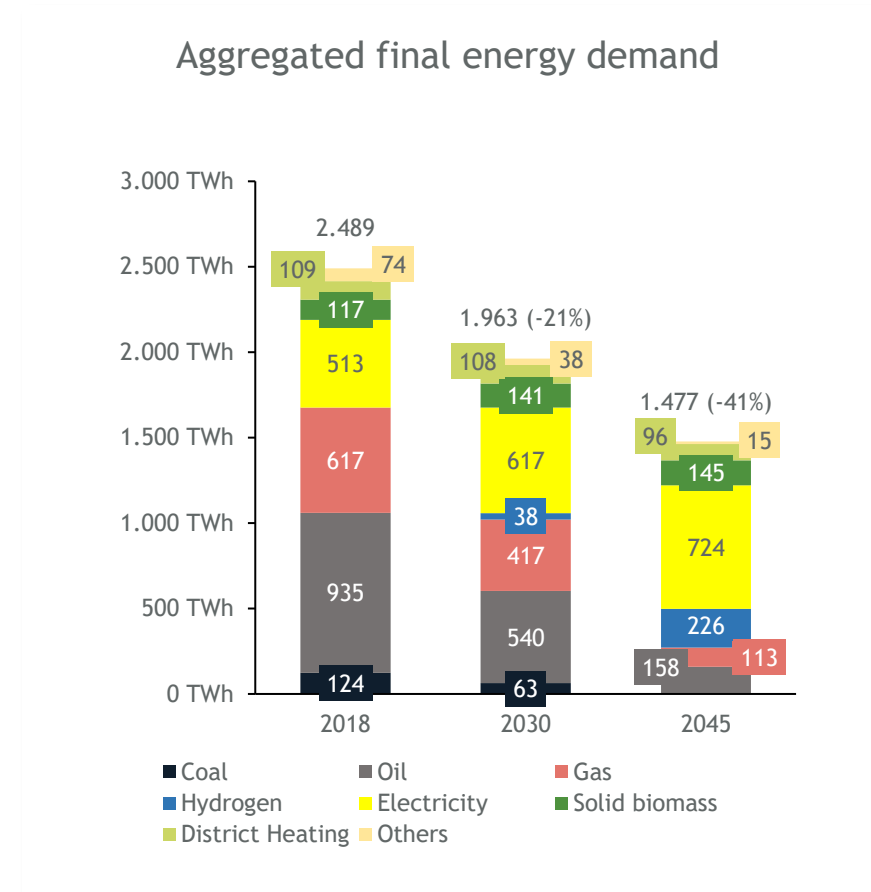
- 35 % fossil fuel consumption in 2030 compared to 2018
- 18 % of final energy consumption are oil and gas in 2045 which are mostly supplied as bio or synthetic fuels

Electricity

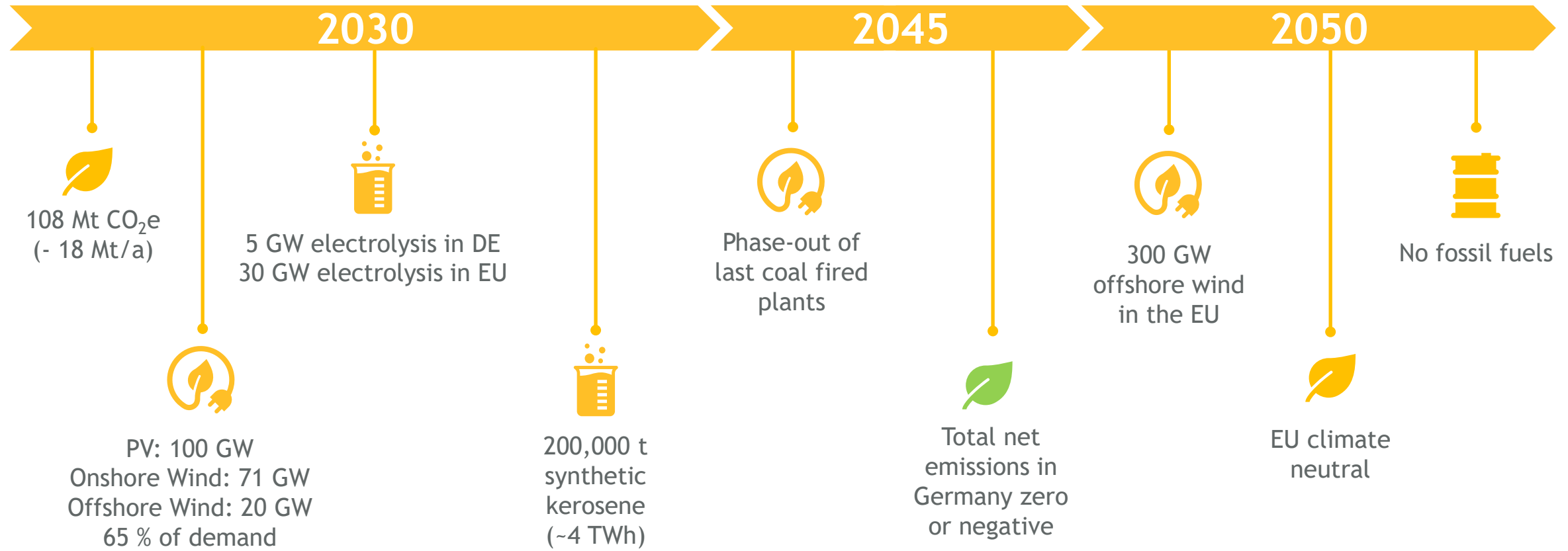
- 31 % of final energy is electricity in 2030
- 50 % of final energy is electricity making it the most important energy carrier in final energy in 2045

Hydrogen

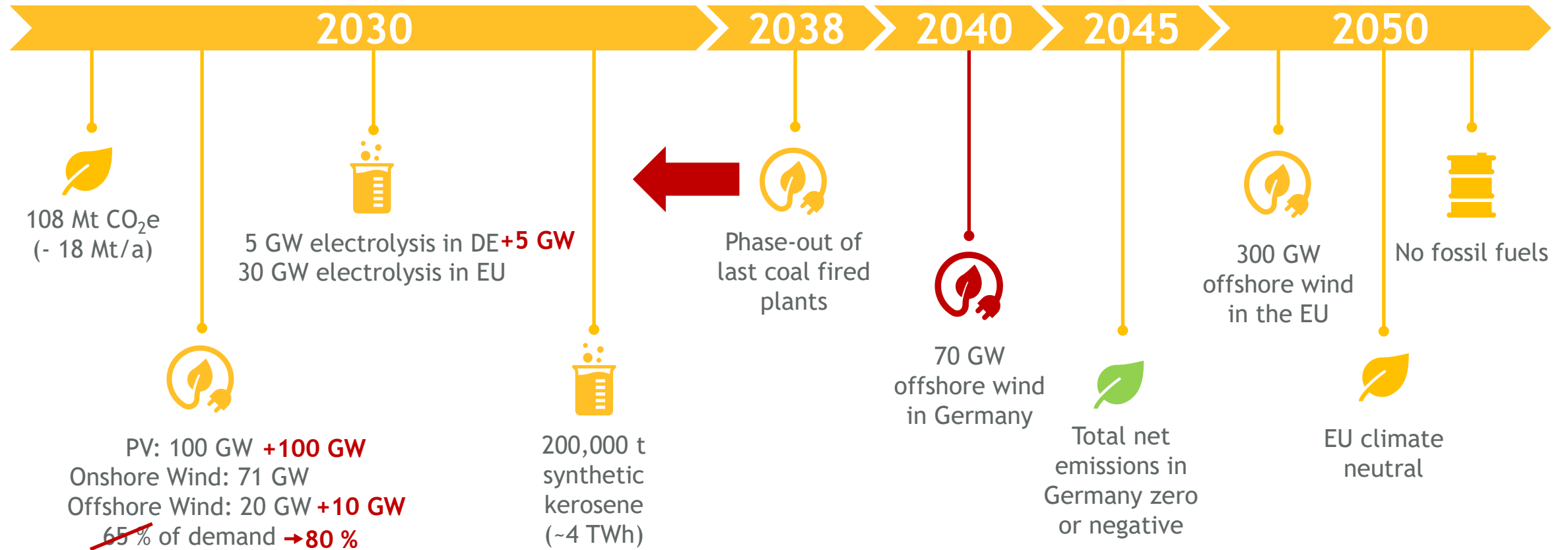
- >20 %_{vol} admixture into natural gas grid allowed
- 38 TWh hydrogen demand mostly from industry in 2030
- 15 % of final energy is hydrogen making it the second most important energy carrier in final energy



Political goals shape the szenario and serve as minimum requirements. ewi



The new German government has set more ambitious targets in the coalition agreement (see EWI website for an exclusive analysis).



With the increase in electrification total electricity demand almost doubles by 2045.

Consumption sectors

+20 % electricity demand in 2030 compared to 2019

+41 % electricity demand in 2045 compared to 2019

District heating

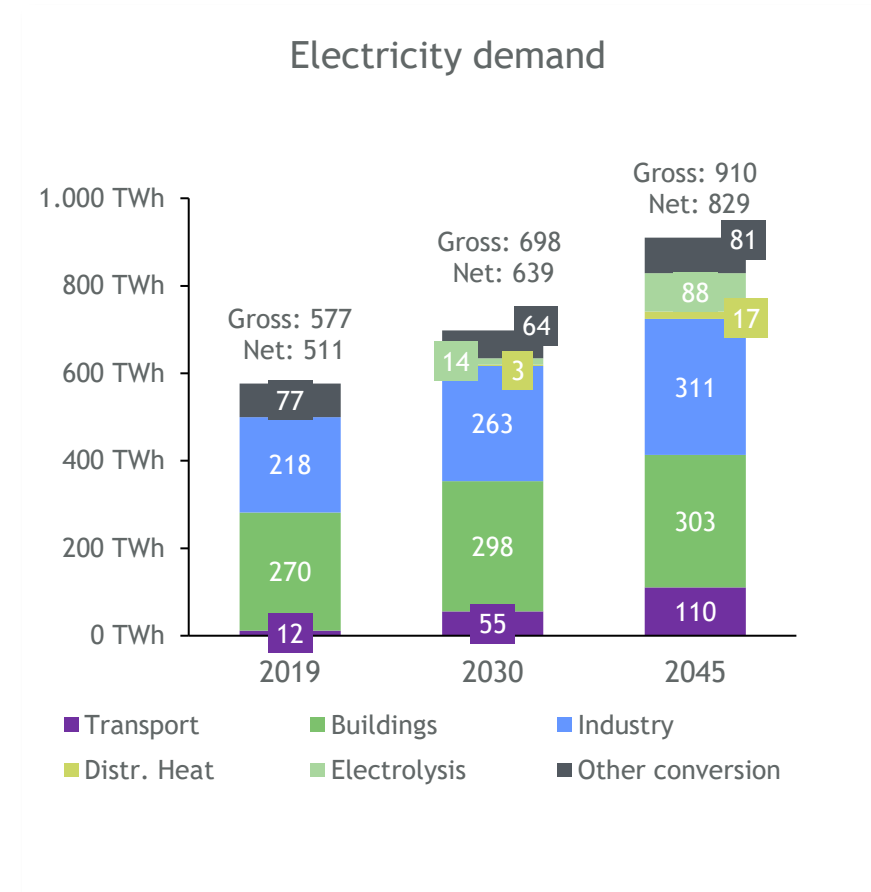
3 TWh electricity used in power to heat processes which partially replace coal CHP

33 % of district supplied by power to heat processes in 2045

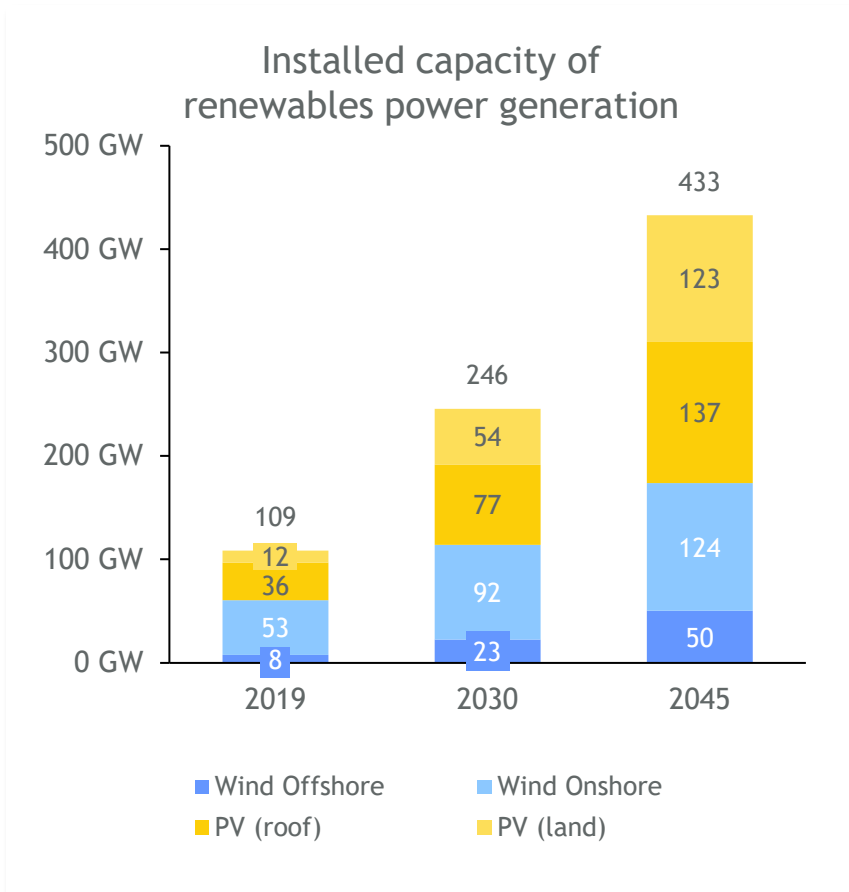
Electrolysis

14 TWh electricity used for electrolysis

9,7 % gross electricity demand from electrolysis



Reaching climate neutrality by 2045 means a fast and complete transformation of generation capacity.



Renewables quadruple due to sharp increase in electricity demand



Net capacity addition of 8 GW/a until 2030



Over achievement with regards to 2030 capacity targets

Dispatchable capacity decreases due to nuclear and coal phase out

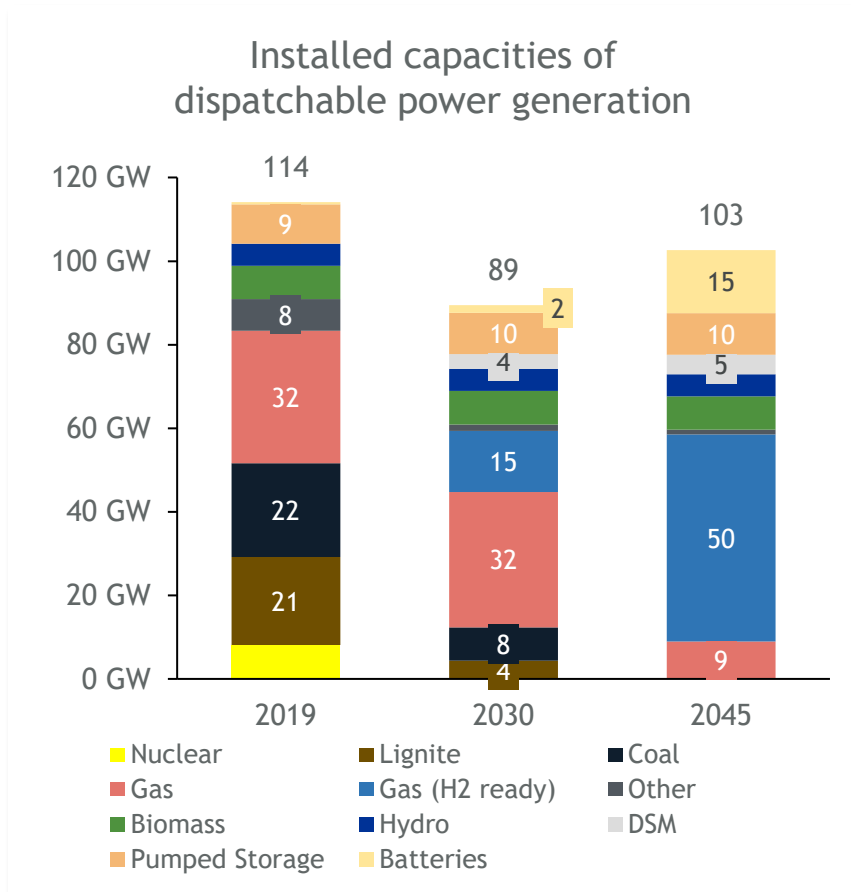


Capacity addition of 15 GW H₂ ready gas power plants until 2030 while coal and lignite are in back up



Battery additions match increase in renewables and provide additional firm capacity

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Renewable shares in electricity generation increase while Germany becomes a net importer.

Thermal generation

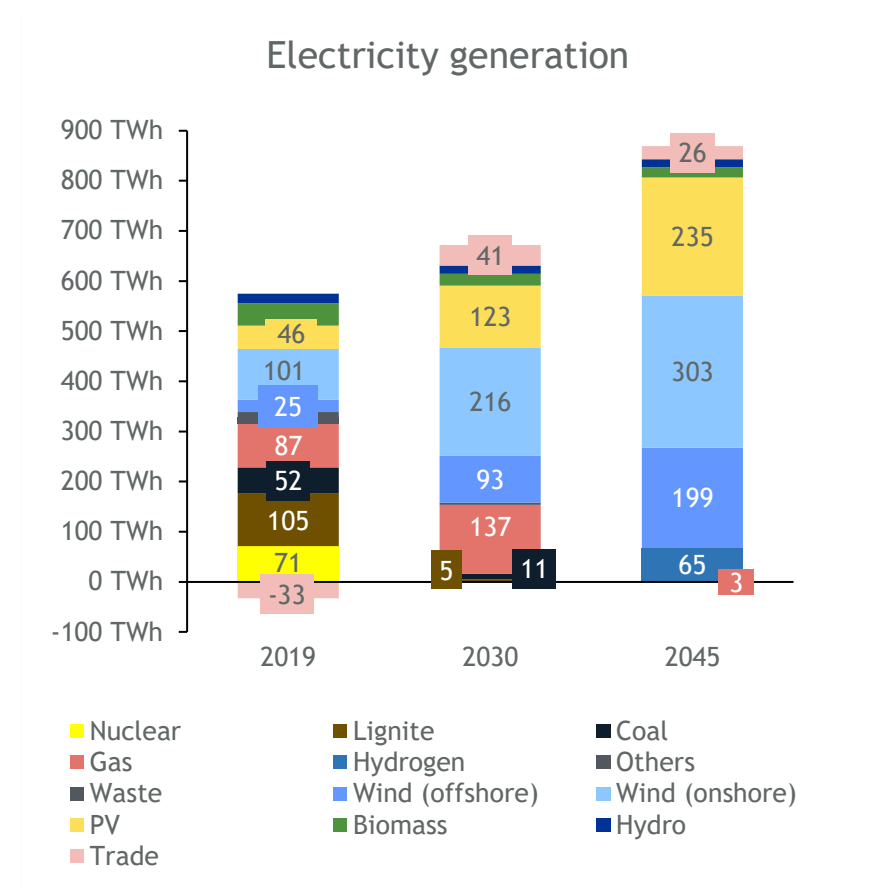
- +60 %** Gas generation in 2030 compared to 2019
- 130 TWh** hydrogen used to generate electricity and heat in 2045
- 70 %** Biomethane in remaining non H₂ ready gas power plants in 2045

Renewables

- 68 %** of electricity supplied by renewable resources in 2030
- 85 %** of electricity supplied by renewable resources in 2045
- 55 %** of electricity supplied by wind in 2045

Electricity trade

- 41 TWh** imports (net) mostly from France, the Netherlands and Northern Europe in 2030
- 7 TWh** exports (net) in 2050



Hydrogen and other synthetic fuels are mostly imported from countries with favourable conditions for renewables.

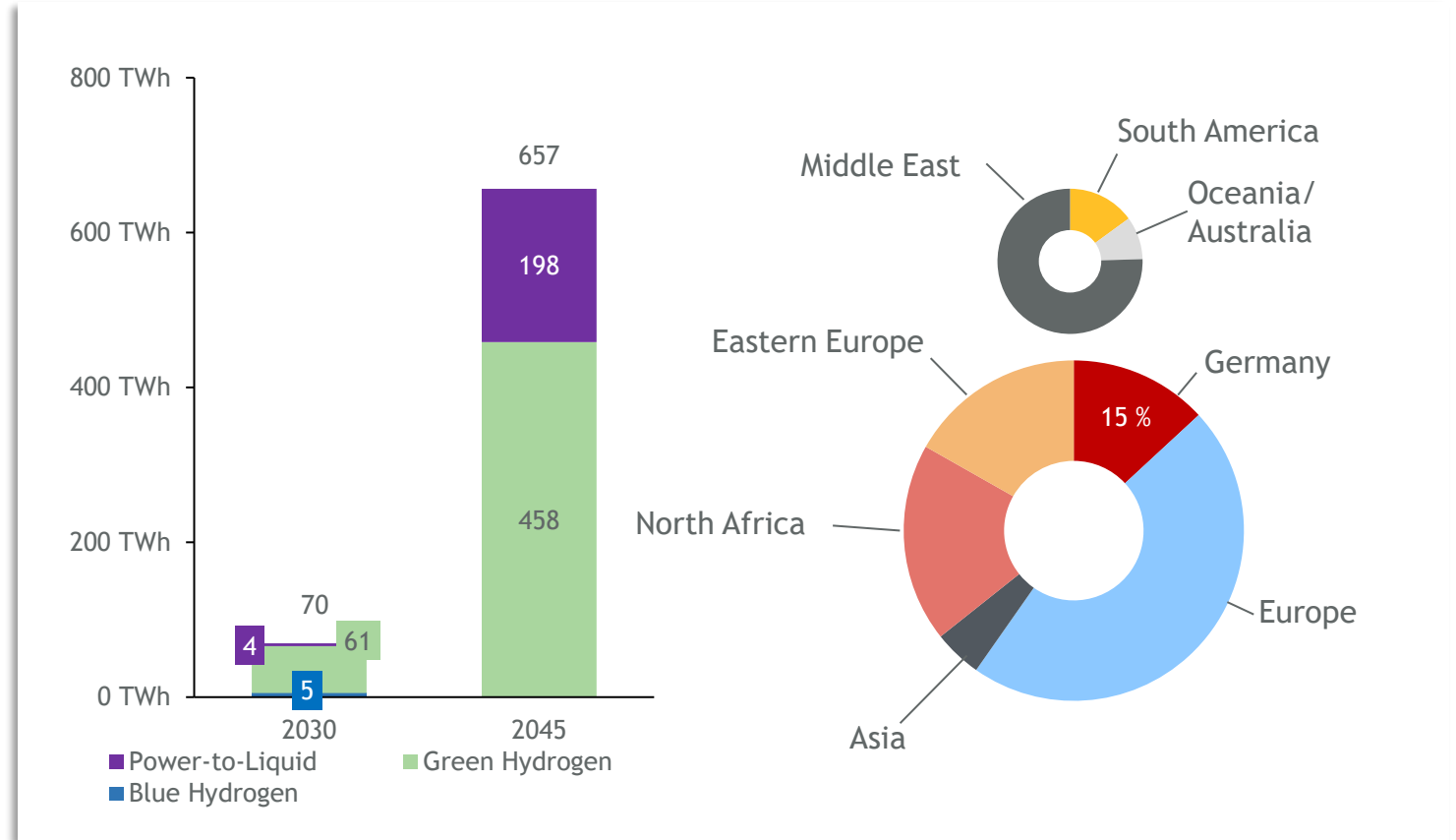


Power-to-Liquids are shipped from distant regions



Hydrogen is produced in Germany or imported via pipeline from Europe and closer regions

Überschrift



With the help of natural and technical sinks Germany becomes net neutral in 2045.

Überschrift



Not all sectors are climate neutral in 2045



Residual emissions from fertilization and livestock industry



Process emissions not entirely compensated within the industry sector



Minor emissions from natural gas combustion where hydrogen grids are unavailable

Technical and natural sinks compensate for residual emissions



Forests and other natural sinks have to be restored and protected in order to provide a sink of 41 Mt CO₂e



Biomass combustion combined with carbon capture and storage/utilization makes the energy sector a sink

Substitution of fossil fuels

Only 5 % of primary energy use are fossil

Natural sinks

Negative emissions of 41 Mt CO₂e

Decrease in final energy consumption

-41 % compared to 2018



Technical sinks and carbon capture

Negative emissions of 46 Mt CO₂e

Renewable Electricity

85 % supplied by renewables

Green Hydrogen

15 % of final energy consumption

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