EnBW's path for hydrogen power plants in Baden-Württemberg

ETN Workshop Stuttgart

EnBW R&D
Wolfram Münch

9 October 2024

Important performance indicators for the EnBW Group

Revenue
€44,430.7 million

Adjusted EBITDA[1]
€6,365.2 million

Installed power plant output
12,226 MW

Of which renewable energies
5,728 MW

Employees
28,630

B2C and B2B customers
5.5 million

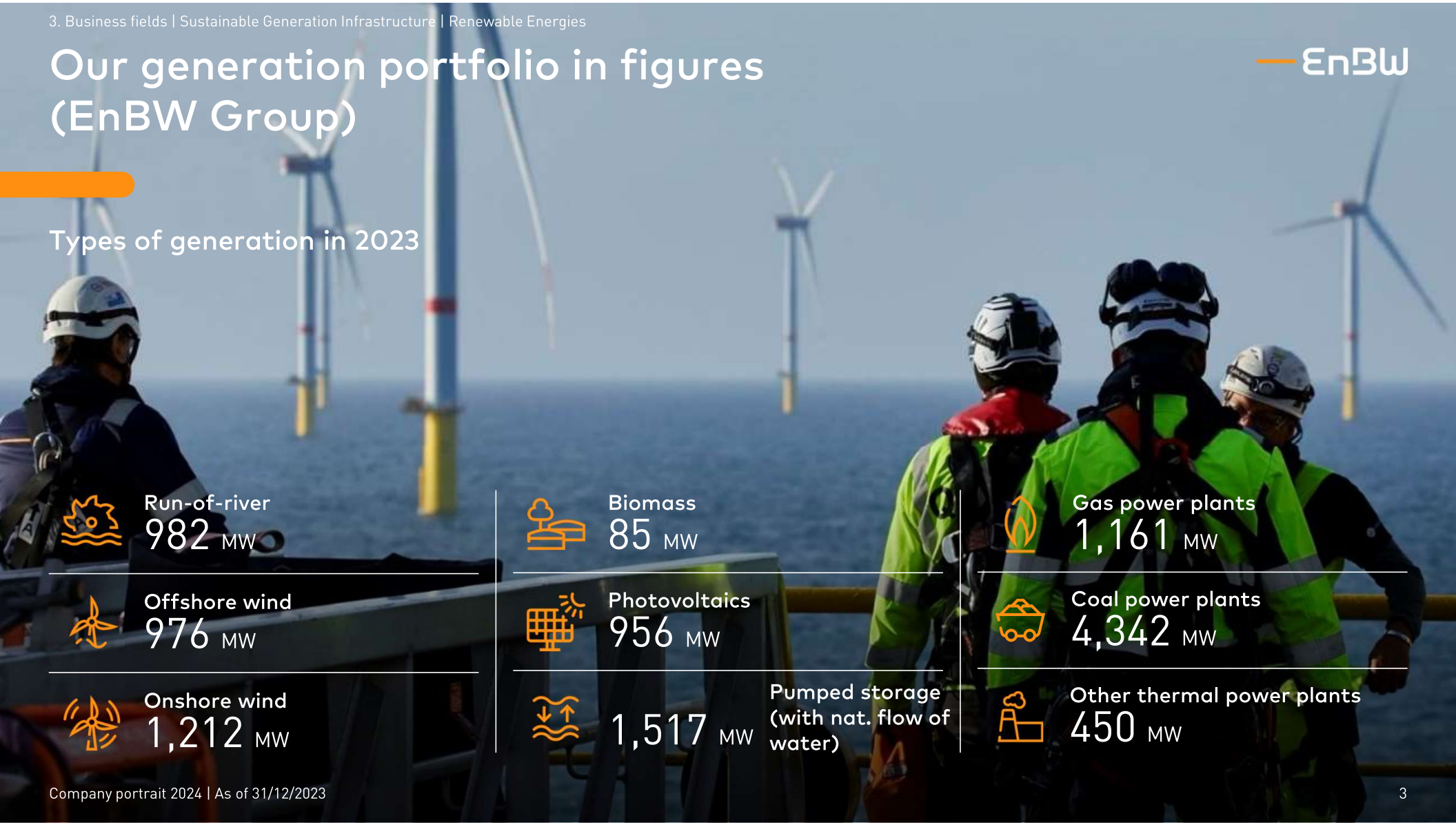
Length of electricity grid
148,000 km

Length of gas grid
31,000 km

[1] Earnings before the investment and financial results, income taxes and amortization, adjusted for non-operating effects.

Our generation portfolio in figures (EnBW Group)

Types of generation in 2023



Run-of-river
982 MW

Offshore wind
976 MW

Onshore wind
1,212 MW

Biomass
85 MW

Photovoltaics
956 MW

1,517 MW Pumped storage (with nat. flow of water)

Gas power plants
1,161 MW

Coal power plants
4,342 MW

Other thermal power plants
450 MW

Vision 2045: Climate neutrality requires a fundamental transformation of the energy system

Renewable energy

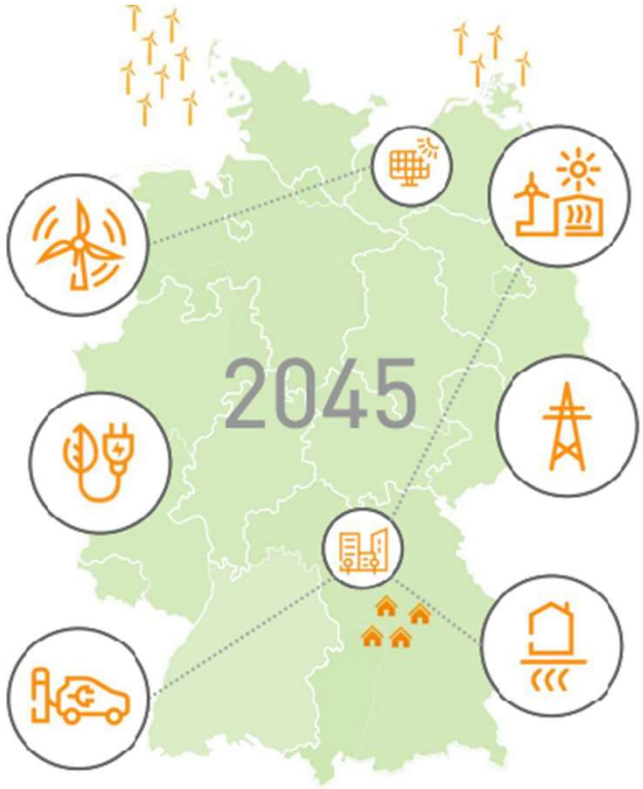
- … provides almost 100% of climate-neutral power generation
- Installed RE capacity: approx. 500 GW (today approx. 145 GW),

Security of supply

- … enabled by gas-fired power plants running on hydrogen, battery storage and hydropower (pumpedstorage):
- 60 GW gas turbines and and CCGT (2021: approx. 30 GW); 15 GW battery storage: 30 GW hydrogen storage (salt caverns)

E-mobility

- Electric power standard for passengercars, approx. 43 m electric vehicles,mainly passenger cars and deliveryvans
- Heavy/long-distance transport powered by H_2, biogenic fuels
  or battery electric



Current usage

- …increases to approx. 800–900 TWh due to high level of electrification in all sectors (2021 approx. 500 TWh)
- Energy efficiency reducing conventional consumption to ~400 TWh
- New consumption from 2025 (~200 TWh by 2045) due to sector coupling

Grids (electricity)

- Massive expansion by 2045
- €165 bn in investment needed in the transmission grid
  €123 bn in investment in distribution grids
- €110 bn to connect offshore wind farms

Heat supply

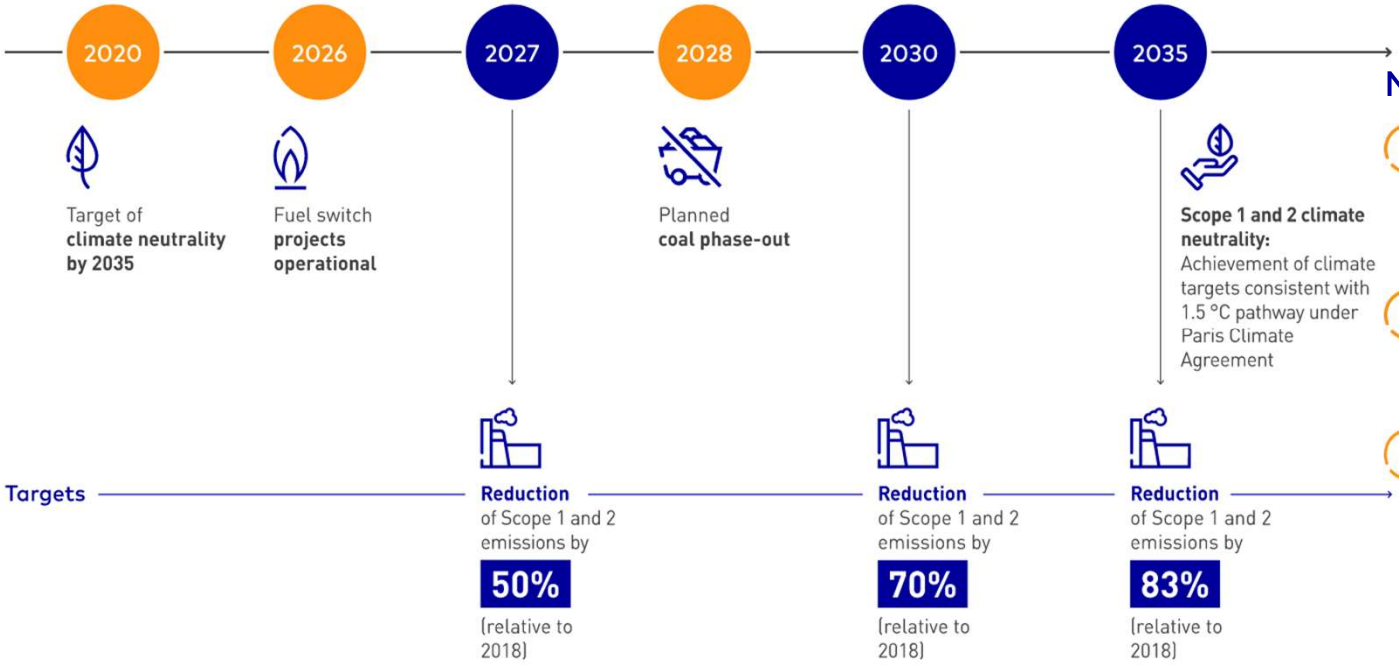
- … Automatically electric or with green gases
- > 13 m heat pumps in residentials (market share >60%)
- Heat demand to case by 15%
- H_2 with ≤20% market share

Source: Source: BMWK, Prognos, BCG, own analysis

Ambitious climate neutrality targets
EnBW plans to phase out coal by the end of 2028

Climate neutrality targets

2035 | 2040 | 2045 | 2050

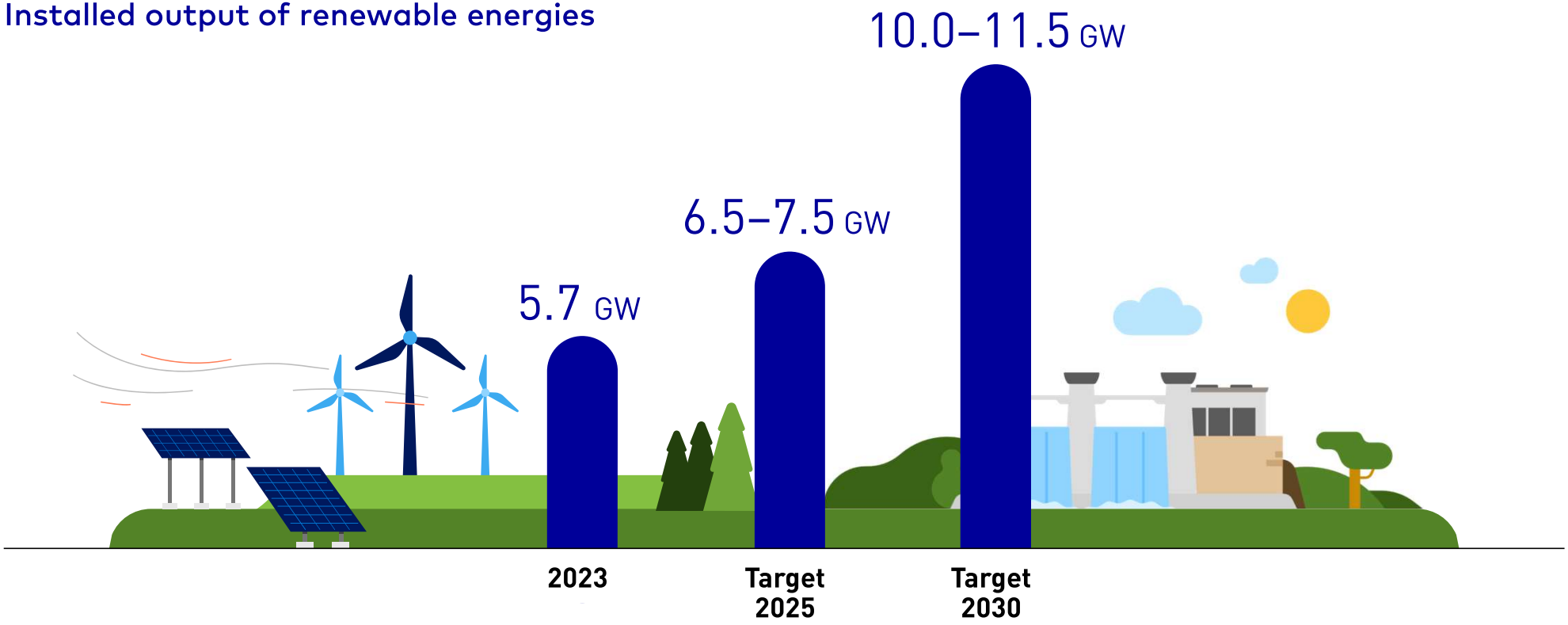


New energy and climate neutrality

1. **Expansion of renewable energies to 6.5–7.5 GW by 2025, taking biodiversity criteria into account** in major projects
2. **Planned phaseout of coal by 2028** and **Science-Based Targets validation** of the climate neutrality target for 2035
3. Making the transmission and distribution infrastructure **H_2-ready**

Renewable energies as a key pillar of generation

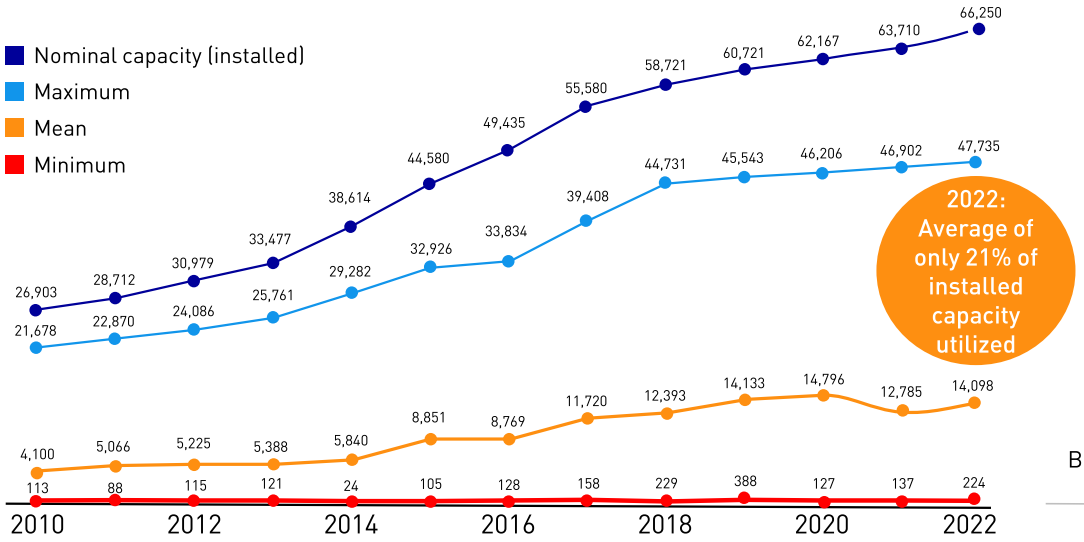
Installed output of renewable energies



Decarbonization Germany: Expansion of renewables increases demand for dispatchable power

Wind power generation in Germany, 2010 to 2021

in MW



Future options for dispatchable power generation

Conventional

Coal

Gas

Renewables

Biomass/-energy

Geothermal

Green gases (H_2, Biogas)

Storage

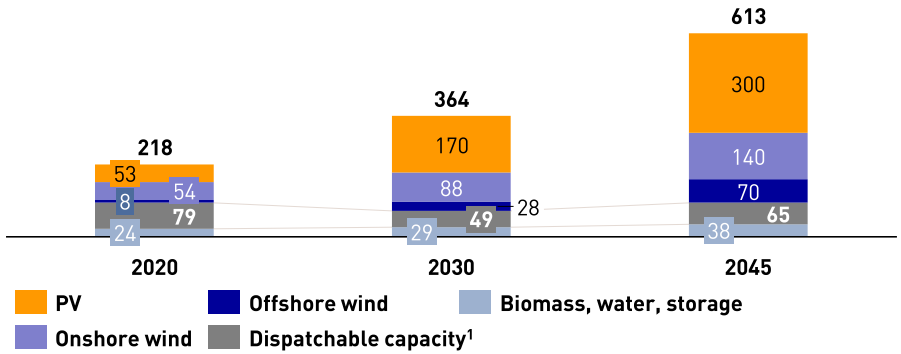
Pumped

Battery

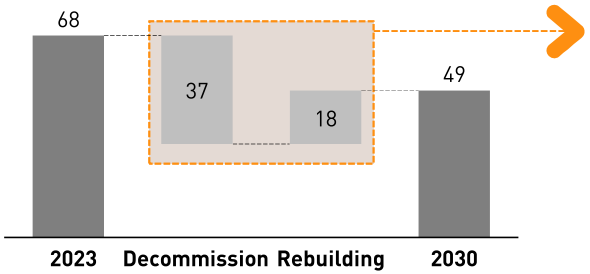
Source: VGB Powertech

The expansion of dispatchable capacity in Germany will be essential in the coming years

Development of installed capacity in Germany (in GWel)



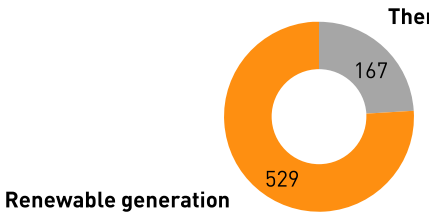
Decommissioning and rebuilding of dispatchable capacity by 2030 (in GW_{el})



Dispatchable power to be replaced

50%

Production shares in 2030 (in TWh)



Ratio of renewable to disposable generation **3 to 1**

[1] From the beginning of the 2030s, gas/hydrogen; Goal in 2045 100% hydrogen

Dispatchable power required
EnBW fuel switch projects, H_2-ready!

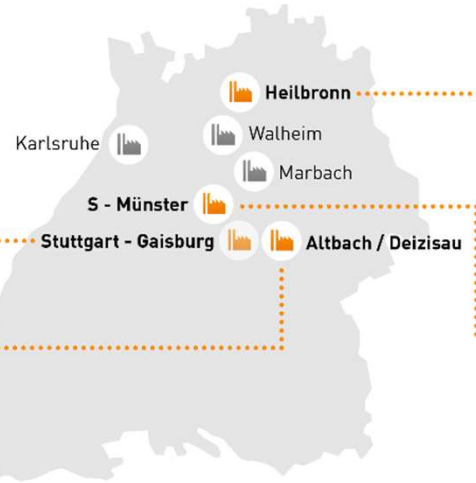
Gas instead of coal - "Fuel Switch" as an intermediate step on the road to climate neutrality

Stuttgart Gaisburg

- CHP plant with 30 MWel and 30 MW thermal output of approx. 30 MW
- Heating plant 175 MW
- **Commissioning 2018**

Altbach/Deizisau

- **CCGT plant with 665 MW el and up to 180 MW heat extraction.** Decommissioning of combined block HKW 2 with 401 MWel.
- **Commissioning 2026**



Heilbronn

- **CCGT plant with 675 MW el and up to 190 MW heat extraction.** Decommissioning of coal block HLB7 with 778 MWel.
- **Commissioning 2026**

Stuttgart-Münster

- **Gas turbine plant with 124 MWel and heat recovery steam generator.** Decommissioning of coal boilers and gas turbines.
- **Commissioning 2025**

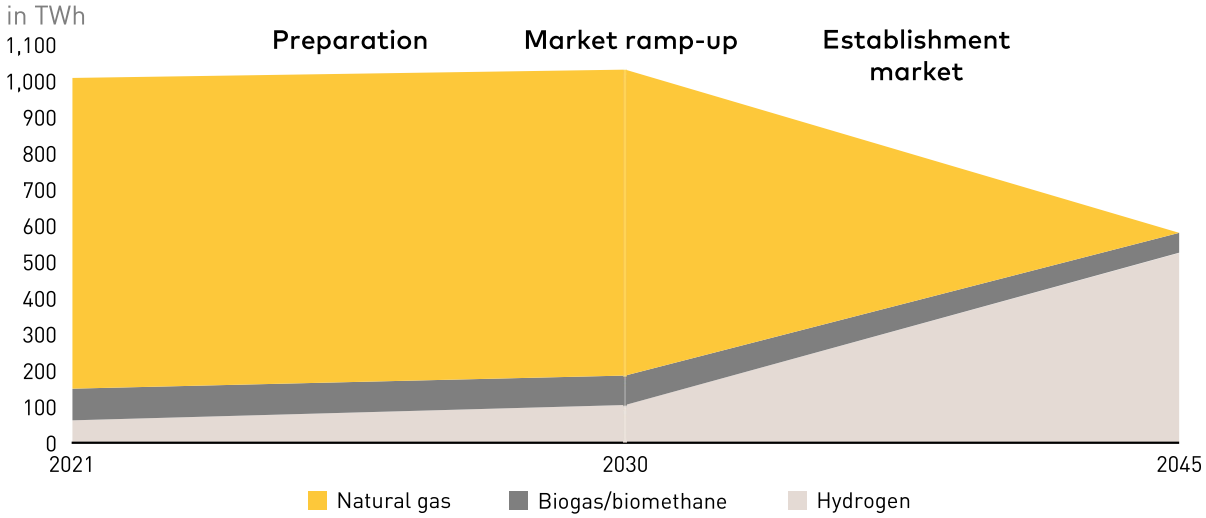
Hydrogen and Gas Turbines: state-of-the art and outlook. Alternatives?

- More than 50 years of operating experience with lower heating value fuels like blends of hydrogen and natural gas.
  - Mainly in refineries and steel mills, not in power generation
- New installed gas turbines are capable to burn approx. 20 Vol-% H_2, depending on type, capacity, emission limits.
- All relevant manufacturer have committed to deliver gas turbines operating with 100 % H_2 combustion systems to meet current emission limits by 2030*.
- Alternative: gas fired CCS-power plants
  - Production cost advantages vs H_2-power plants?
  - But CO_2- transport and storage infrastructure has yet to be developed
  - Stick with fossil energy vs renewables?
  - Which infrastructure to keep or to develop for CH_4 , CO_2, H_2?

* Sources: General Electric, Mitsubishi Heavy Industries , Siemens Energy

Decarbonisation Germany: Natural gas gradually being replaced by climate-neutral gases

Expected gas demand in Germany (incl. feedstock use)[1]



Explanatory notes

- EU climate neutrality requires fossil fuels to be replaced in all sectors by 2050[1]
- Time to 2030 should be used for setting up the market and improving the technologies
- Three aspects are particularly important:
  - Rapid establishment of a universal **hydrogen infrastructure**
  - Creation of an appropriate market regulatory framework (such as certification of origin for green hydrogen)
  - Creation of incentives promoting demand for climate-neutral hydrogen

our hydrogen expectation 2045

Demand 530 TWh/a

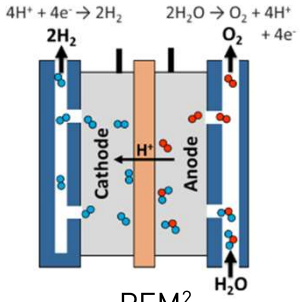
About 40-47 GW Electrolysis capacity

Share own Production 20% Import 80%

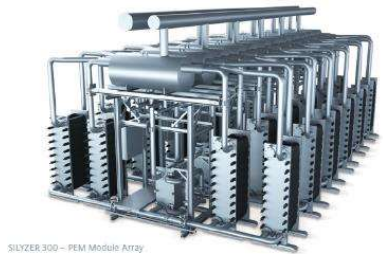
[1] Assumption: Green Deal consistently implemented by 2050

Production of Green Hydrogen

Water electrolysis is the technology to produce hydrogen out of renewable energy



PEM[2]



PEM-stack[2]

Alkaline-Stack[2]

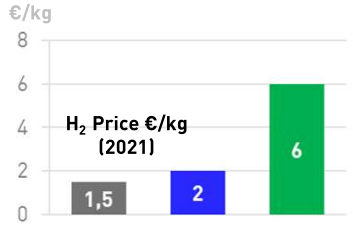
Explanation

- Technologies of water electrolysis include alkaline, polymer electrolyte membrane (PEM), solid oxide electrolyser cell (SOEC) and anion exchange membrane (AEM).
- Alkaline technologies are extensively developed in the chlor-alkali industry and dominate the market.
- PEM technologies are also commercially available, whereas SOEC and AEM are under demonstration.
- Current global installed electrolyser capacity is approx. 20 GW dedicated mainly to the production of chlorine, with hydrogen being a by-product of the process. Capacity is predicted to increase > 130 GW by 2030.
- Typical efficiency is in the range of 60 to 75 % (LHV[1]), depending on used technology, interfaces (hydrogen pressure, cooling system) etc.

[1] Lower Heating Value
[2] Sources: International Energy Agency, NEL, Siemens Energy

Massive increase in renewables is a pre-condition for Green Hydrogen production

- Germany: gas demand must be replaced by renewable gases, especially Green Hydrogen.
  - Green hydrogen is politically preferred, since no fossil fuels are used for production.
  - Blue Hydrogen has lower production costs, but important to start the H_2 market at all
- To completely cover the gas demand in Germany from green gases by 2050, a massive expansion of renewable energy generation is necessary, e.g
  - In Germany: 300 $GW_{Wind\ offshore}$
    - 2023: 8,4 GW installed
    - 2045: 70 GW *(current policies)*
  - Or in North Africa: 400 GW_{PV}



Grey H_2: from methane (natural gas)
Blue H_2: from methane with CCS
Green H_2: from RE- electricity

- A large amount of Green hydrogen is expected to be imported from other countries even in the long term!

Global H_2- production and -procurement for Germany

Procurement- options for hydrogen and -derivates[1]

Important aspects

- **In 2023, share of imported H_2 and –derivatives: 50-70 %** according to national hydrogen strategy (Nationaler Wasserstoffstrategie)
- Potenial import-/production regions for EU: **North- and Southamerica, Northafrica and South Asia**
- US-Subsidies (IRA) may have a significant impact on further development
- **Bilateral trade agreements** between large producer- and customer regions
- **Blue hydrogen** will probably have lower production costs than Green hydrogen until the 2040'ies

[1] especially NH_3 (and some synthetic hydrocarbons)

Transport of Hydrogen

- Pipelines are the economically preferred transport option up to a certain distance
  - The European Hydrogen Backbone is a vision for a hydrogen transport infrastructure, connecting 21 countries by 2040 and grows from 2,000 to 40,000 km.
  - Hydrogen transmission pipeline length need to be expanded rapidly .
- For longer distances shipping becomes more cost-effective.
  - Hydrogen shipping requires very high pressure and/or very low temperatures (LH_2), or conversion to a liquid energy carriers such as ammonia, synthetic hydrocarbons
  - Ammonia and hydrocarbons have an existing transport infrastructure across the globe, but ammonia is currently not used as an energy carrier
  - The infrastructure for LH_2 and additional infrastructure for ammonia including large scale crackers have yet to be built
- Of course, the production infrastructure for the new sustainable energy carriers also have to be developed, including the renewables


Source vng


Source vng


Source wikipedia


Source BASF

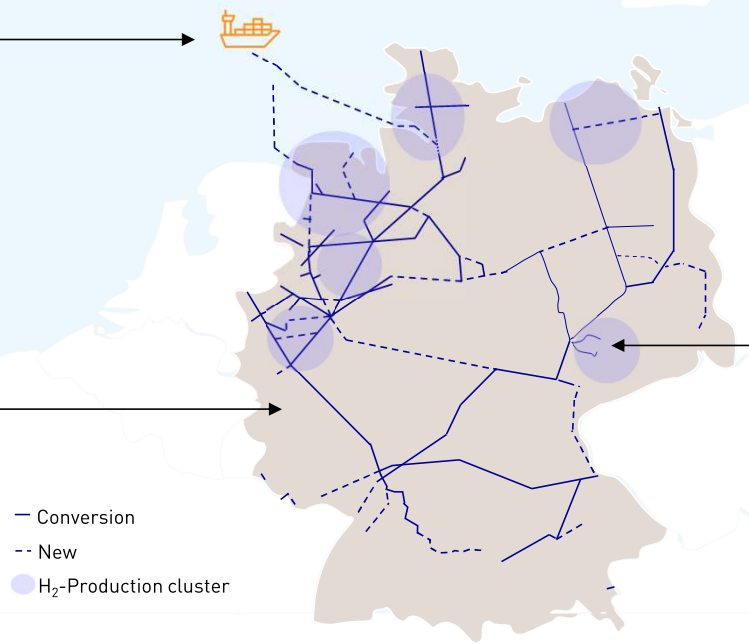
Hydrogen Infrastructure by 2030

Imports of hydrogen
from 2025

- Starting in 2025, larger quantities from 2028 expected, Ammonia as hydrogen carrier, to a large fraction based on Blue H_2 until early 2040

Hydrogen-transport
Pipeline from 2027

- Transport by ship, rail, and trailer expected in the years ahead
- Regional pipeline-infrastructure by 2030, nationally connected up from 2032 onwards



Hydrogen-storage

- Various storage projects in the planning stage (new/conversion) in the middle and the north of Germany

National project pipeline
Approx. 8.000 MW

- For hydrogen production – FID for approx. 300 MW achieved

Wide variety of hydrogen activities already in progress across the EnBW Group

1 Öhringen Hydrogen Island — Netze BW

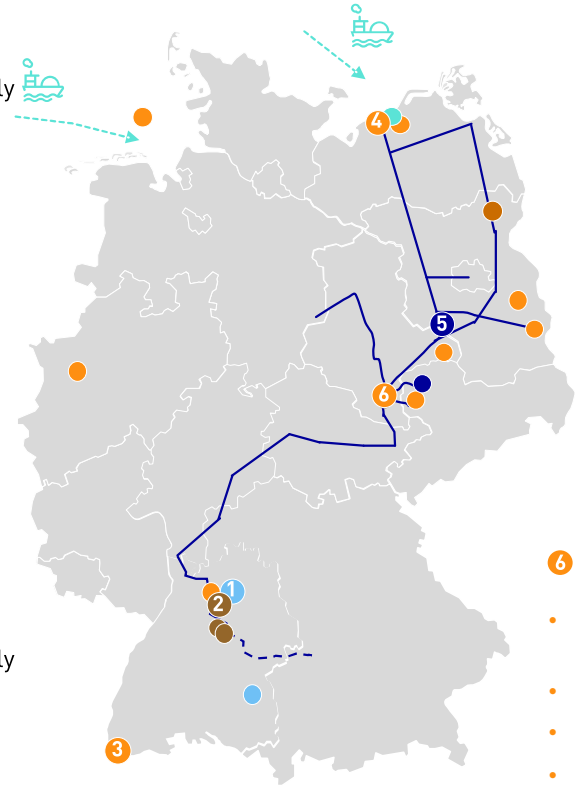
- Up to 30% hydrogen blended into gas grid for heat supply
- Supply of operating site plus 26 households
- Operating buildings supplied from 2021

2 Fuel-switch power plants — EnBW

- Conversion of three coal-fired heat and power plants to natural gas and subsequently hydrogen
- Total output 1,500 MW_{el}, 820 MW_{th}
- Planned start-up: 2026, conversion to H_2 from beginning 2030s

3 H_2 Whylen Real-World Lab — EnBW

- Up to 30% hydrogen blended into gas grid for heat supply
- Supply of operating site plus 26 households
- Operating buildings supplied from 2021



4 Rostock hydrogen port — EnBW

- Production of green hydrogen
- Consortium project (Port of Rostock, Rheinenergie, RWE)
- Generating capacity: 100 MW_{el}
- Electrolyser planned to start operating in 2026
- Demonstration plant for an ammonia cracker (EnBW, VNG and JERA)

5 Doing Hydrogen & Green Octopus — ONTRAS

- Conversion of natural gas pipelines and construction of additional hydrogen pipelines for total of 900 km (Rostock-Leipzig-Salzgitter axis)
- First sections of pipelines planned to start operating from 2027

6 Doing Hydrogen & Green Octopus — VNG

- Integrated project along hydrogen value chain in project consortium (uniper, Terrawatt, DBI)
- Hydrogen produced used in industry
- Electrolyser generating capacity: 30 MW_{el}
- Wind farm, electrolyser and pipeline planned to start operating in 2025

Summary

- Dispatchable power plants are an important ingredient for the renewable energy system in Germany
- EnBW's gas fired dispatchable power plants will be H_2 -ready on commissioning and run on H_2 when sufficient supply will be available
- Starting in small quantities, hydrogen will be available as a sustainable energy carrier from 2025
- Most of the Green hydrogen in Germany will be imported
- An enormous increase in renewable production on a global scale is critical for Green hydrogen to be successful

Wanting the energy transition means doing projects!

The success of the energy transition process depends on six elements:

- Expansion of renewable generation
- Expansion of dispatchable capacity
- Modification of the transmission nets
- Conversion of Distribution networks
- Demand management of the customers
- Use of Gas & Transformation to H_2

Quelle: Fortschrittsmonitor 2024 BDEW & EY