Flexibility in the Energy System

Perspectives and Trends from Germany

May 2026

Twenty years of Indo-German Energy Forum 2006-2026

ENERGY IS US

Agenda

1. **Energy Situation in Germany and Europe**
2. The Need for Flexibility
3. Consequences of Flexibile Operation
4. Outlook and Conclusion

Energy Policy Targets of the EU and Germany

Targets	Germany				EU	
	2030	2040	2045	2050	2030	2050
Climate						
Greenhouse gas emissions (GHG) reduction Reduction compared to 1990 levels, including all sectors.	65%	88%	GHG neutral	GHG net sink	55%	GHG neutral

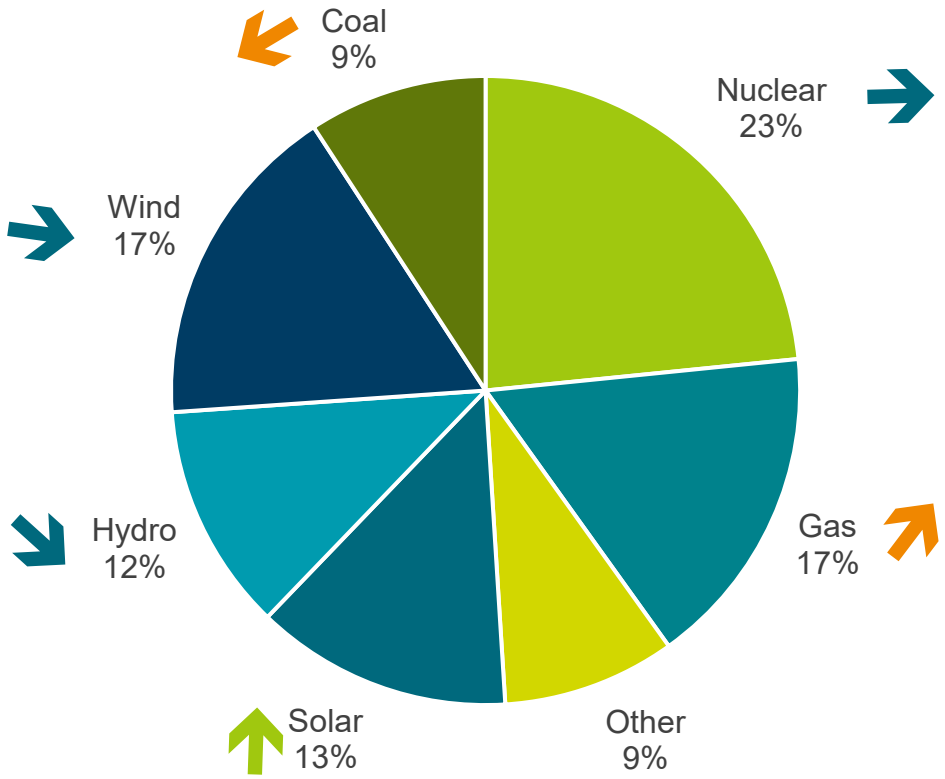
Source: Guidehouse 2023 based on BMWK 2022, Federal Government 2022 & EC 2022

- **European Green Deal** (2050 climate neutrality, 2030 GHG -55%)
  - Just Transition Mechanism (€55B support)
    - **Fit for 55 Package** (2030 climate measures)
      - **REPowerEU** (energy independence, hydrogen targets)
        - Energy Performance of Buildings Directive (update)

- **Clean Industrial Deal (2025)**: Industrial decarbonisation, 100 GW renewables p.a.
- **Affordable Energy Action Plan** (2040 €260B savings/year)
- 2040 Climate Target Proposal: **-90% net GHG vs. 1990**
- Carbon Border Adjustment Mechanism (CBAM) adjustments

Electricity Mix in Europe 2025

Status 2025: 2.770 TWh (gross production)



Source: Ember EER2026

Key take-aways:

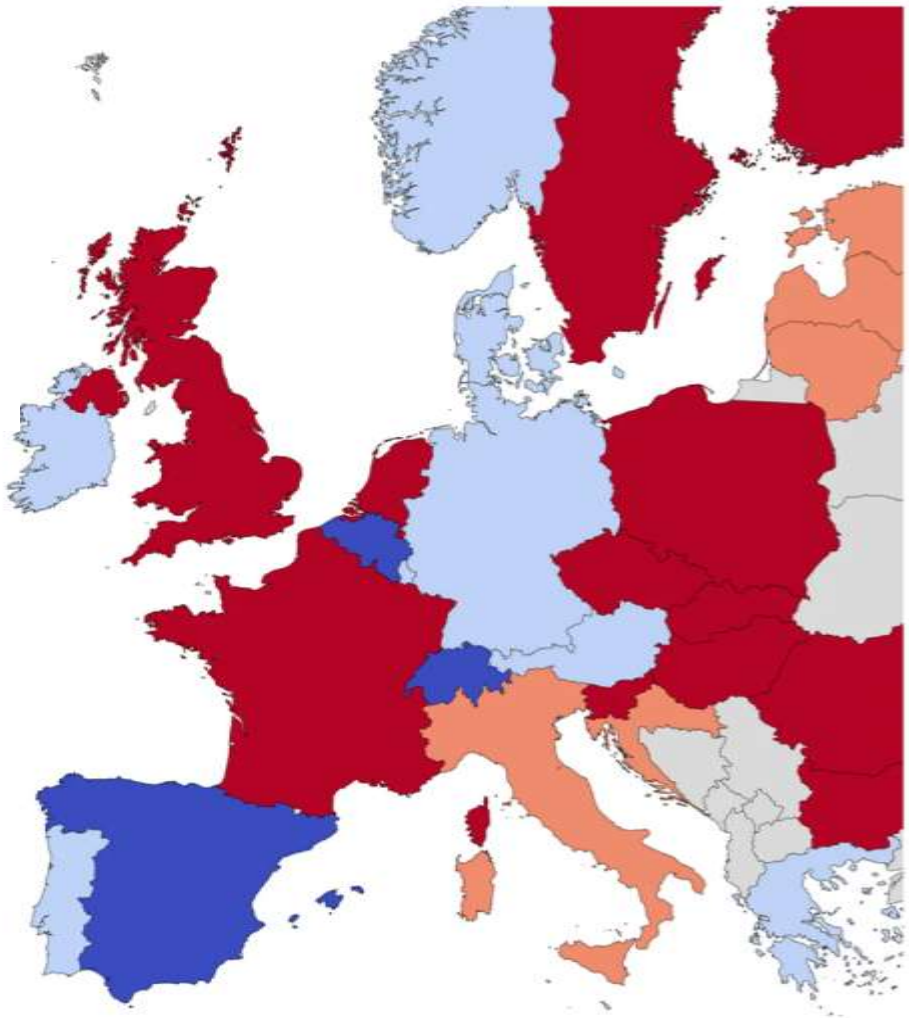
- For the first time, wind and solar produced more electricity (30%) than fossil fuels (29%)
- Small increase in demand
- RES with increased share of 47.7%
- Solar (+20%, +62 TWh) overtakes hydro and coal
- Hydro and Wind with weather-induced drawback
- Gas increased since 5 years by 8%
- Coal fell to historic low of 9.2%

Power Generation Portfolio Development in Europe: Nuclear & Coal

Energy Brainpool
– part of the MONTEL GROUP

Nuclear Power Expansion in Europe

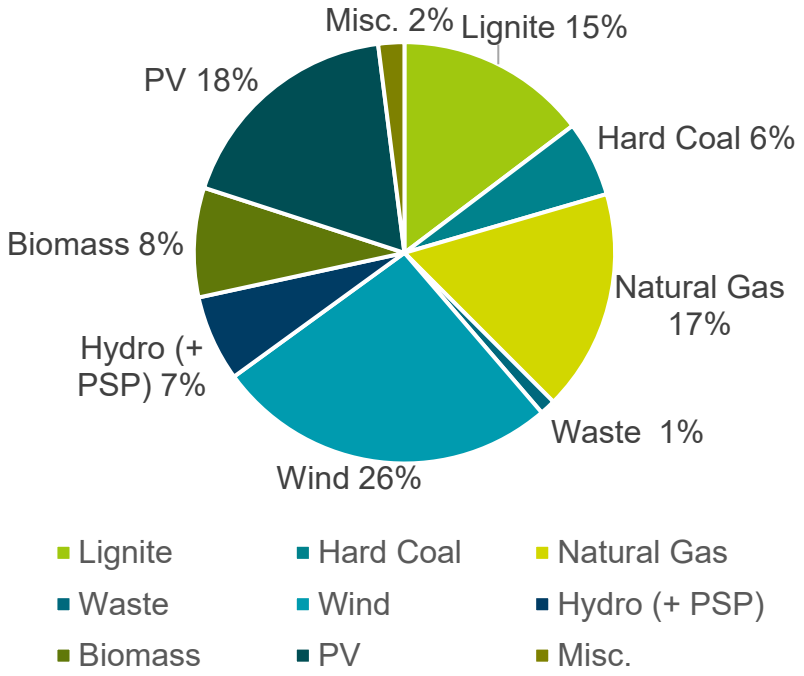
- No plans for nuclear
- Phase-out plans
- New build plans
- Interest in SMR only



- No coal in power generation
- Coal phase-out until 2030
- Coal phase-out after 2030
- Coal phase-out under discussion
- No official coal phase-out discussion

Power Generation in Germany in 2025

Net generation: 485.7 TWh – 58% from renewables
Import / export: 79.6 TWh / 60.2 TWh



Installed capacity:	
Lignite:	14.7 GW
Hard coal:	15.4 GW
Natural gas:	35.5 GW
Wind:	75.2 GW
PV:	101.0 GW
Hydro/pumped storage	5.6/9.9 GW

Coal phase-out in 2038

Sources: AG Energiebilanzen, Bundesnetzagentur, Fraunhofer ISI, Statistisches Bundesamt

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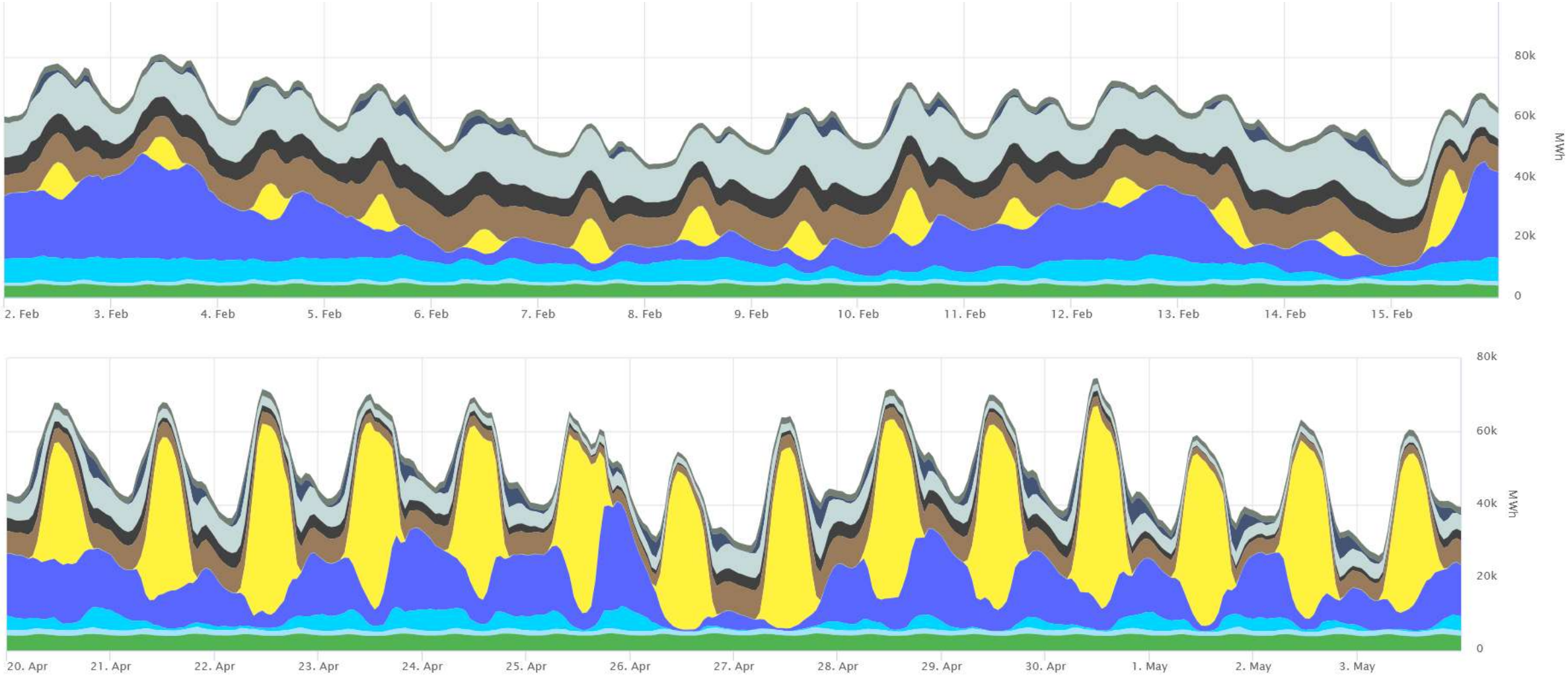
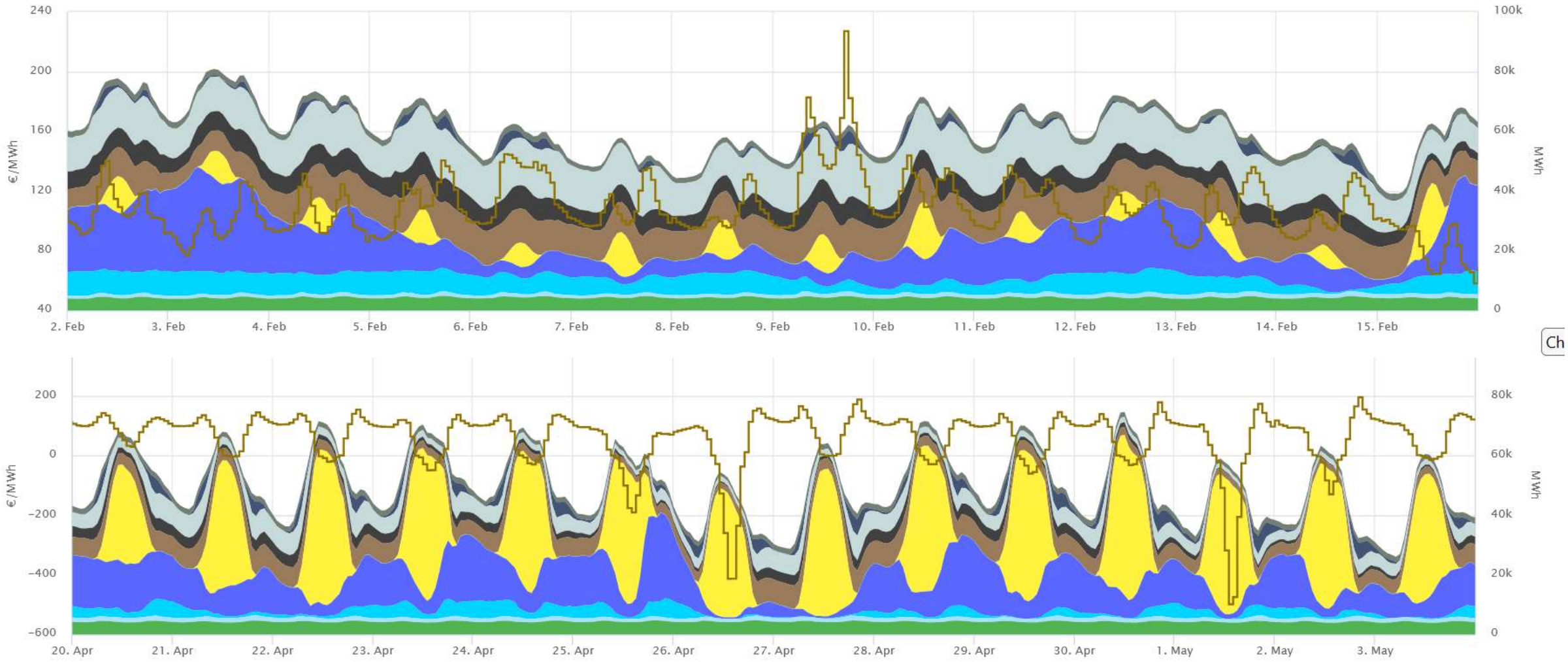
Power Generation in Germany: February and April/May



Source: www.smard.de

green: biomass, blue: wind, yellow: PV, brown: lignite, black: hard coal, grey: gas

Open Energy Market: Electricity Prices at Stock Exchange



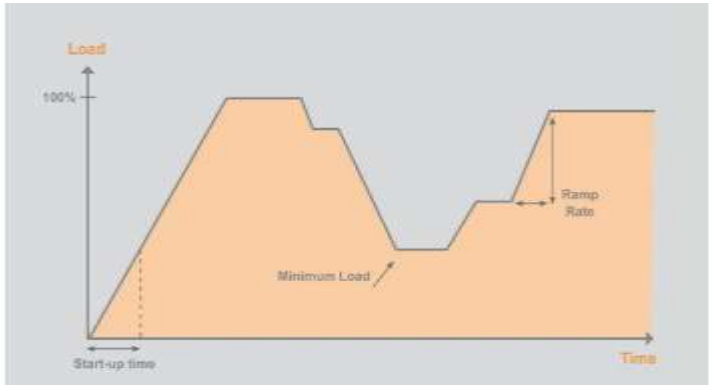
Source: www.smard.de

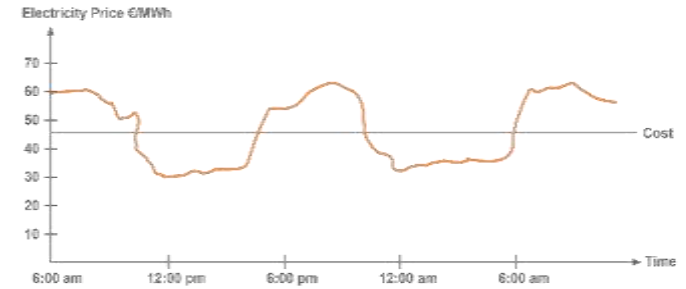
Flexibility Parameters of Thermal Power Plants

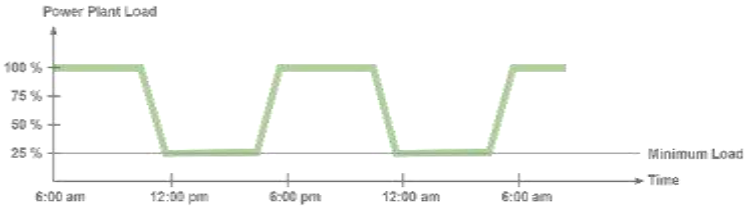
Plant type	Hard Coal	Lignite	CCGT
Ramp rate [% / min]	2 to 4	2	4 to 8
in the load range [%]	40 to 90	50 to 90	40* to 90
Minimum load [%]	25 to 40	30 to 40	30* to 40
Start-up time hot start <8 h [h]	2 to 3	4 to 6	1 to 1.5
Start-up time cold start >48 h [h]	4 to 7	6 to 8	2 to 3

Source: VDE and own studies

*as per emission limits for NO_x and CO; CCGT = Combined Cycle Gas Turbine Plant







Type of coal	Calorific value [kJ/kg]	Ash content [%]	Water content [%]	Sulphur content [%]
Indian coal	11,715 – 20,900	25.0 – 60.0	10 – 20	0.30 – 0.80
German lignite	7,800 – 11,300	2.5 – 20.0	40 – 60	0.15 – 3.00
Imported hard coal used in Germany	~25,000	7.0 –15.0	9.0 – 12.0	< 1.0

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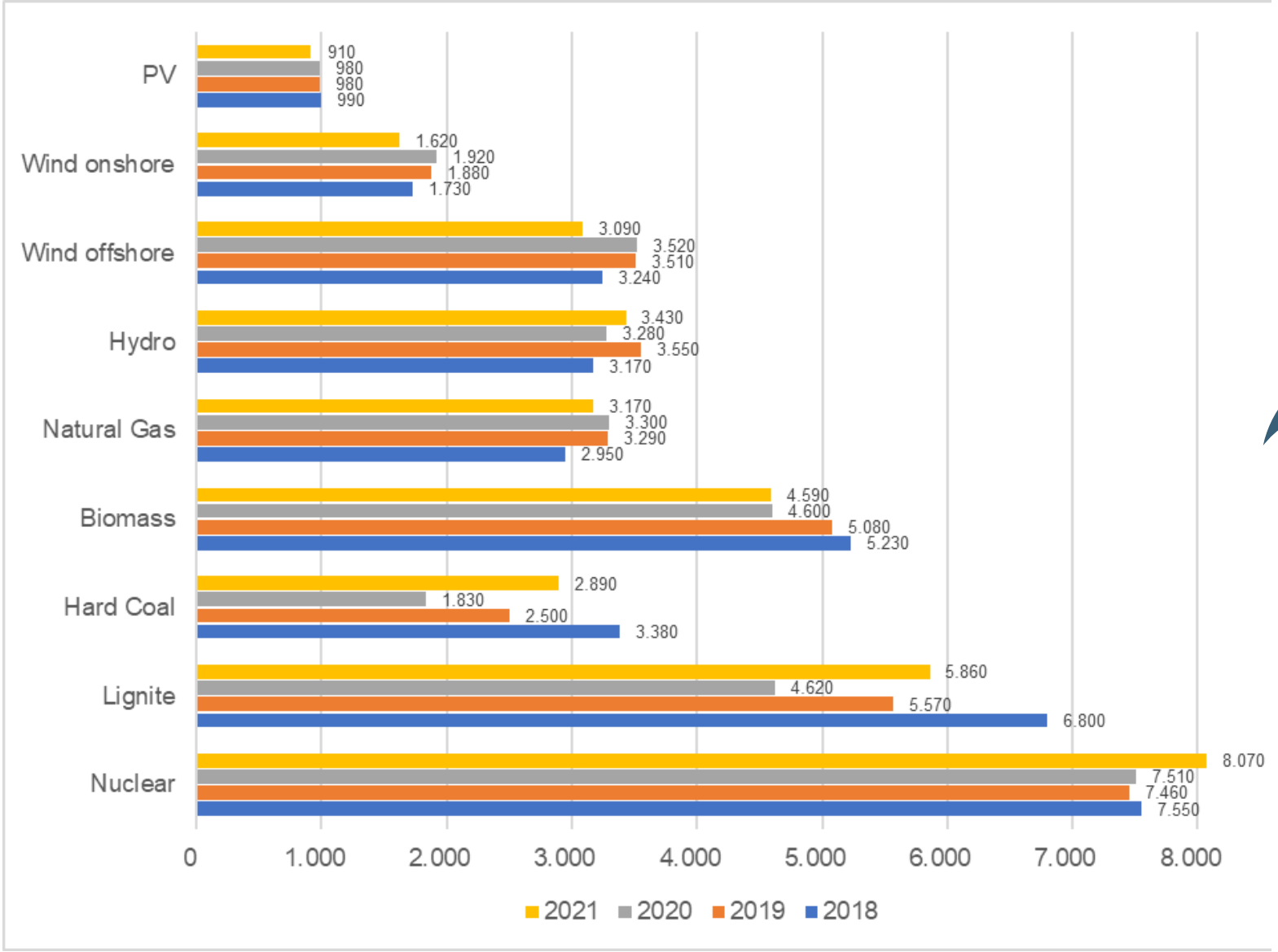
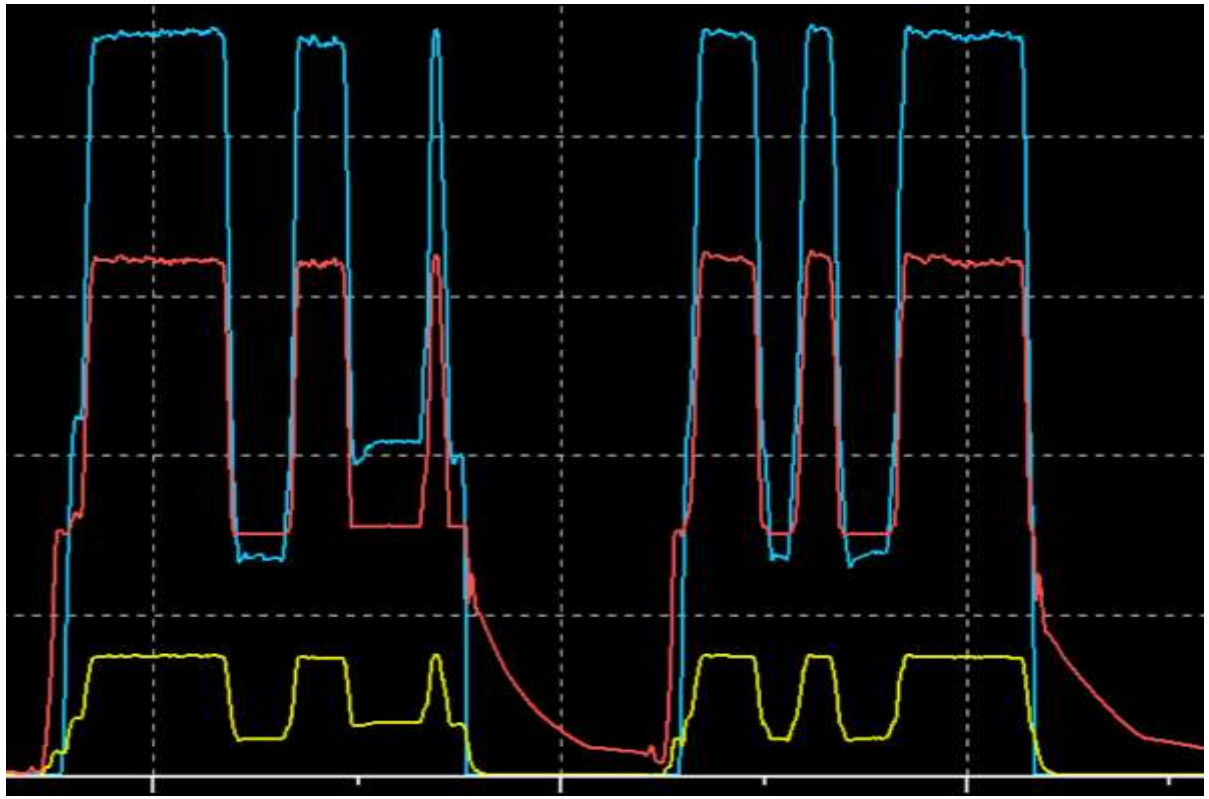
Full-load Hours of German Power Plants



Flexible power plant operation results in less full load hours

Source: BDEW

Typical Load Profile of a Hard Coal Power Plant



Typical weekly profile of a coal-fired power plant:

Duration:	Monday to Friday
Plant type:	USC / pulverized coal
	Live steam temperature > 600°C
Capacity:	800 MW
Blue line:	Electrical output
Red line:	Live steam pressure
Yellow line:	Reheat steam pressure

Design Data vs. Actual Operational Regime

Design data operation hours by load (per year):

Load	Operating hours
100 %	4950
75 %	650
50 %	1750
< 50 %	450
total	7800

Actual operational regime:

Load	Operating Hours (OH)
100 %	80−90 % of OH
75 %	mainly only transient
50 %	mainly only transient
< 25−30 %	10−20% of OH
total	1500−2500

There are basically only two load regimes: either low load or full load.
Exceptions only apply in the event of redispatch demand from the grid operator.

Consequences for O&M

Process Understanding

- in-depth process understanding is key
- stable combustion and even heat distribution in the boiler should be ensured
- high level of auto-mation is beneficial

Damage Mechanism

- lifetime consump-tion particularly related to cycling fatigue stress
- creep is no longer the dominant damage mechanism

Condition Monitoring

- calculate the lifetime consumption based on metal temperature measurements (e.g. boiler fatigue monitoring)

Inspection

- inspection methodology to be adjusted – e.g. use of ultrasonic testing
- inspection sequences to be adjusted – e.g. for actuators due to higher switching rates

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Benefits of Repurposing Coal Power Plant Sites

Well-developed external infrastructure

Grid | Transport: harbour, roads and railway | Gas network | Water | District heating

Miscellaneous benefits

Highly qualified personnel | Availability of space | Existing permits | Saving decom-missioning costs

Well-developed internal infrastructure

Digitalised site | Cooling systems | Water treatment | Heating systems | Steam systems

Access to existing consumer base

Households and offices | Business and agriculture | Industry

Repurposing Technology Options

Renewable Energies

Capacity extension with PV and/or wind energy plants

Sector Coupling

From heat and steam provision to the integration of H_2 production and CCUS as well as the production of green gases and/or biofuels

Storage

Integration of storage systems such as large scale batteries as well as thermal and mechanical storage

Source of picture: Steag GmbH

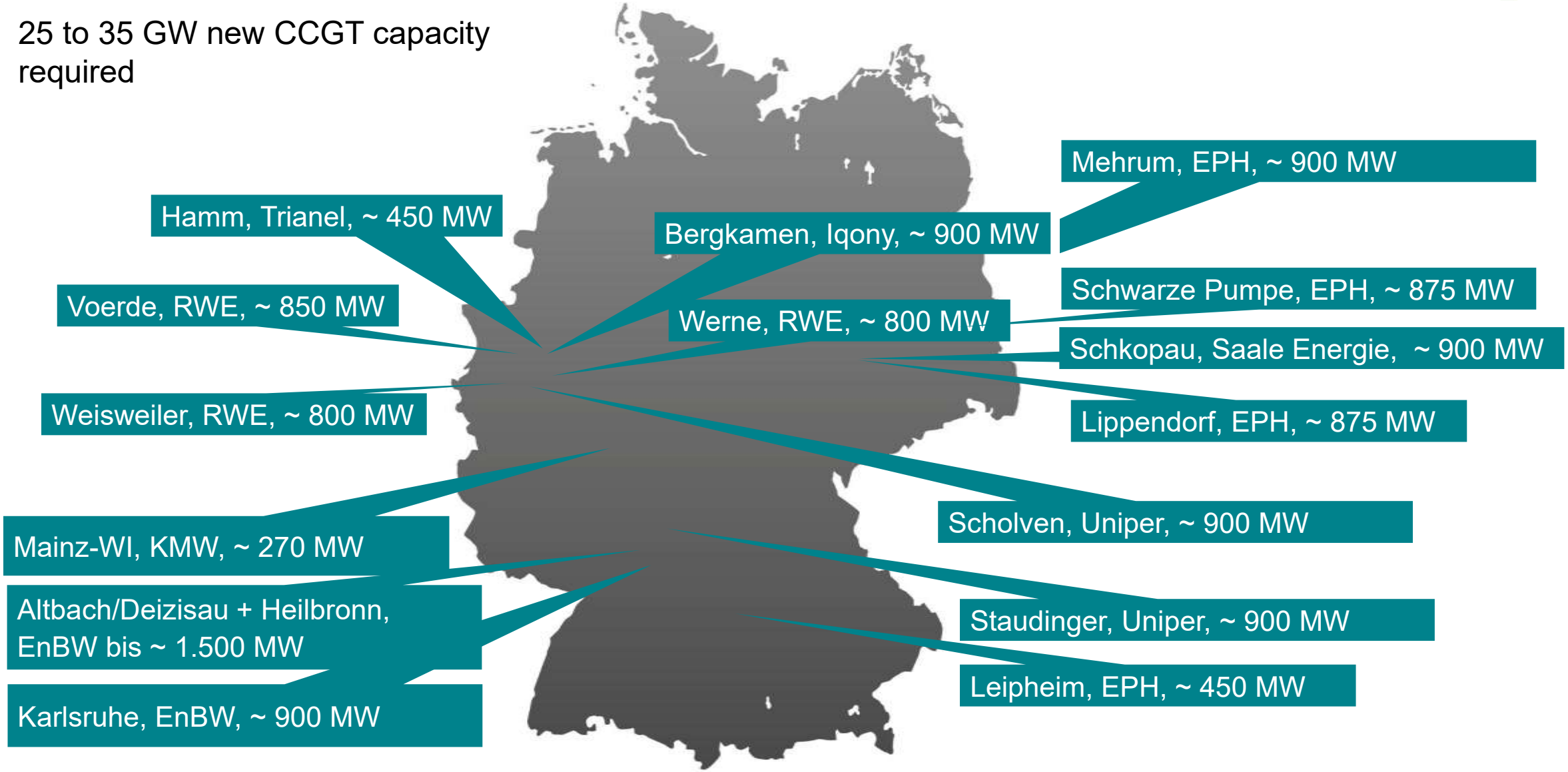
Fuel Blending

Partial fuel substitution with biomass or green gases

New built gas-based combined cycle power plants that are hydrogen ready

How to Secure Dispatchable Generation

25 to 35 GW new CCGT capacity required



Summary

- The share of fossil-based power generation is declining in Germany and Europe.
- Thermal power plants operate very flexibly – minimum load operation, efficient start-ups and adjusted O&M concepts are required-
- Flexible operation does not necessarly result in more damages. It is imperative to know:
  - how to operate the plant at low loads, in transient conditions and during start-up and shut-down (e.g. even heat distribution, stable combustion, smooth controls),
  - where and how to monitor and to inspect,
  - how to adjust maintenance procedures.
- In the future, dispatchable generation capacity will be provided by gas-based plants.

Thank you for your attention.

be energized
be inspired
be connected
be informed

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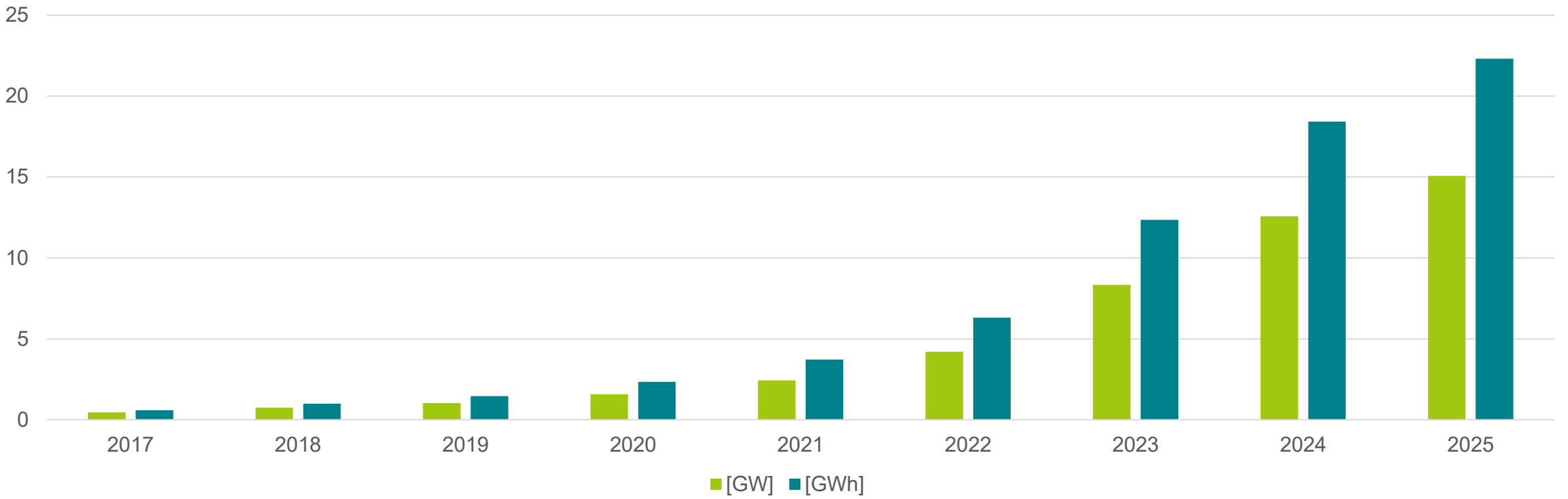
BACK-UP

BESS in Germany



Source: Fraunhofer https://www.energy-charts.info

Experiences from Germany: Two-shifting

Sensible plant shut-down

⇒ Stop O_2 dosing of feed water and increase pH value by switching to AVT mode 2−4 hrs before shut-down

⇒ Use of the FD fan should be kept to a minimum; just enough to purge the boiler; the ID fan should run long enough to remove the flue gas from the system

⇒ Conduct soot blowing before plant shut-down

Maintain the plant in ready-to-go state

⇒ Ensure that the water-steam cycle remains as warm as possible – the pressure should be kept as high as possible by closing all steam, drain and ventilation valves

⇒ Consider the installation of a damper into the flue gas duct in order to mitigate heat losses during short stand-still periods

Prepare for fast start-up

⇒ Define the optimal sequence of mills for start-up in order to synchronize as fast as possible – timely pre-heating of mills is beneficial.

⇒ Prepare /keep the condensate and feed water system ready for start-up.

⇒ Early start-up of the lube oil system of big components such as ID and FD fan, as well as mills, is needed in order to ensure proper oil heating.

Adapting your operational procedures to new situation is essential to become and stay competitive in the new market design.