Flexible coal power generation

technical, economic and climate considerations

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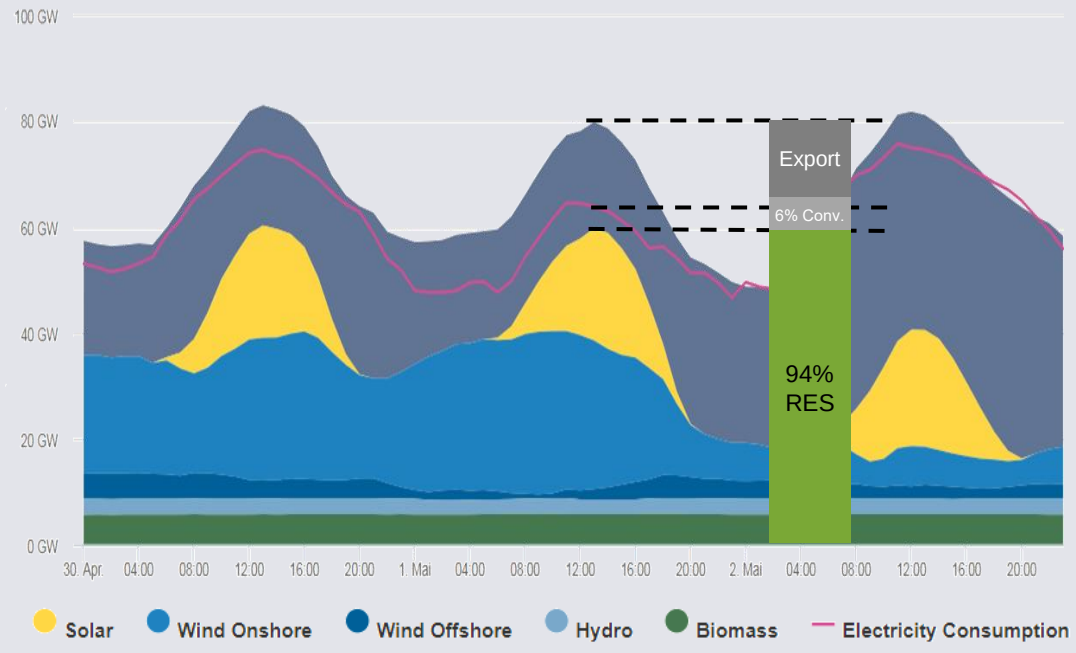
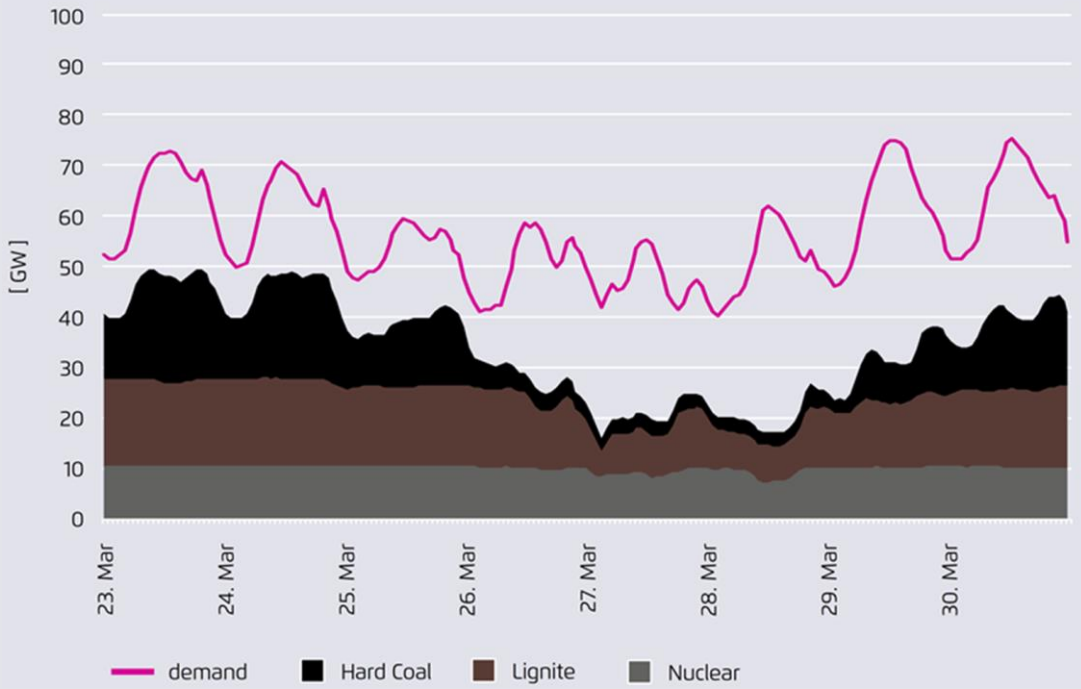
- **Think Tank** and **Policy Lab**
- Round about **100 energy transition experts**
- **Independent** and non-partisan with a diverse financing structure
- **Our Vision** - A prosperous and **carbon neutral global economy** by 2050
- **Policy advice** to deliver **clean power, heat and industries** – in Germany, Europe and around the Globe
- **Headquartered in Berlin**, with offices in Brussels, Beijing and Bangkok
- Consortium member of the **Clean, Affordable and Secure Energy for Southeast Asia (CASE) programme**

Flexibility has become the new paradigm of power systems. Baseload is an obsolete concept!

Electricity generation in Germany 30.4-2.05.2018 (links); Power generation from nuclear, hard coal and lignite power plants and demand in Germany, 29.04-06.04.2018;(right)

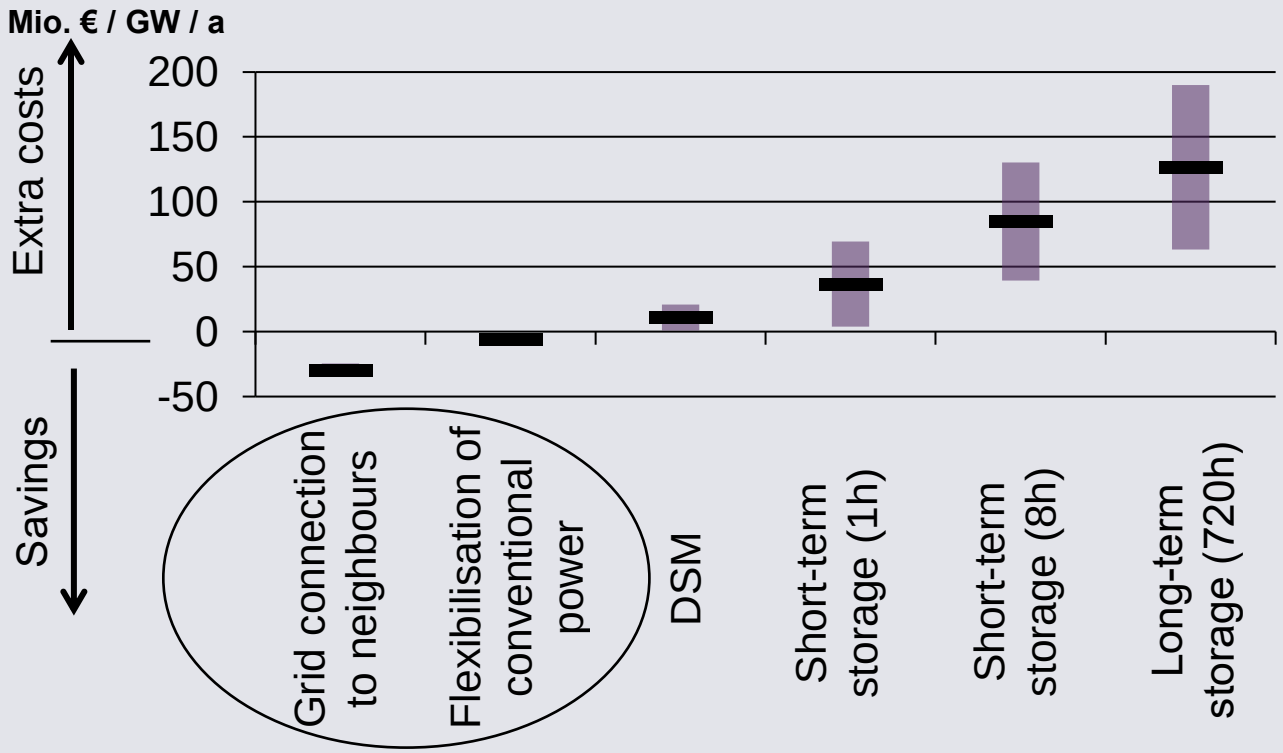




Agorameter - Agora Energiewende (2018)

Various technologies can provide flexibility. A cost-benefit analysis of flexibility options provides the basis for better planning and better regulation

Costs/savings of one GW of flexibility in Germany (43% renewable scenario)



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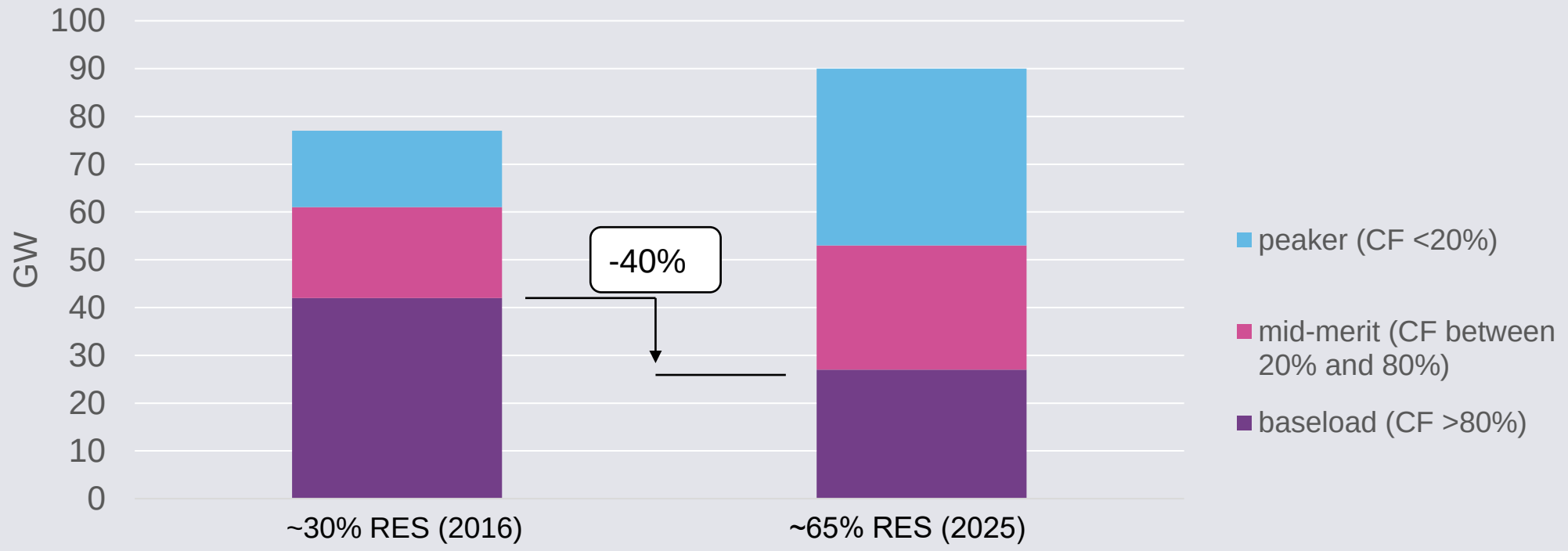
- Grids, flexibilization of conventional generation, demand side management (DSM) are the cheapest flexibility options in Germany.
- In Germany, the flexibility needs are so far nearly mostly met by flexible power plants and interconnectors with neighbours
- From an overall system perspective, new storage is required only at very high shares of renewable energies.
- But short-term storage can today deliver several ancillary services at competitive costs. Furthermore, they can help avoiding distribution grid expansion.

The variability of renewables shifts the cost-optimal structure of the portfolio of conventional power plants

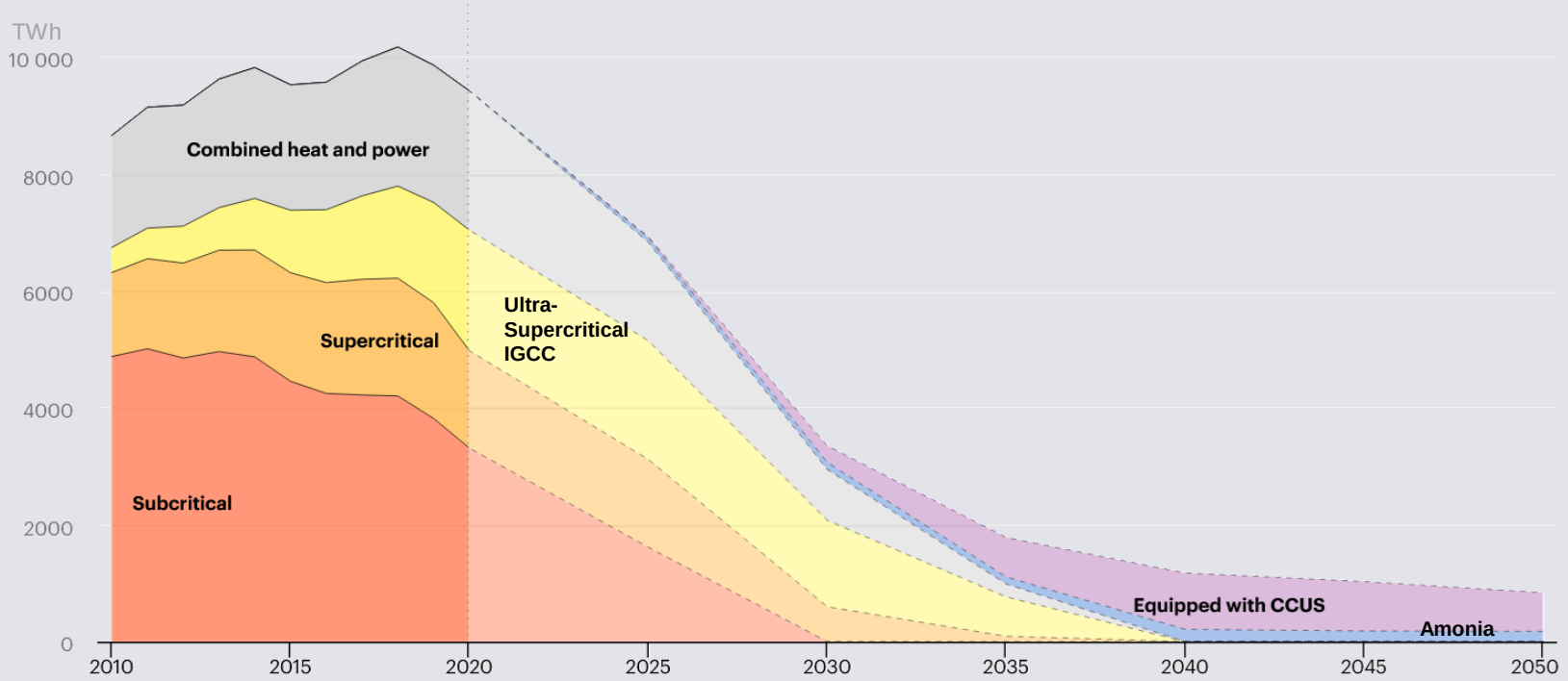
Structure* of the residual power plant park in Germany in 2016 and in 2025 (~65% renewables).



Agora Energiewende, Artelys Crystal Super Grid. *The structure is derived from assumed capacity factor (CF) values: Plants with a capacity factor of 80% or larger (>7000 full load hours), a capacity factor between 20% and 80% (1750-7000 full load hours) and a capacity factor smaller than 20% (<1750 full load hours) are shown.

Reaching net-zero emissions by mid-century requires to phase-out unabated coal by 2040 worldwide. In some countries, like Indonesia, coal power plants will continue to play a role during the transition.

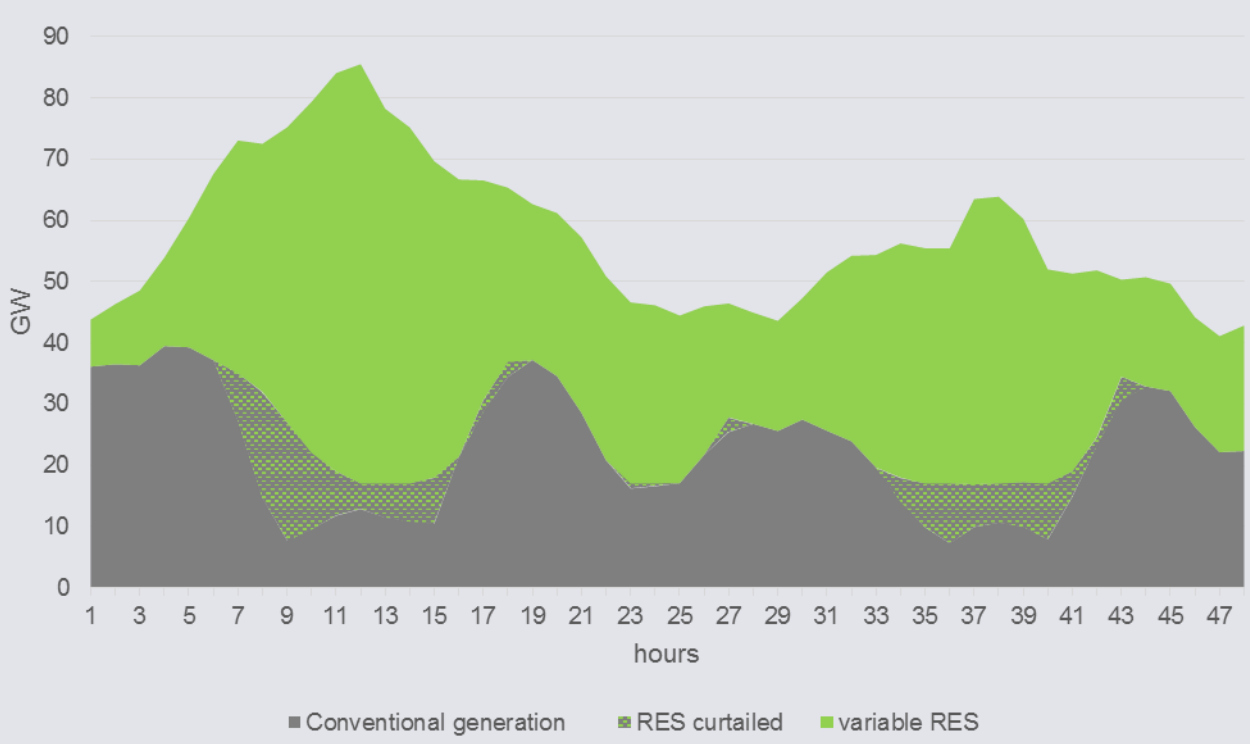
Coal-fired electricity generation by technology in the IEA Net Zero Scenario, 2010-2050



IEA (2021)

Making conventional power plants more flexible can be a key strategy to integrate large shares of renewables more effectively in power systems dominated by coal assets.

Renewable and conventional power production during two exemplary days in a system with 60% RES in 2030



Agora Energiewende (2017)

In several countries, **the development of VRES is hampered** after a certain level → operators claim that the existing power system cannot cope with this variability

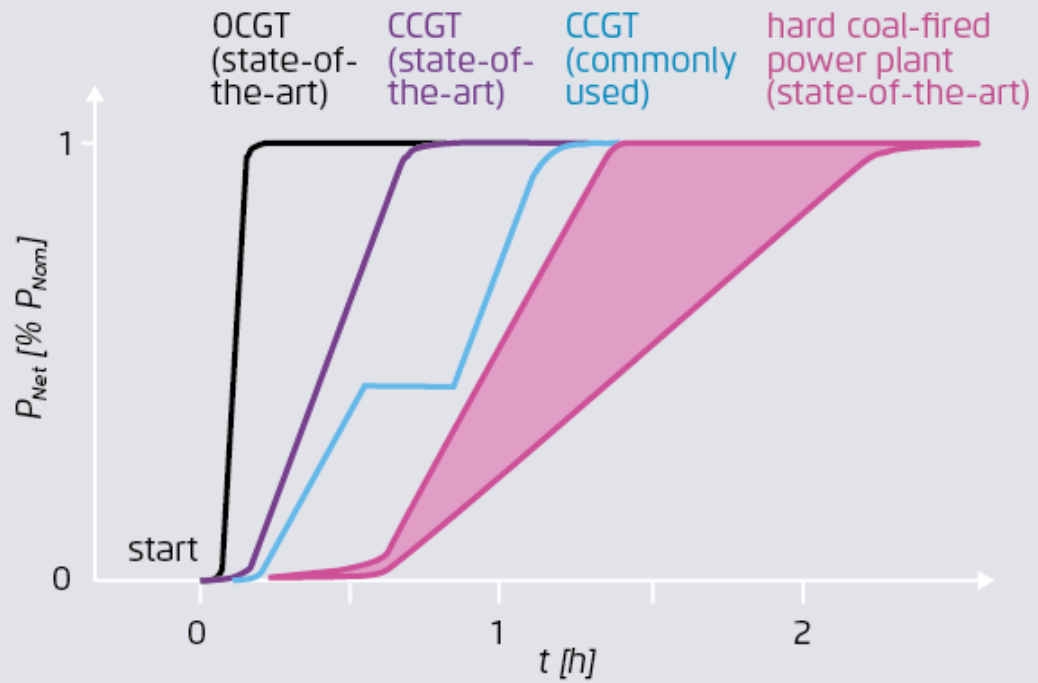
This situation results in **high level of renewable energy curtailment**, when priority is given to baseload operation of conventional generators.

Making **conventional power plants more flexible** can be a key strategy to integrate higher VRES, in markets characterized by few other flexibility options.

But keeping (flexible) coal power plant in the system can also **push out less emitting power plants** (such as gas). In the absence of CO2 pricing, emissions can stagnate, despite an increase of RES!

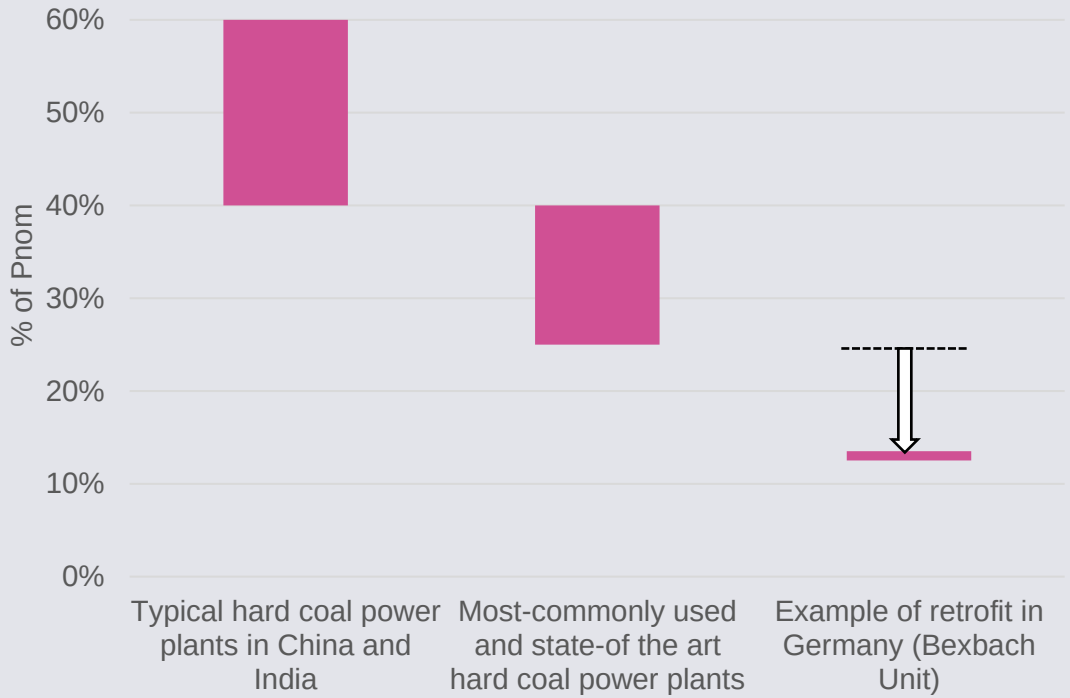
Old coal-fired power plants are inflexible but modern ones can be almost as flexible as commonly used combined-cycled gas turbines

Ramp rates and start-up of gas VS coal power plants



Fichtner (2017), based on VDE (2012)

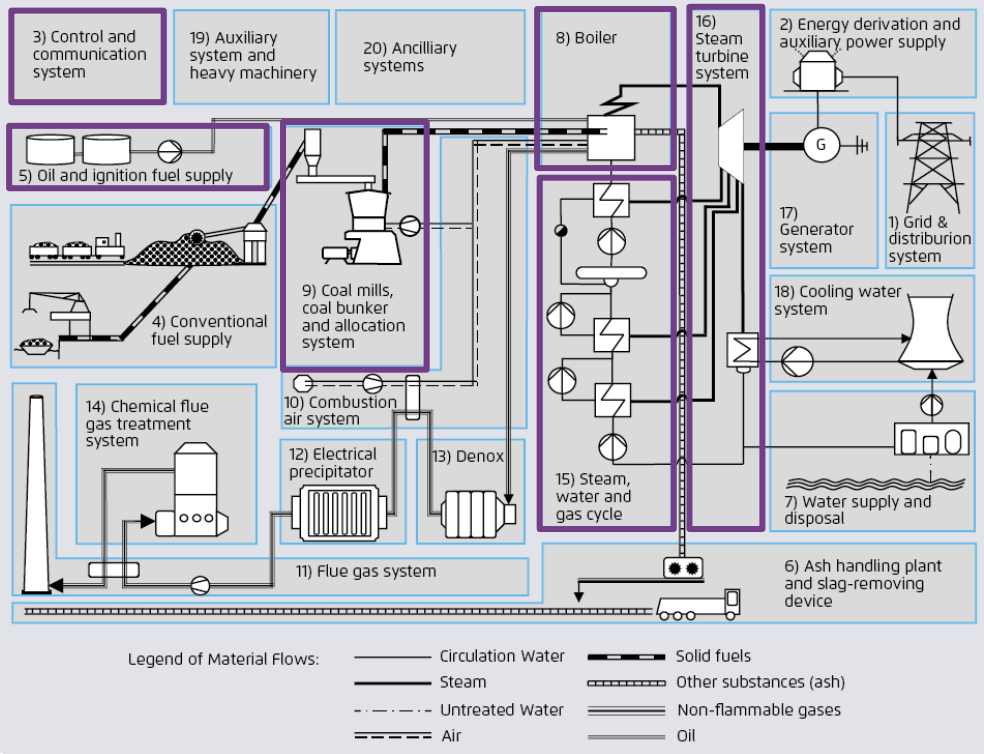
Minimum load of different hard coal power plants (as a percentage of nominal capacity)



DEA, NREL, Fichtner

Numerous technical possibilities exist to increase the flexibility of coal power plants

Illustrative subdvision of a coal power plant (purple indicates key components to improve flexibility)

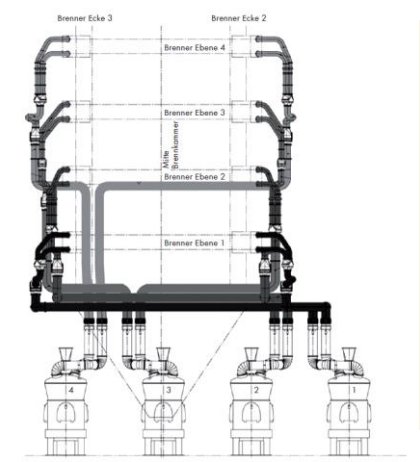


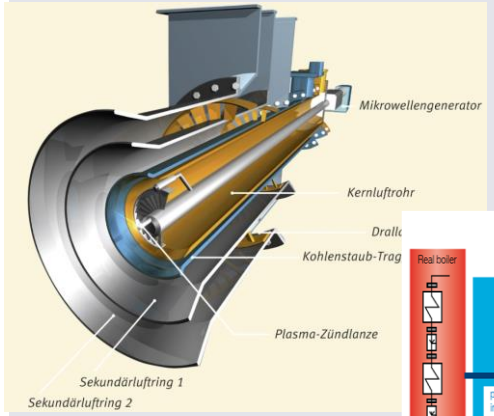
Klumpp (2009)

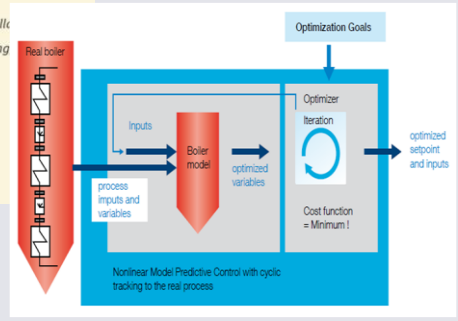
Retrofit measure for reducing:	Minimum load	Start-up time	Ramp rate	Limitations
Indirect Firing	✓		✓	Fire stability
Switching from two mill to single mill operation	✓			Water-steam circuit
Control system and plant engineering upgrade	✓		✓	Fire stability/ thermal stress
Auxiliary firing with dried lignite ignition burner	✓		✓	Fire stability and boiler design
Thermal energy storage for feed water pre-heating	✓			N/A
"Repowering"		✓	✓	N/A
Usage of optimized control system		✓		Thermal stress
Thin-walled components /special turbine design		✓		Mechanical and thermal stresses
"New" turbine start		✓		Turbine design
Reduction of wall thickness of key components			✓	Mechanical and thermal stresses

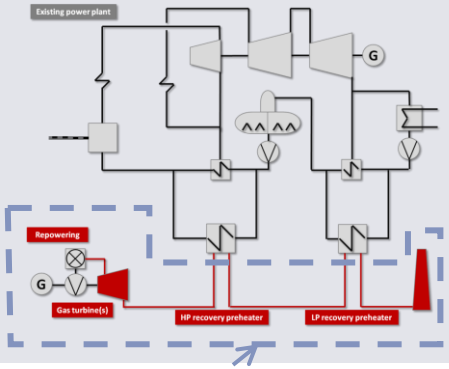
Fichtner (2017)

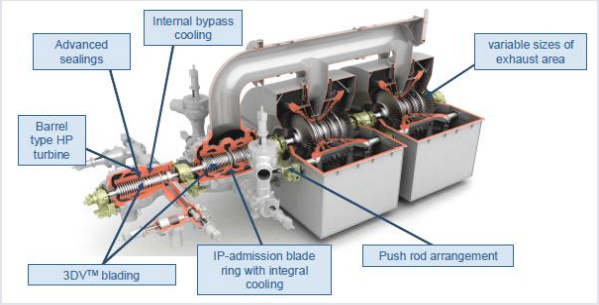
Retrofit measures to increase flexibility were employed in numerous coal-fired plants in Germany, Denmark and the US. The flexible operation of coal power plants reduces however their lifetime.











Reducing minimum load bring the most benefits. The most important enabling factors are the adoption of **alternative operation practices**, rigorous inspection, training programs.

Several retrofit measures were implemented on German power plants for enhancing their flexibility:

- Bexbach (780 MW), reached a min. load of 11% (!) by switching from two mills to single mill operation;

- Unit G and H of Wesweiler, increased ramp rates to 10 MW/min by upgrades in plant engineering

Investment costs for retrofit in flexibility is about 100 to 500 €/kW (must be evaluated case by case). Retrofit usually increase the technical lifetime of a power plant by about 10-15 years*

* For comparison, the investment in a new power plant ranges between 1.200 €/kW and more than 3.000 (with CCS), for a lifetime of more than 40 years.

In order to fully tap the technical potential for increased flexibility, it is crucial to adapt the power market conditions.

Lignite generation in Germany in December 2012 (up) and December 2017 (down)

Agora Energiewende (2018)

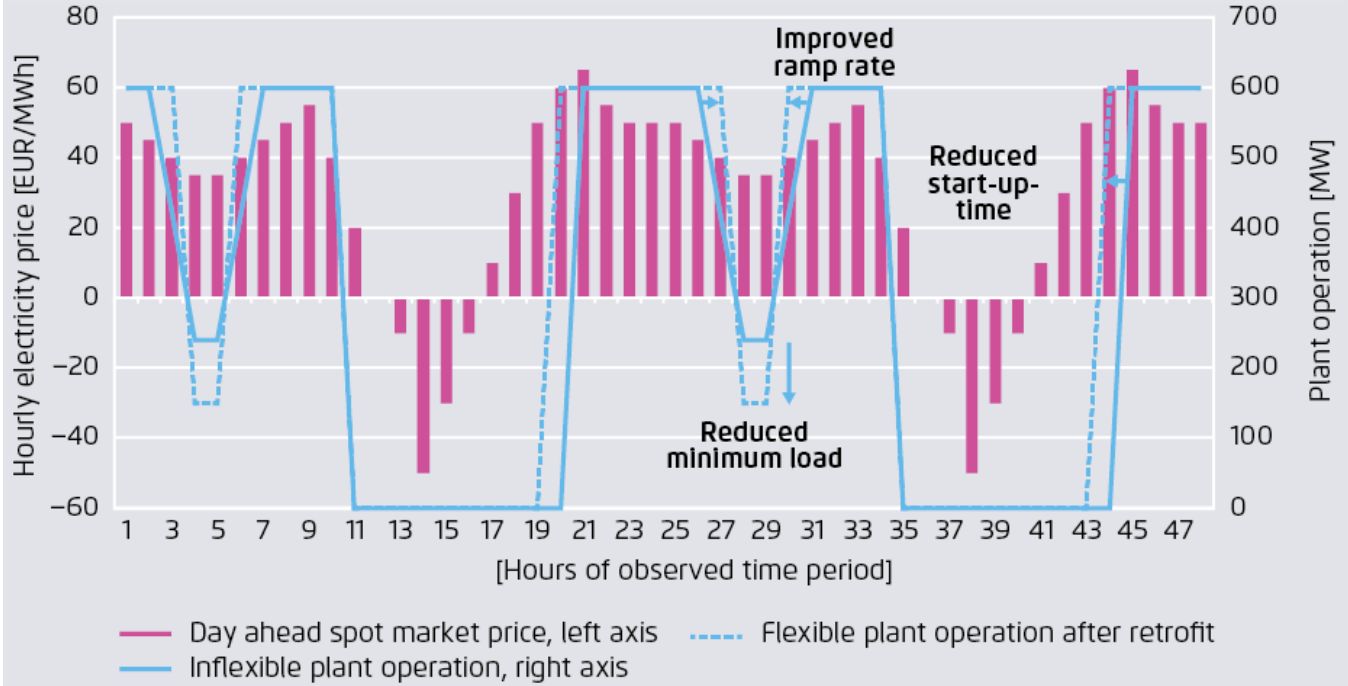
Economics of flexible coal (retrofit) is driven by the availability of **remuneration options for flexibility**. A market design which hampers flexibility provision will not incentivize coal power plants flexibility and other flexibility options. → Inflexibility check!

With high shares of RES, **electricity markets** should help to fully integrate market players that provide valuable flexibility options.

The **market design to value flexibility is key**! For example: dispatch based on marginal costs, no long-term PPA but short trading arrangement (e.g. intraday), adjustment of the balancing power arrangements…

Enhancing the flexibility parameters of coal power plants can improve significantly their economic situation within a proper market environment

Hard coal power plant operation before and after retrofitting with lower minimum load, increased ramp rates and reduced start-up time in a 48-hour example period

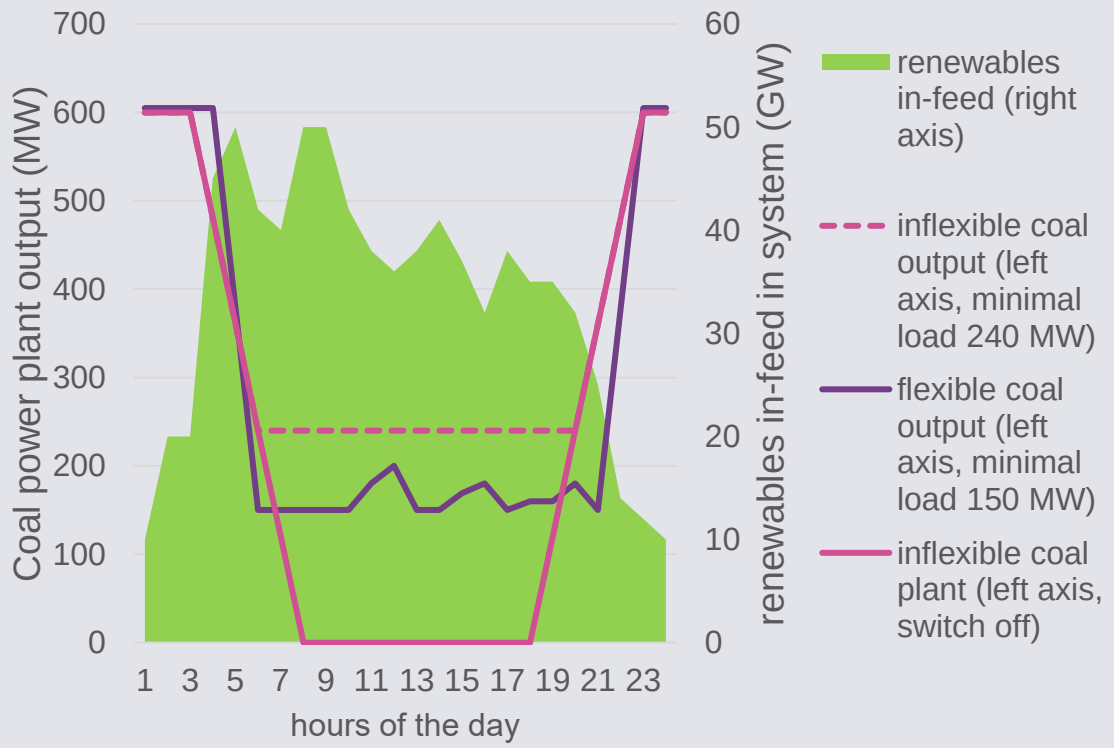


Prognos (2017)

- If markets are adequately designed, flexibility needs are **reflected in electricity prices** at the wholesale level.
- Because of high shares of RES generation, the coal power plants **face periods of low and even negative electricity prices.**
- Flexible operation **minimizes the losses** from increasing shares of VRES (and the decreased utilization of the coal power plants).
- If plants must stay in the market (e.g. to provide system services), **more flexibility has direct economic value** for the operator.
- Switching off a power plant entails start-up costs. Therefore, a **tradeoff exists** between avoiding losses from negative prices and the costs associated with start-up.

Flexible coal is not clean, but making existing coal plants more flexible enables the integration of more wind and solar power in the system, contributing to decrease CO2 emissions.

Illustrative power production of one coal power plant in a day with high share of renewables (comparison of a flexible and inflexible power plant)



Agora Energiewende (2017)

With high vRES, the flexible operation of coal power **generally reduces overall CO2 emissions** (since coal power plants produce in general less electricity over the year, avoiding wasteful curtailment of RES)

However, **complex system effects** can lead to periods of higher CO2 emissions:

-> CO2 emissions increase at low operating points

-> CO2 emissions can increase if lower minim load prevents the power plant to shut-down

-> when gas is competing against coal, those effects can be amplified (flexible coal pushes out gas)

In order to avoid those drawbacks, an **effective carbon pricing mechanism** is key for achieving a net reduction in CO2 emissions.

[1] without being compensated by the avoided CO2 emissions of start-up processes.

Overview of Key Findings

1

Existing thermal power plants can provide much more flexibility than often assumed, as experience in Germany and Denmark shows. Coal-fired power plants are in most cases less flexible compared to gas-fired generation units. But as Germany and Denmark demonstrate, aging hard coal fired power plants (and even some lignite-fired power plants) are already today providing large operational flexibility. They are adjusting their output on a 15-minute basis (intraday market) and even on a 5-minute basis (balancing market) to variation in renewable generation and demand.

2

Numerous technical possibilities exist to increase the flexibility of existing coal power plants. Improving the technical flexibility usually does not impair the efficiency of a plant, but it puts more strain on components, reducing their lifetime. Targeted retrofit measures have been implemented in practice on existing power plants, leading to higher ramp rates, lower minimum loads and shorter start-up times. Operating a plant flexibly increases operation and maintenance costs — however, these increases are small compared to the fuel savings associated with higher shares of renewable generation in the system.

3

Flexible coal is not clean, but making existing coal plants more flexible enables the integration of more wind and solar power in the system. However, when gas is competing with coal, carbon pricing remains necessary to achieve a net reduction in CO2. In some power systems, especially when gas is competing against coal, the flexible operation of coal power plants can lead to increased CO2 emissions. In those systems, an effective climate policy (e.g. carbon pricing) remains a key precondition for achieving a net reduction in CO2 emissions.

4

In order to fully tap the flexibility potential of coal and gas power plants, it is crucial to adapt power markets. Proper price signals give incentives for the flexible operation of thermal power plants. Thus, the introduction of short-term electricity markets and the adjustment of balancing power arrangements are important measures for remunerating flexibility.

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