

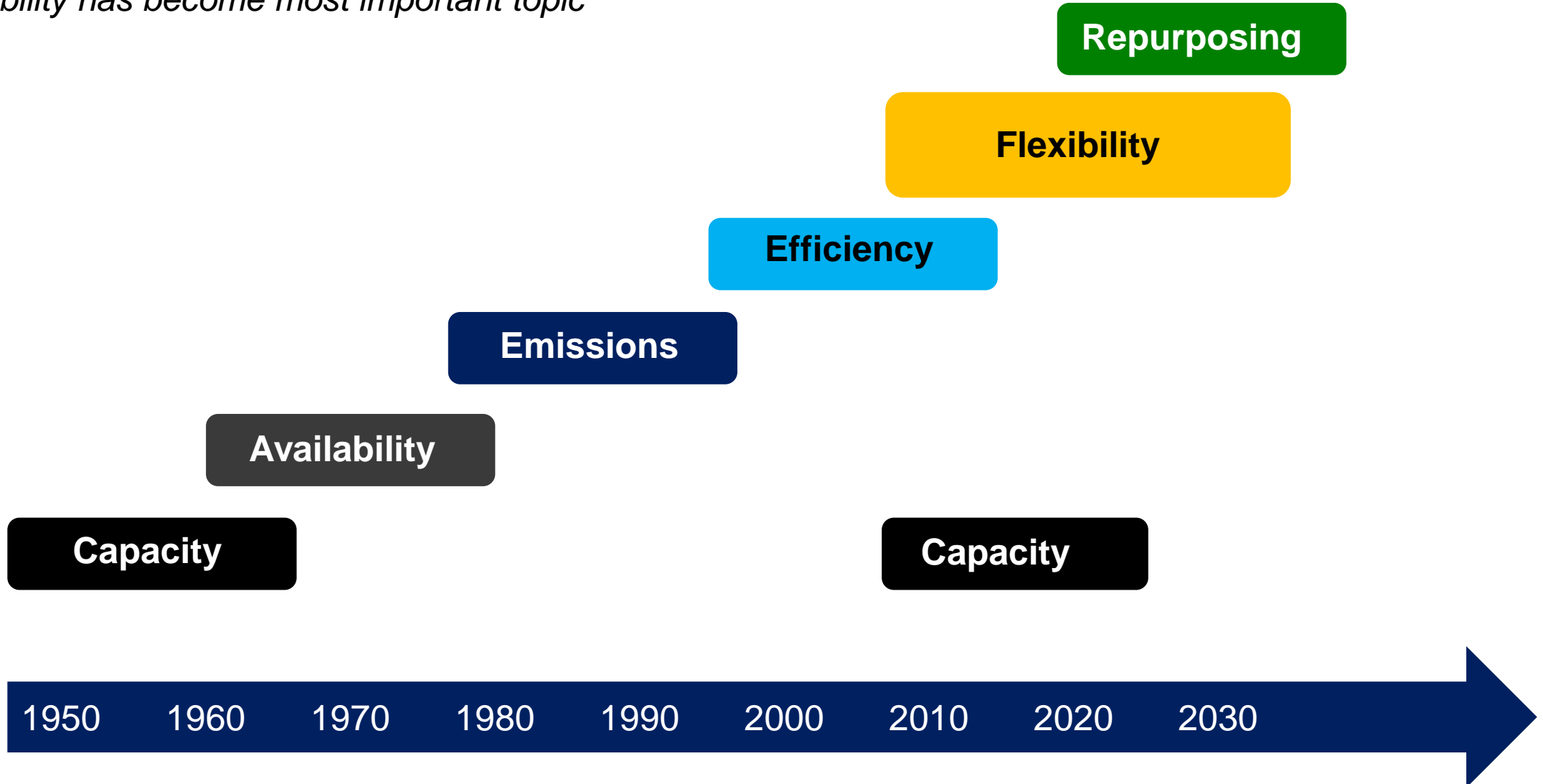


Important role of existing TPS for the energy transition

22nd of November 2022, Kolkata

History of TPS Discussions in Europe

Flexibility has become most important topic



Power (not capacity) from Renewables in Germany in 2022

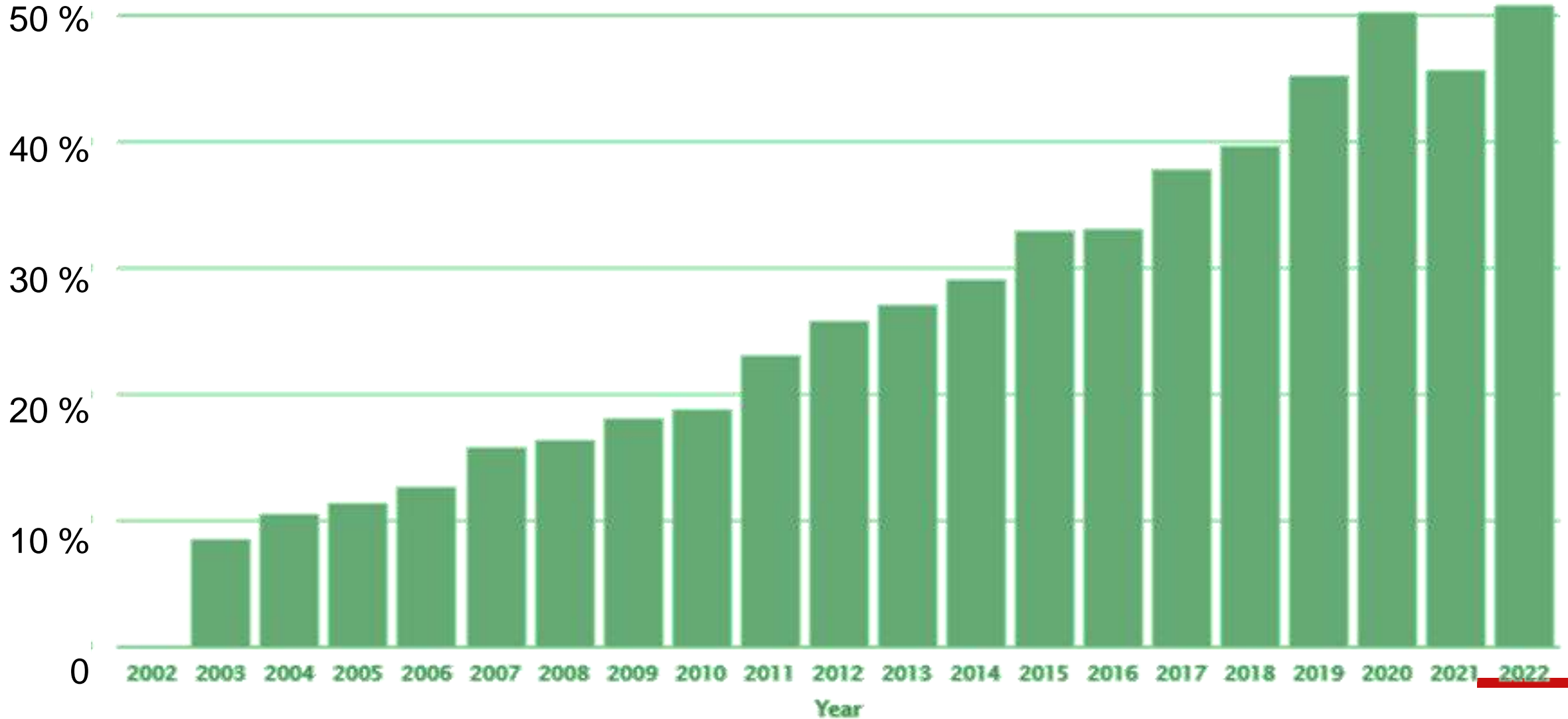
Avg. annual power cut time per client is around 13 min.

51% RE

Annual RE Share in % of Power Demand in Germany

In 2018 already 2 days with 100% RE share for hours

2022: 51 %



Source: https://www.energy-charts.info/charts/renewable_share/chart.htm?l=en&c=DE&interval=year

Wind and Solar Penetration Levels in India in 2018

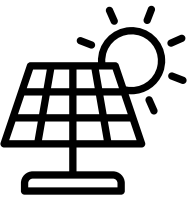
Some states show penetration levels similar to Germany!

State	Wind and Solar Penetration (2018-19)	Maximum Daily Energy Penetration of Wind and Solar	Maximum Instantaneous Penetration of Wind and Solar
Karnataka	23%	56%	90%
Tamil Nadu	13%	38%	48%
Andhra Pradesh	21%	51%	71%
Gujarat	11.6 %	33.2 %	39.5 %
Maharashtra	5.7 %	18%	23%
Madhya Pradesh	8.7 %	30%	42%
Rajasthan	14.2 %	34%	50%
Western Region	8.3 %	20%	24.2 %
Southern Region	15%	30%	47%
All India	8%	15.1 %	19.4 %

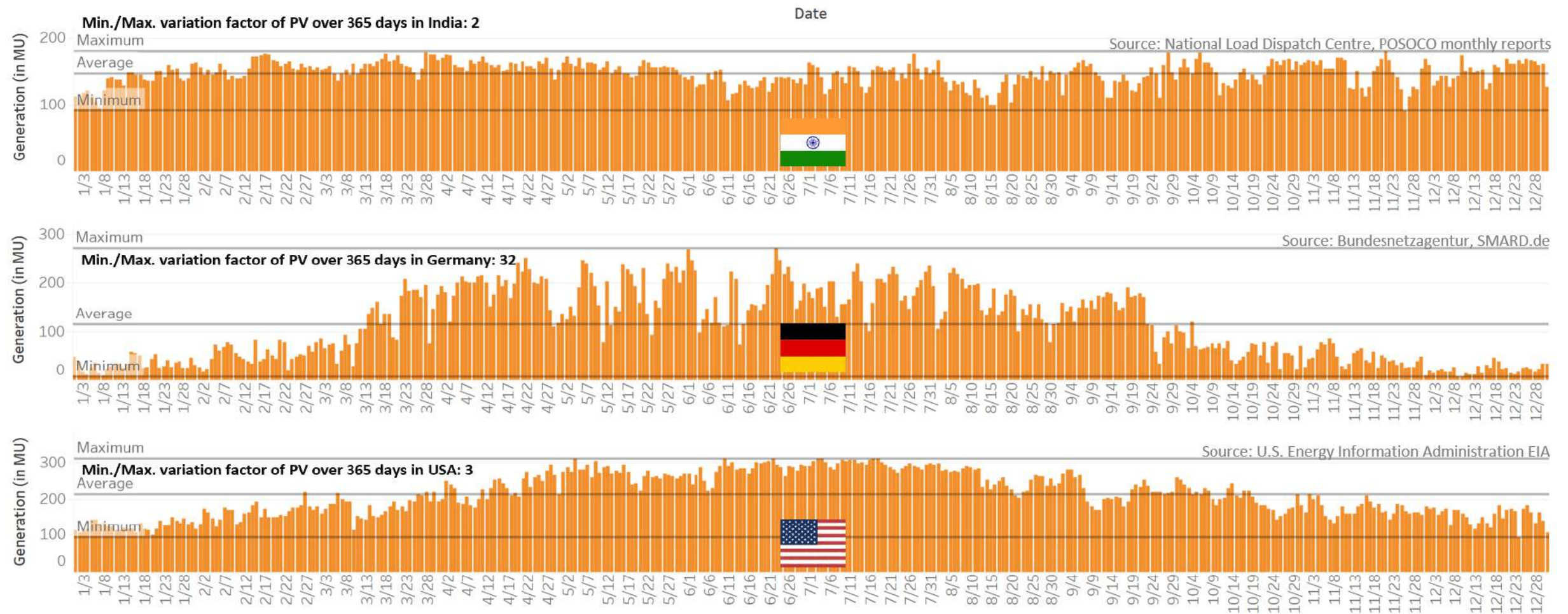
Source: POSOCO 11/2019

...in some states some days already exceed 50 % RE power

India has high solar energy security

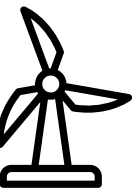


365 days of PV generation in India, Germany and USA in 2020

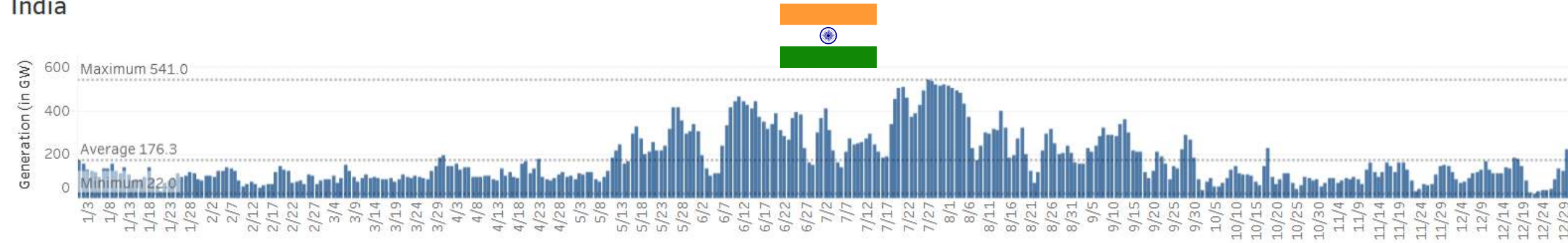


Good wind conditions with wind blowing often at night

365 days of generation from wind in India, Germany

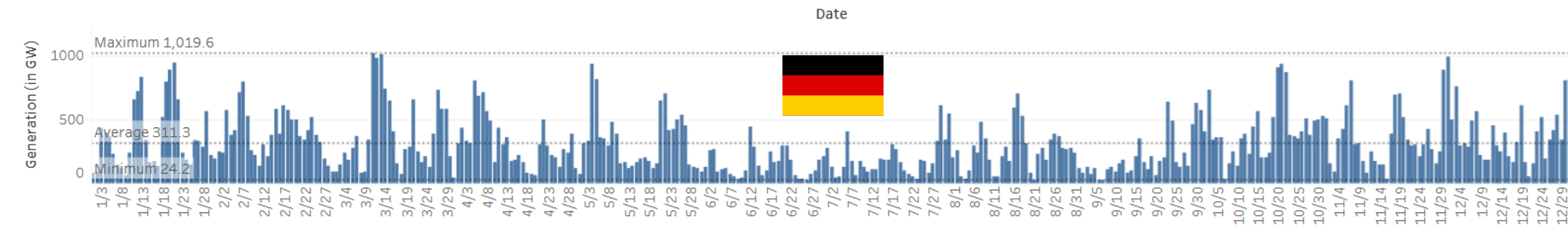


India



Source: National Load Despatch Centre, POSOCO monthly reports

Germany

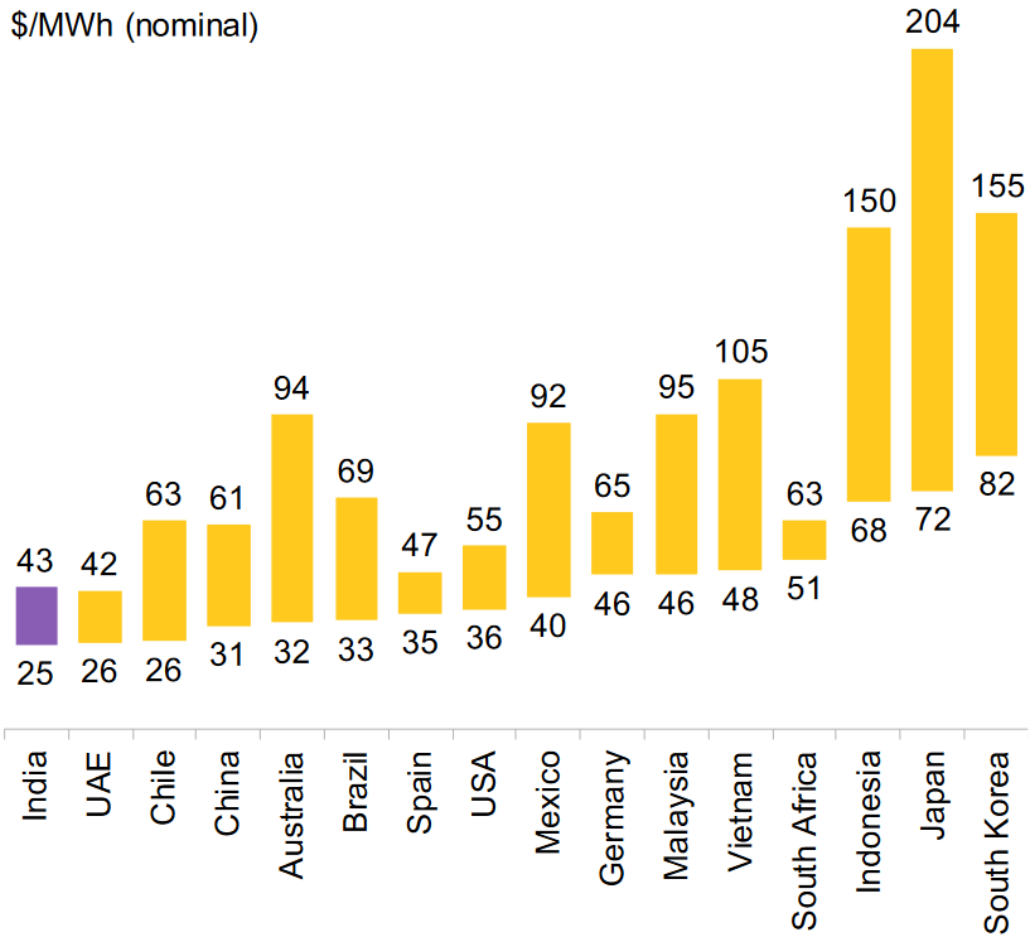


Source: Bundesnetzagentur, SMARD.de

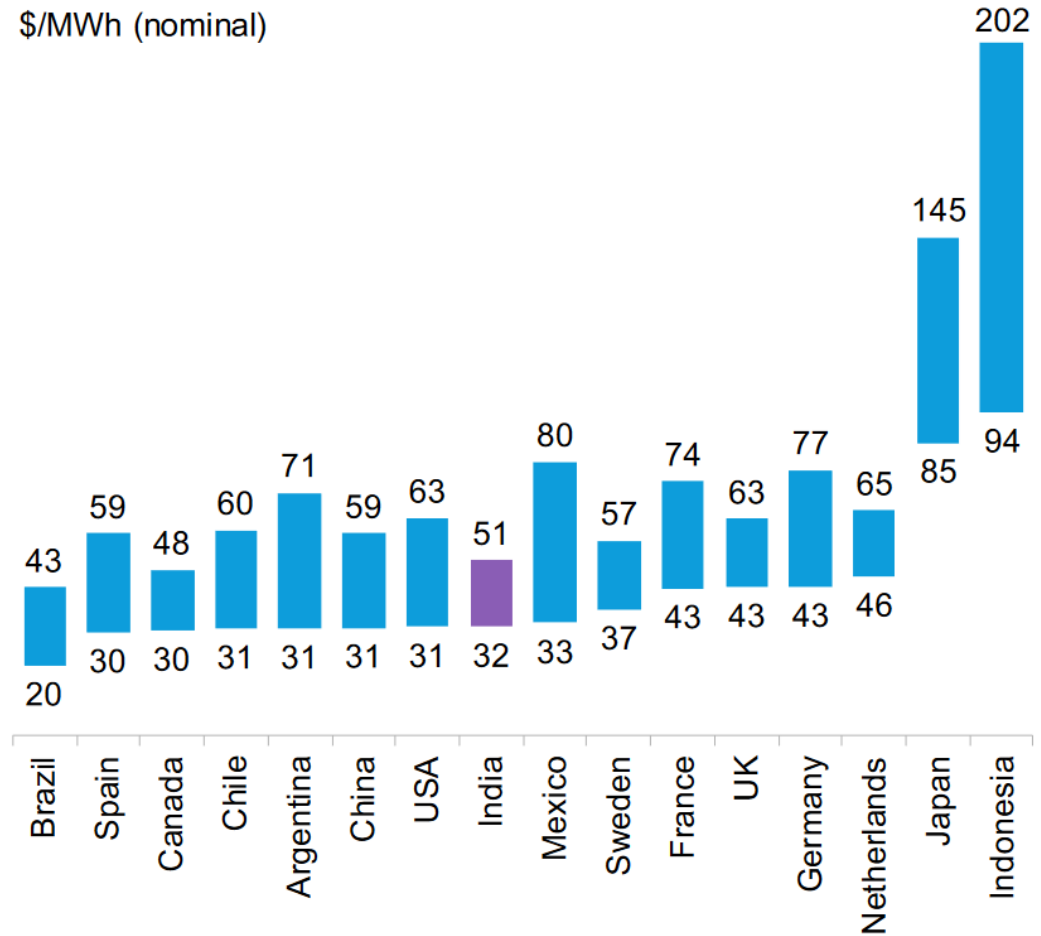
India generates wind and solar power cheaper than many others

LCOE for fixed-axis PV and onshore wind in India, 2021

\$/MWh (nominal)



\$/MWh (nominal)



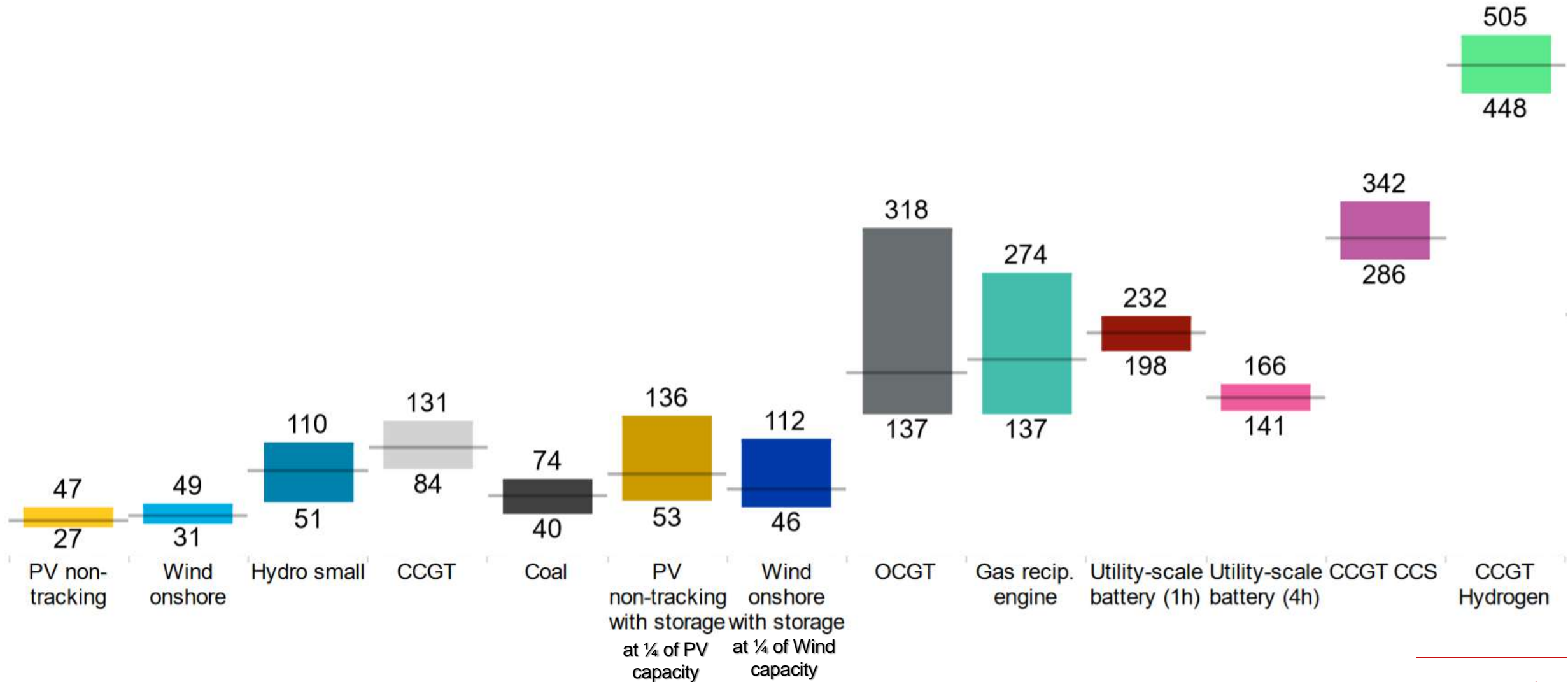
Source: BloombergNEF. Note: The range of the LCOE represents a range of costs and capacity factors. All LCOE calculations are unsubsidized and exclude curtailments and tax-credits.

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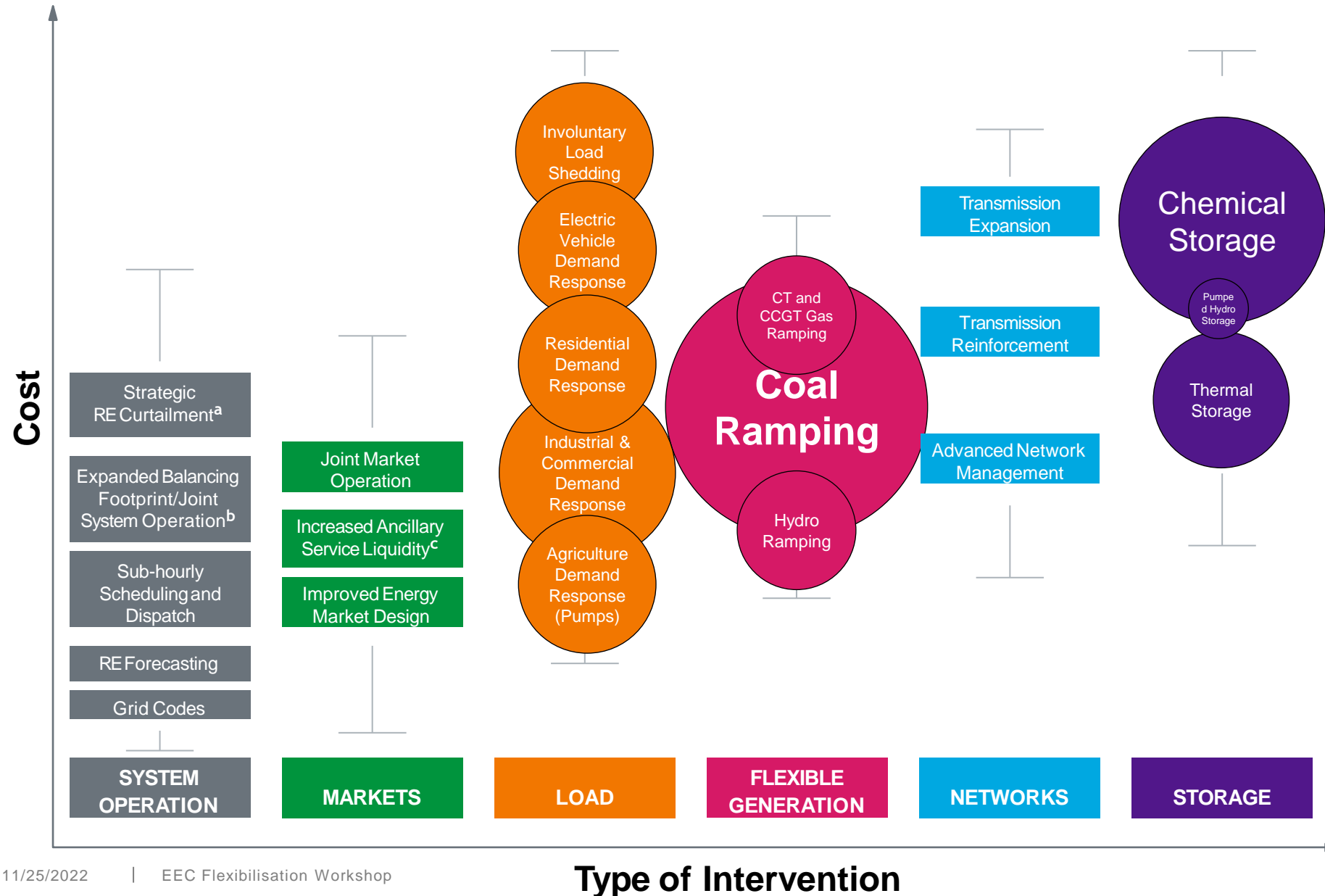
Source: [Power Foundation, BNEF 2022](#)

LCOE range (USD/MWh, nominal) in India, 1st Half 2022

Current LCOE of coal is based on calculations with PLF above 50 %



Coal is largest RE-Integration Option available at reasonable price



Source: <https://www.nrel.gov/docs/fy14osti/61721.pdf>, 2014, S.K. Soonee and others

Flexibility is Value

...as e.g. practiced with RRAS and FRAS.

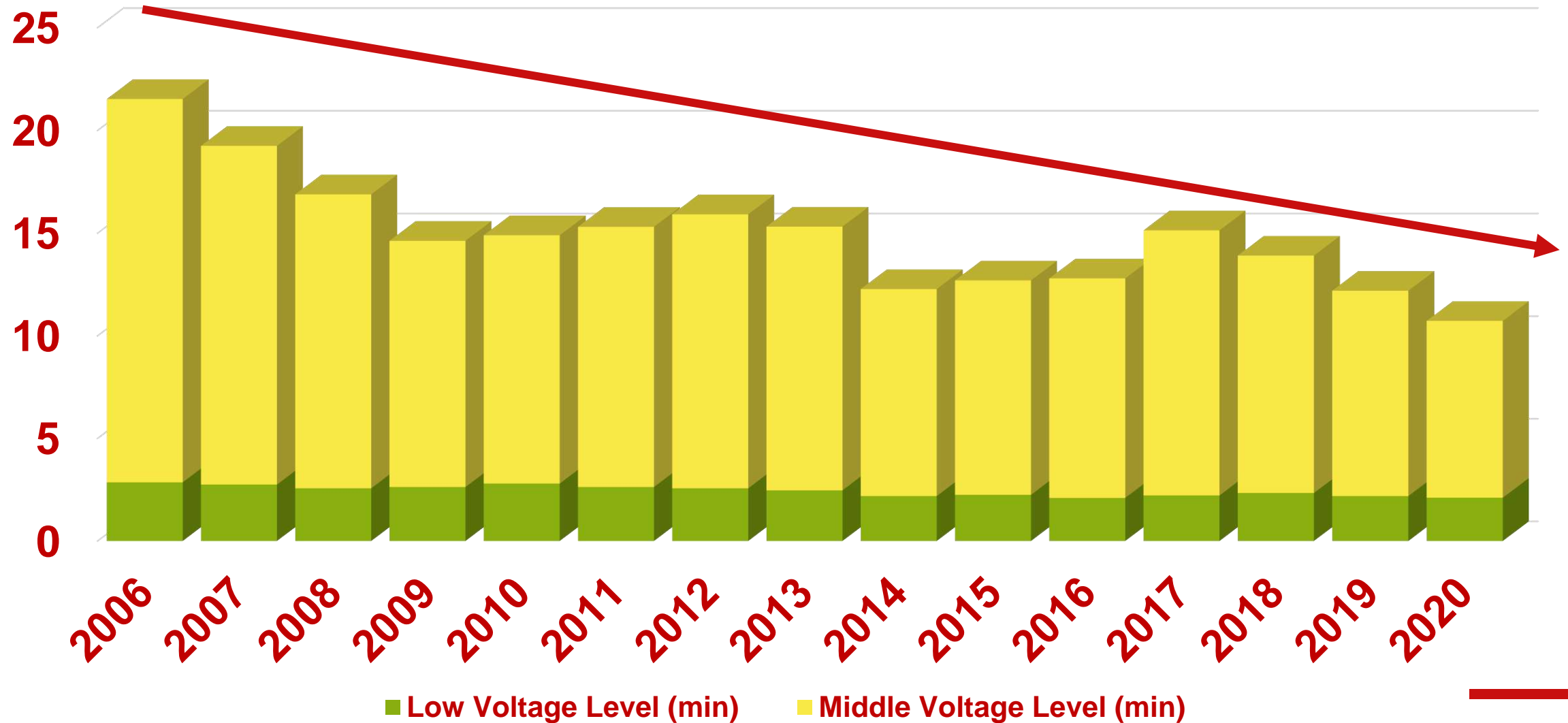
- 1. Value Flexibility and give it a Premium**
- 2. Flexibilise Thermal Units**
- 3. Establish Pumped Storage**
- 4. Establish Battery Storage**

धन्यवाद

Annual powercut duration per connection in Germany during the entire year 2020

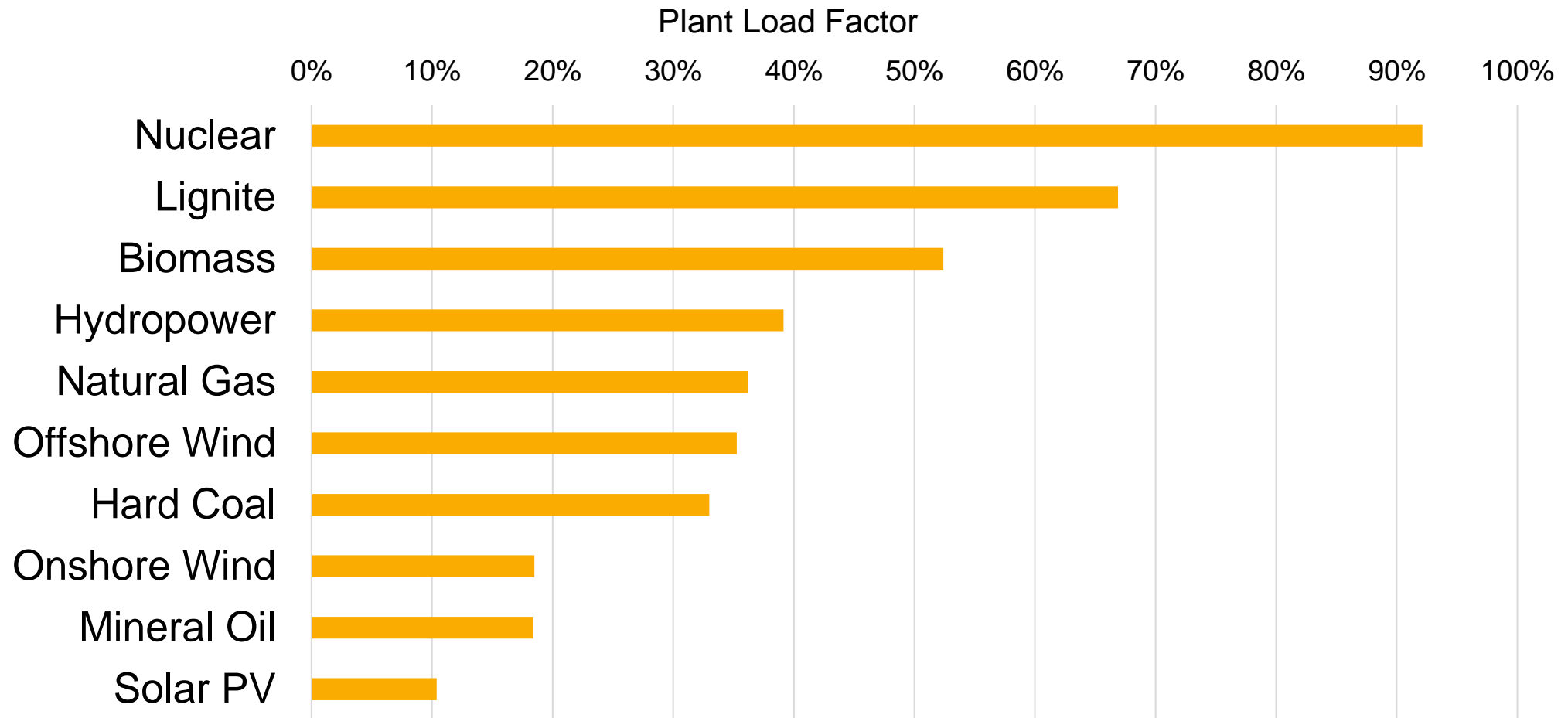
11 min.

Annual powercut duration per connection (in min.) in Germany coming further down



Plant Load Factors for Generation Plants in the Market

In Germany, 2021



Source: BDEW, own graph

Power Outages and Share of Renewables in Energy Generation in Germany



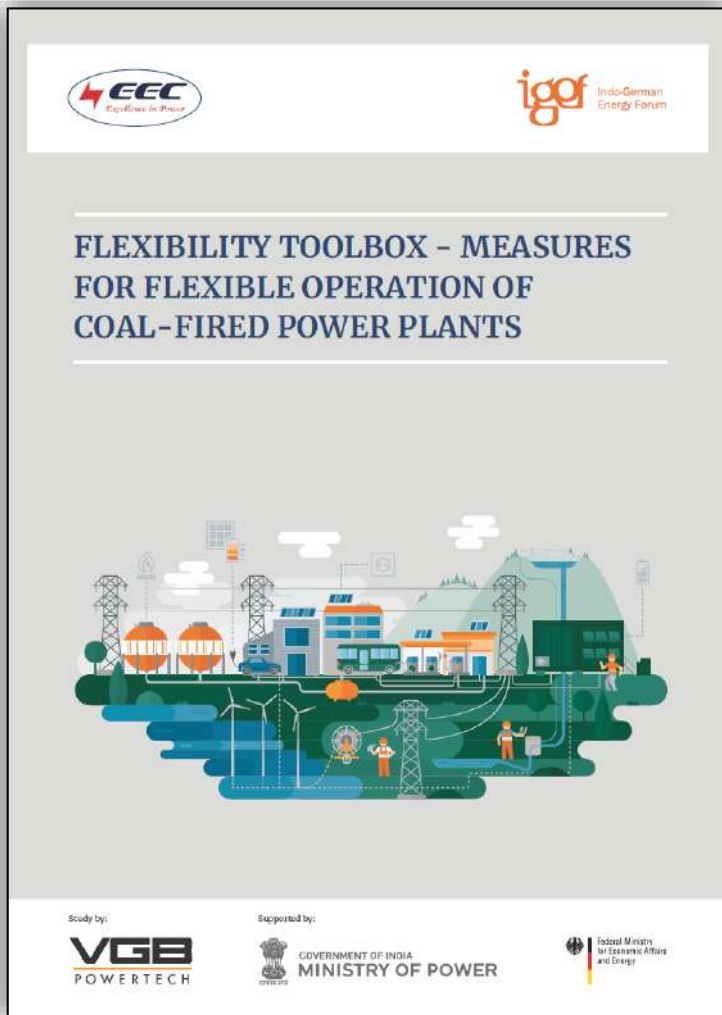
■ Share of Renewables in Energy Generation in %

—●— Power Outages in Minutes

Source: IKZ.de, Bundesverband Erneuerbare Energie e.V., Bundesnetzagentur

Key message: Low minimum load most important flexibility dimension

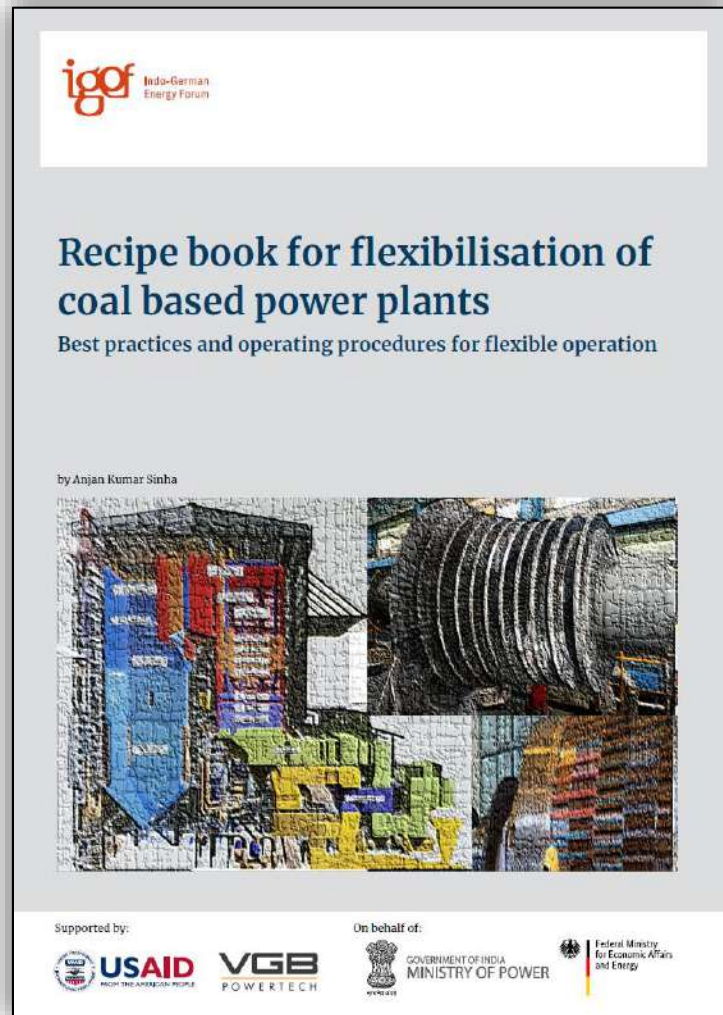
10 steps to achieve flexibility, start with low cost retrofit measures which have highest effect



On behalf of MoP by Task Force Flexibility (NTPC, BHEL, POSOCO, IGEF+VGB+EEC) Lead author: Dr. Claudia Weise, VGB PowerTech e.V.

Plant type in Europe	Hard Coal	Lignite	CCGT
	Conservative / state of the art / very advanced		
Ramp rate [% / min]	2 / 4 / 9	2 / 4 / 8	4 / 8 / 12
in the load range [%]	40 to 90	50 to 90	40* to 90
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36% stable minimum load of coal achieved in India – national record!



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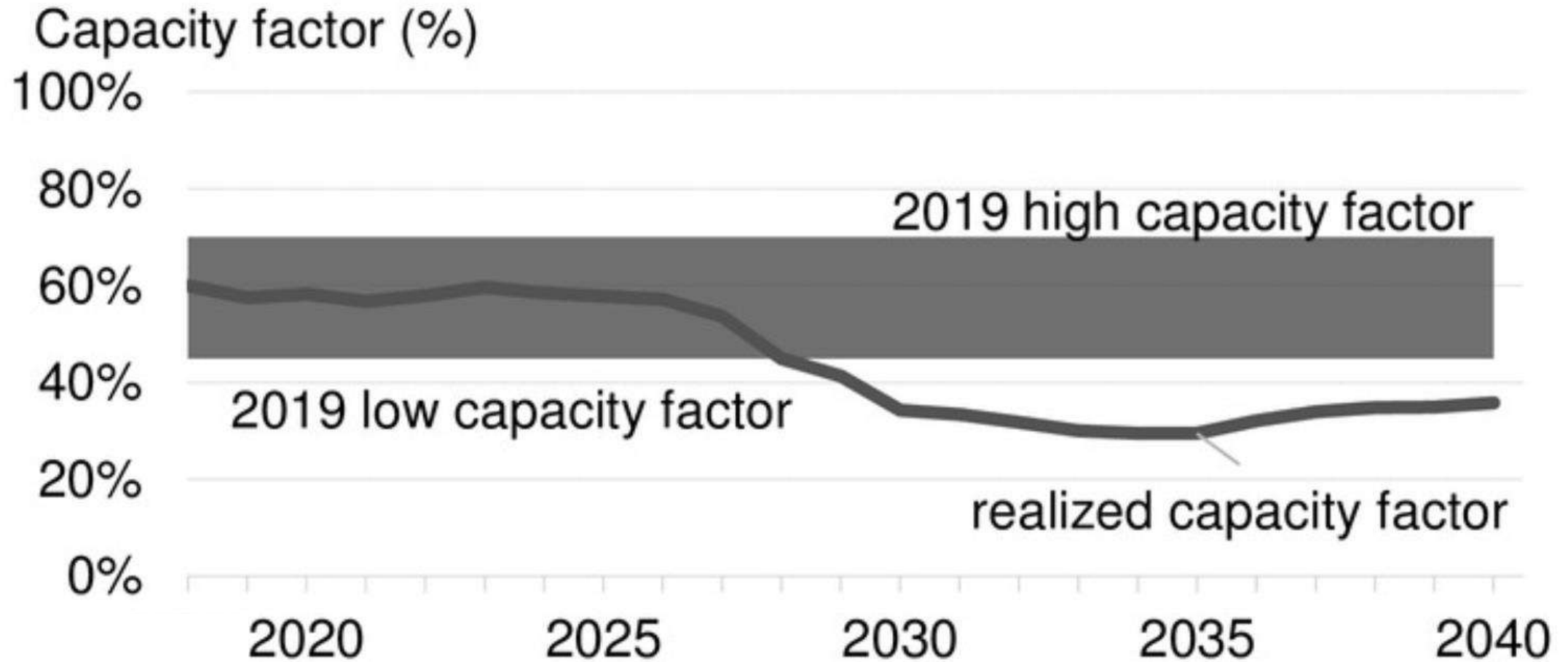
Findings from pilot studies and test runs conducted at various coal-based units in India over the last five (5) years.

Test runs conducted in India by IGEF Task Force Flexibility on request of Shri Dewanganji. **40% stable minimum load achieved and can be sustained with minimum retrofits** like improved C&I systems, boiler condition monitoring, combustion optimizer, coal analysers etc.

List of **potential damages** which may occur to the power plant **if the power plant operator is not properly trained** in minimum load running and ramping of coal fired plants.

Update: **New national record at JV DVC+TATA Maithon of 36% Minimum Load** achieved by Task Force Flexibility.

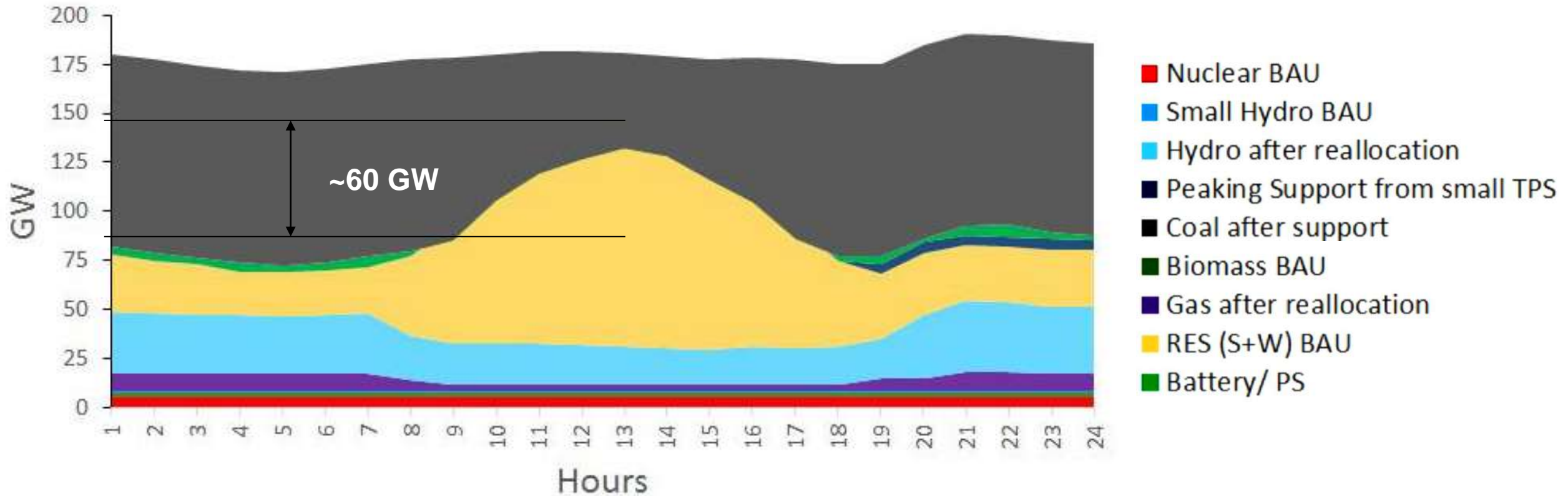
Range of Coal Capacity Factors - Germany



Source: BloombergNEF

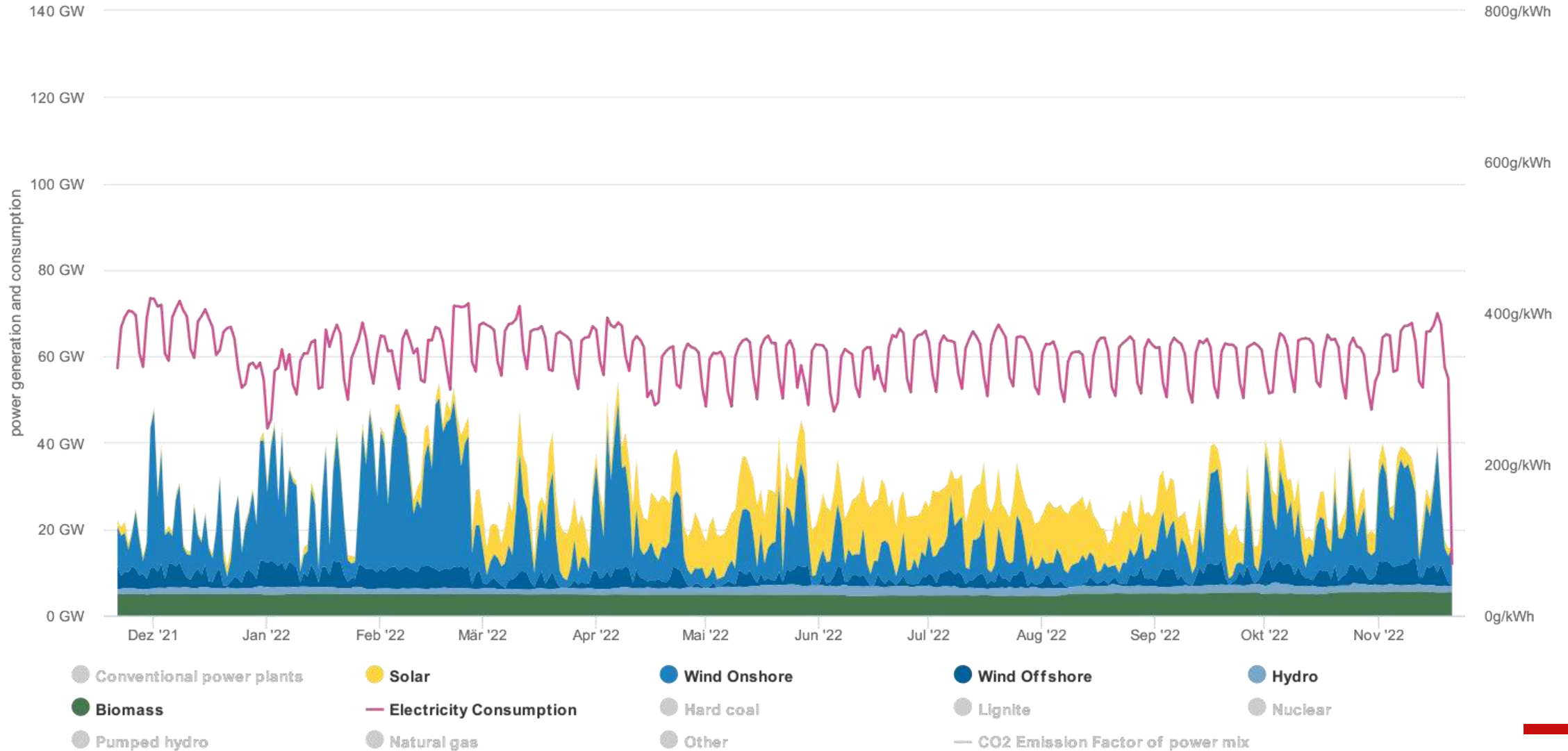
Key message: 175 GW RE require min. 50 GW Coal Ramping

A day in July w/o curtailment requires around 60 GW of Coal Ramping and Flexibility Support from Hydro + Pumped Hydro + Battery + Gas + Small TPS. COVID Light Switch-Off Event was 31 GW total & 1,25 GW/min.



Renewable Energy Generation and Total Electricity Consumption

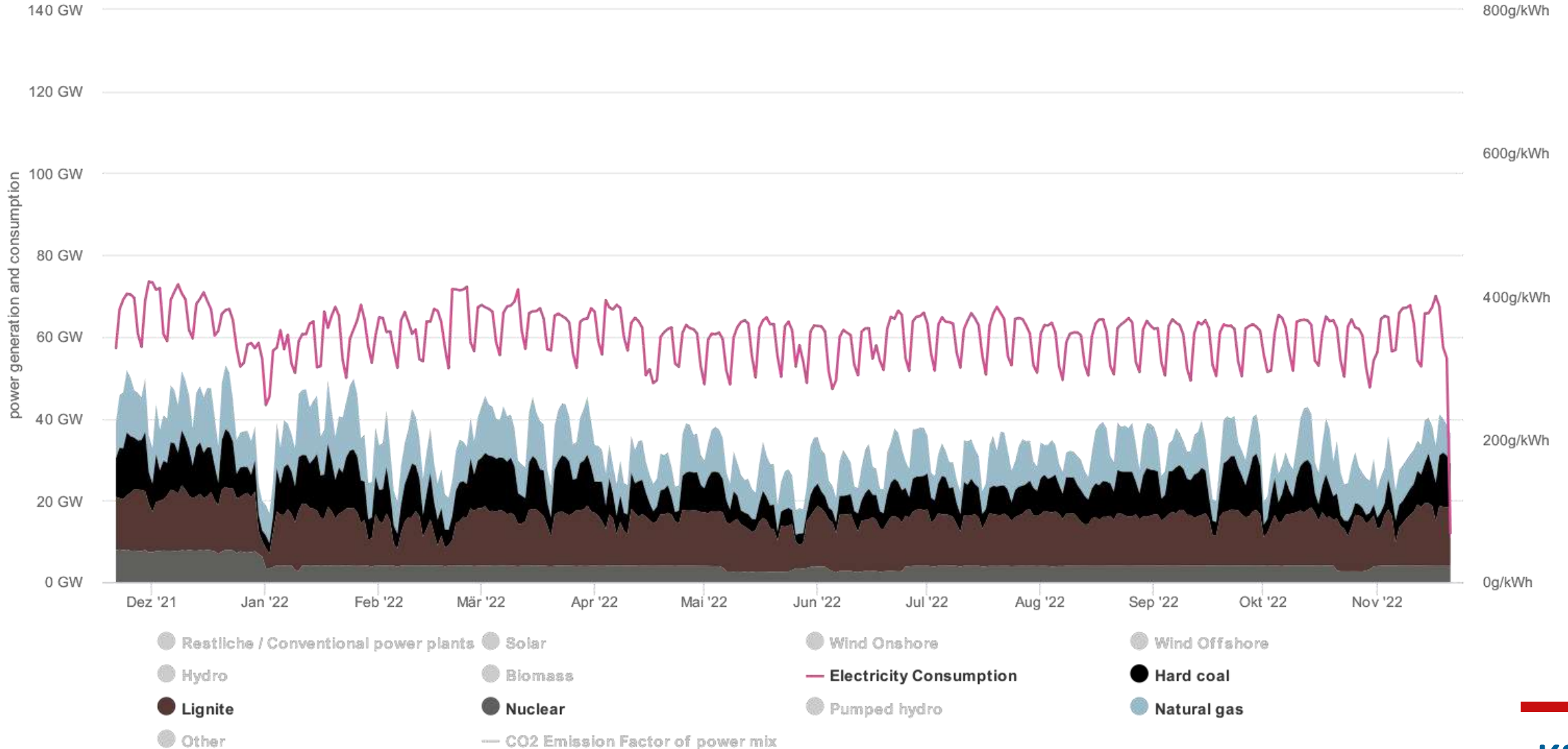
In Germany 21/11/2021-21/11/2022



Source: Agora Energiewende, 21.11.2022

Power Generation from Conventional Sources

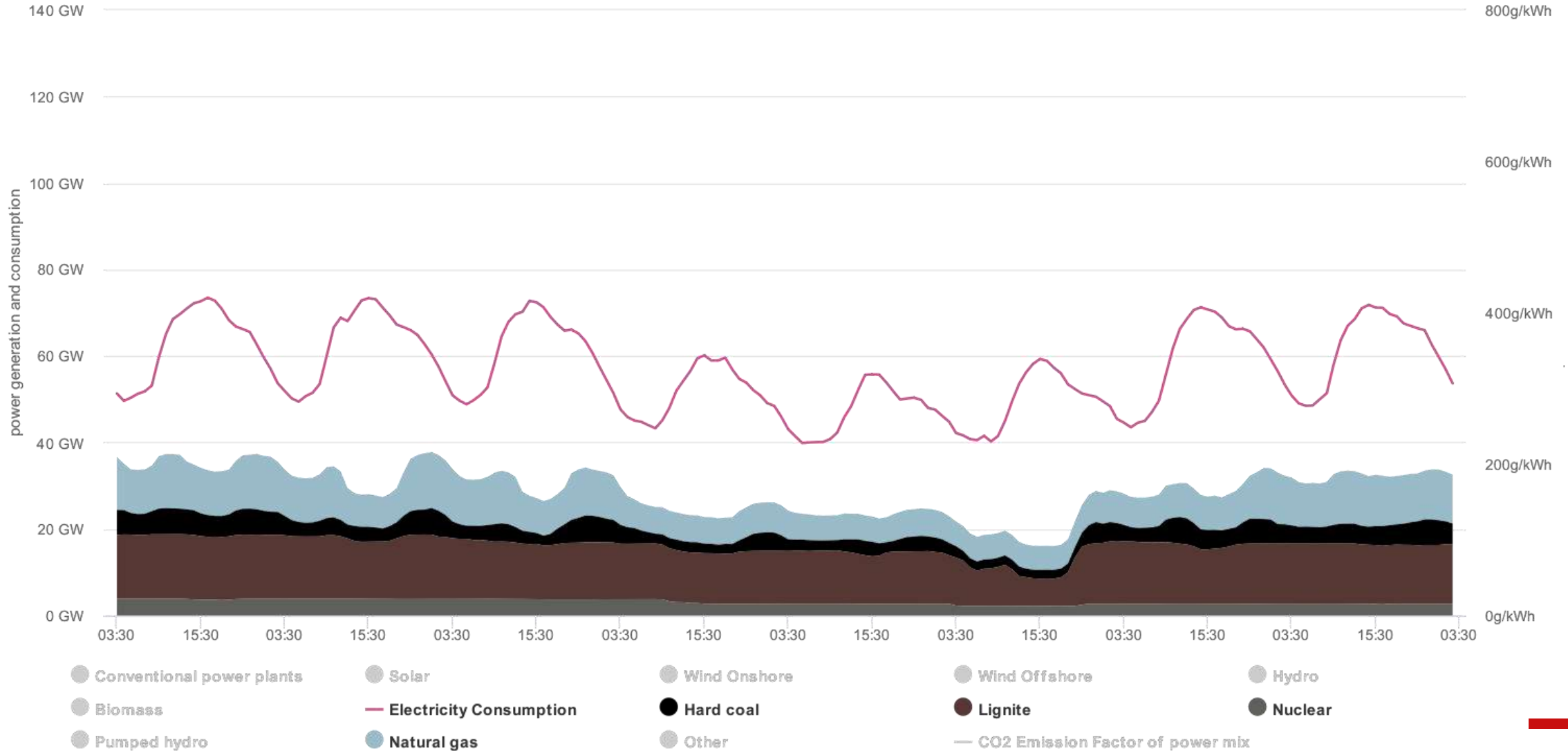
In Germany 21/11/2021-21/11/2022



Source: Agora Energiewende, 21.11.2022

Even remaining Nuclear is being ramped up and down – See: June 22

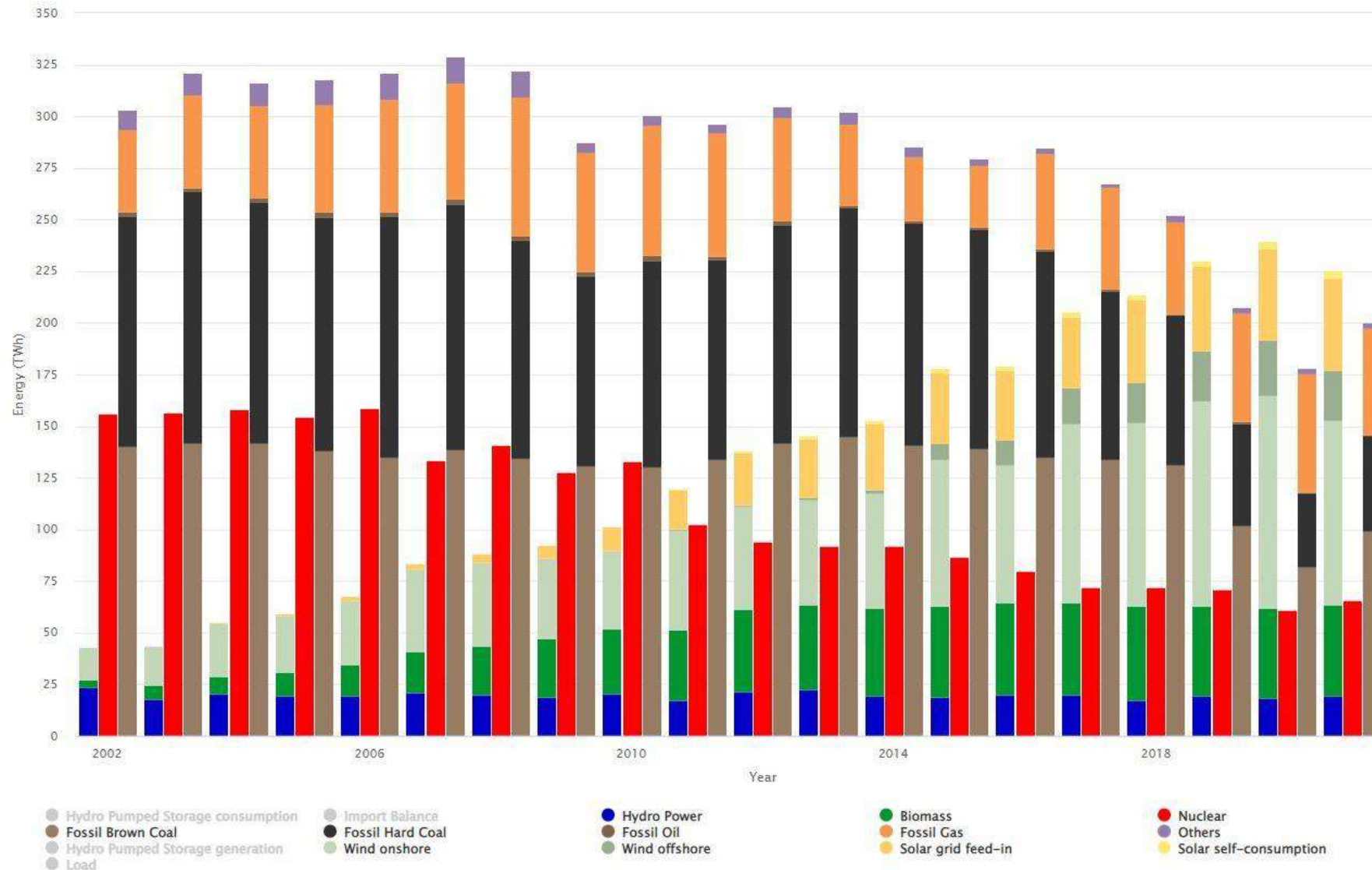
In Germany 01/06/2021-08/06/2022



Source: Agora Energiewende, 21.11.2022

Growing Share of Renewables in Germany in the last 20 years

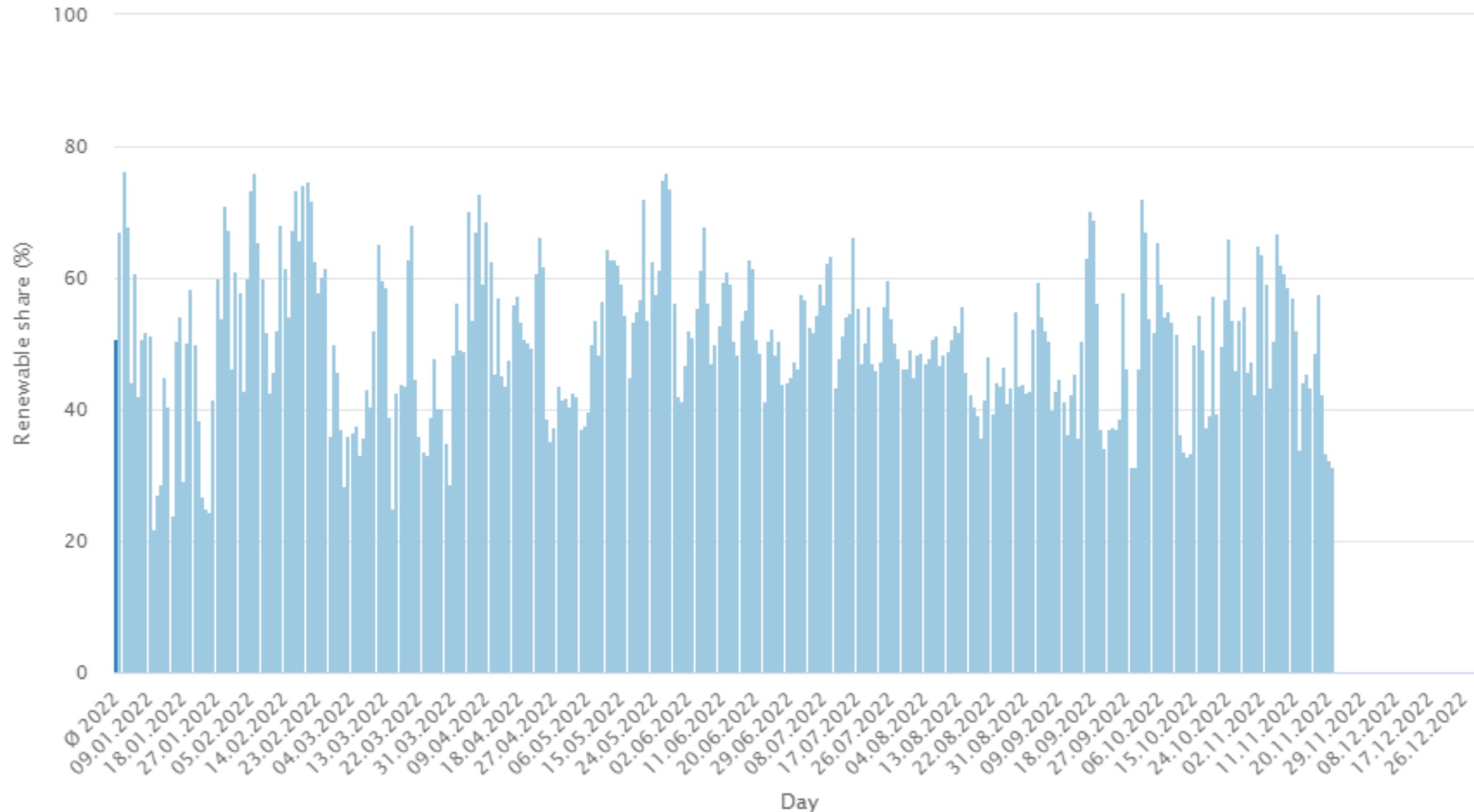
Annual Net Electricity Generation



Source: Fraunhofer ISE, energy-charts.info

Daily renewable share of public electricity generation in Germany

Energetically corrected values

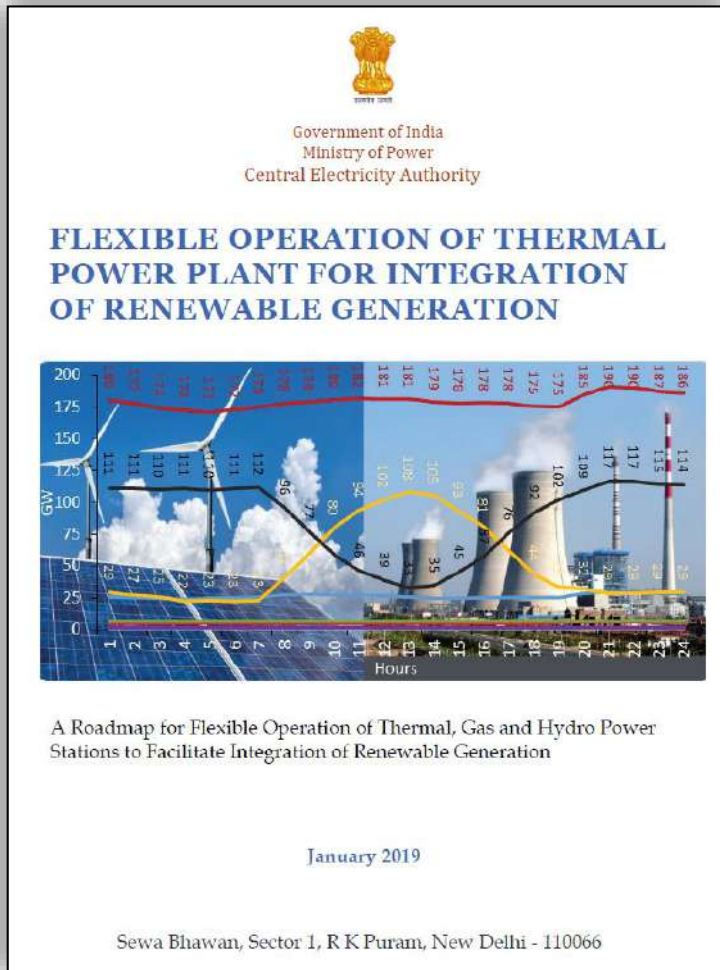


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धन्यवाद

Key message: 175 GW RE require min. 80 GW Flexibility in the System

...to avoid curtailment of RE



By committee (CEA, POSOCO, NTPC) under Ministry of Power, 2019
Lead author: B.C. Mallick, Chief Engineer (TPRM), CEA

- 108 GW peak generation from 175 GW RE assumed in July
- **Daily RE load swings of up to 86 GW**
- Balancing ramp rates of ~300 MW/min. at 9 am and 4 pm

If also considering other generation running in flexible mode as support:

- hydro (+/- 10 GW in July), gas (+/- 5 GW) & pump + battery (+/- 13 GW)
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➔ **at least 50 GW coal ramping required**

➔ **with all coal down to ~57% minimum thermal load (MTL)**

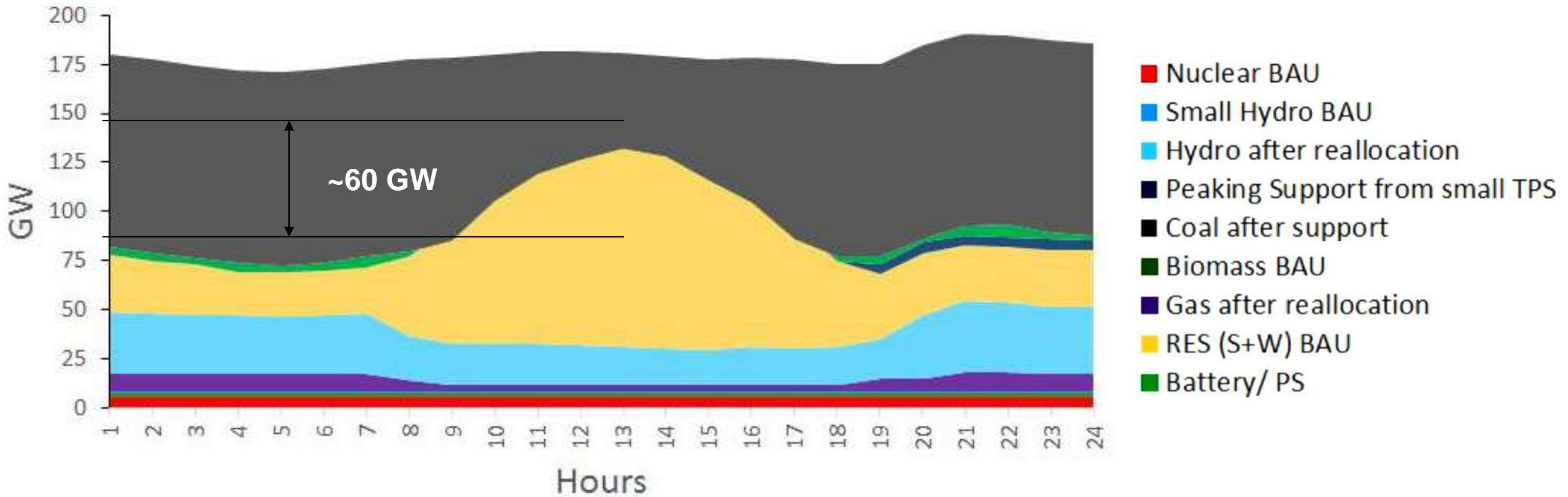
➔ **without flexible support of hydro etc. MTL ~45% for coal**

➔ **without 1% curtailment MTL of ~38% for coal estimated**

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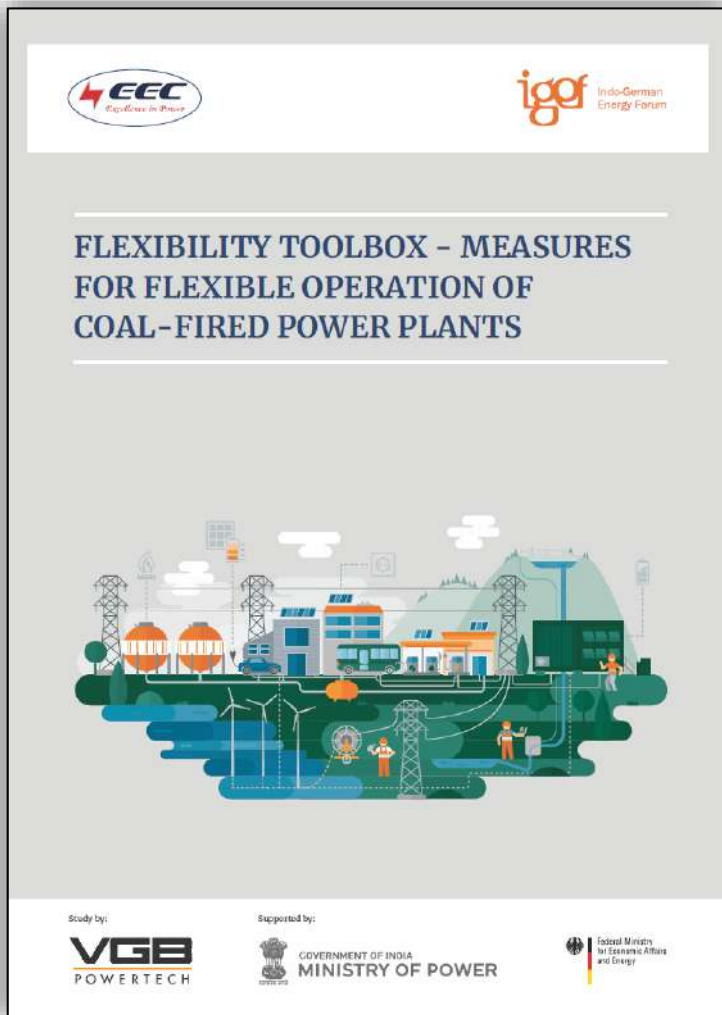
Main recommendations given by CEA: Value Flexibility and give it a Price

...as e.g. practiced with RRAS and FRAS.

1. Value Flexibility and give it a Price
2. Incentivise Demand Shift / Demand Side Management
3. Flexibilise Thermal Units
4. Establish Pumped Storage
5. Establish Battery Storage

Key message: Low minimum load most important flexibility dimension

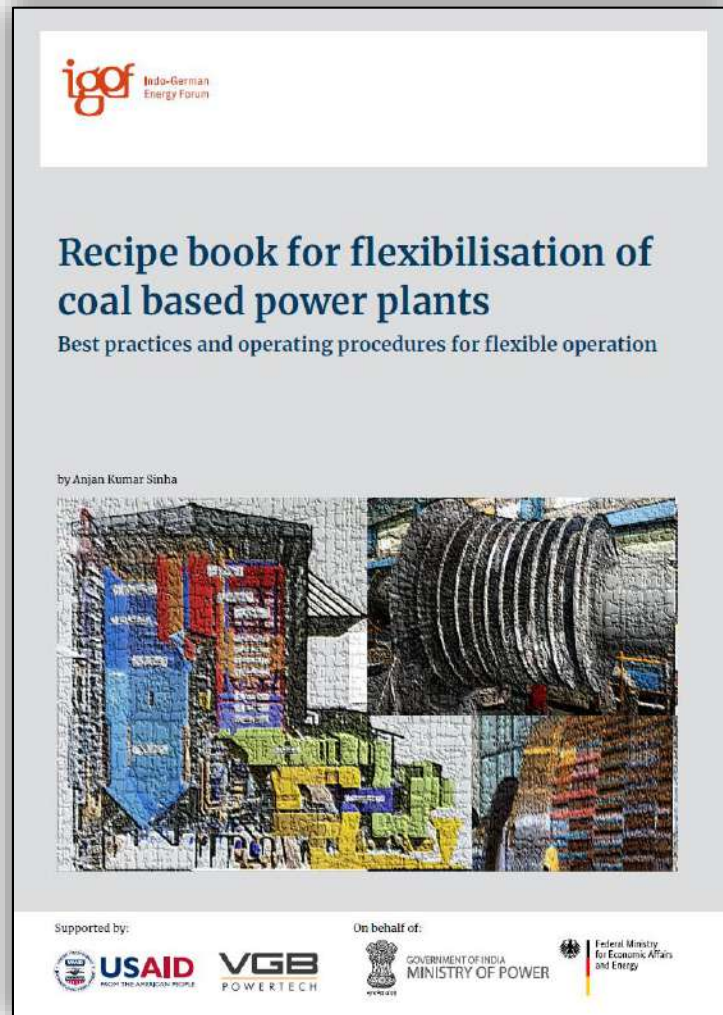
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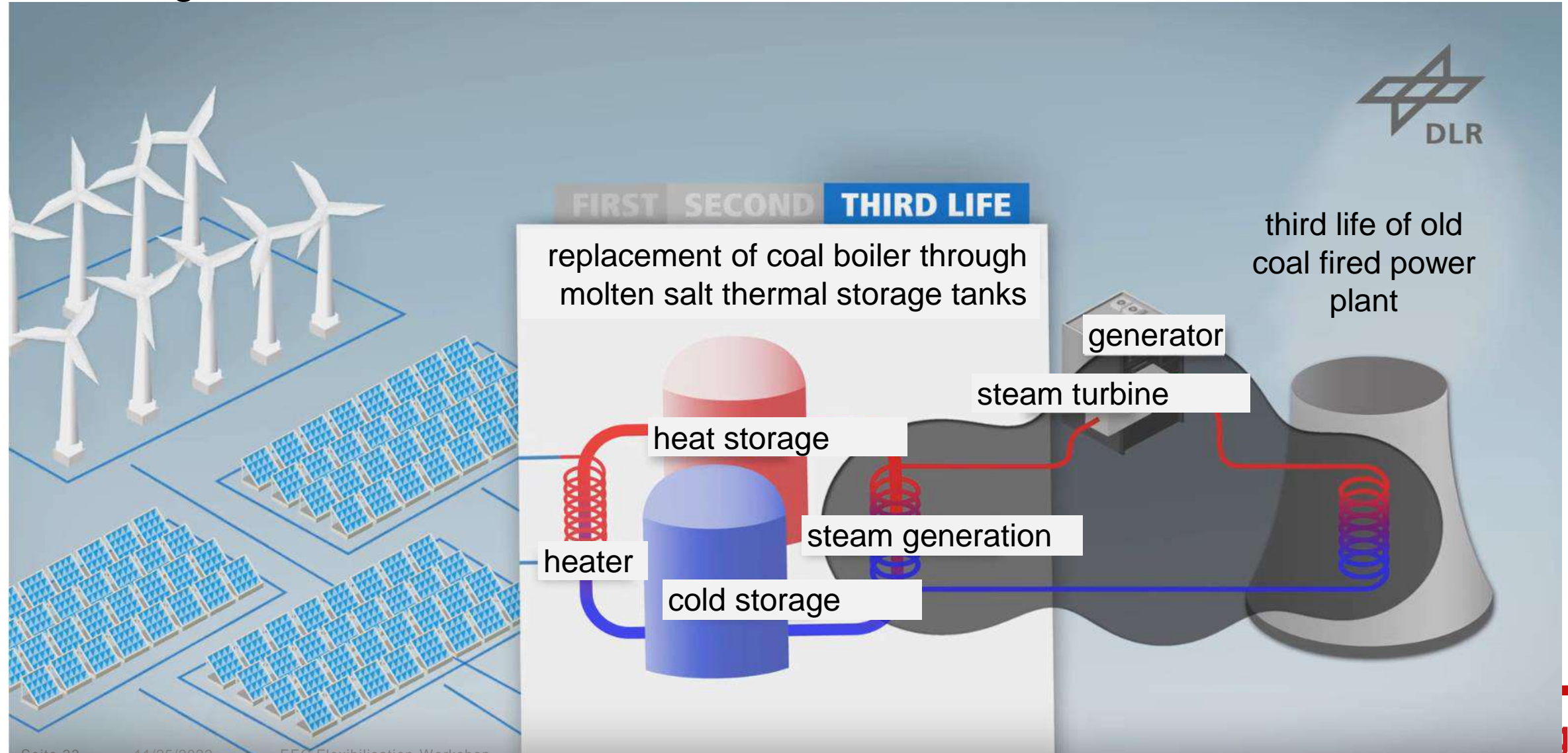
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धन्यवाद

India requires GW-scale +6h power storage solution

Research in Germany and Chile ongoing by DLR with conversion of coal fired power plants into Storage

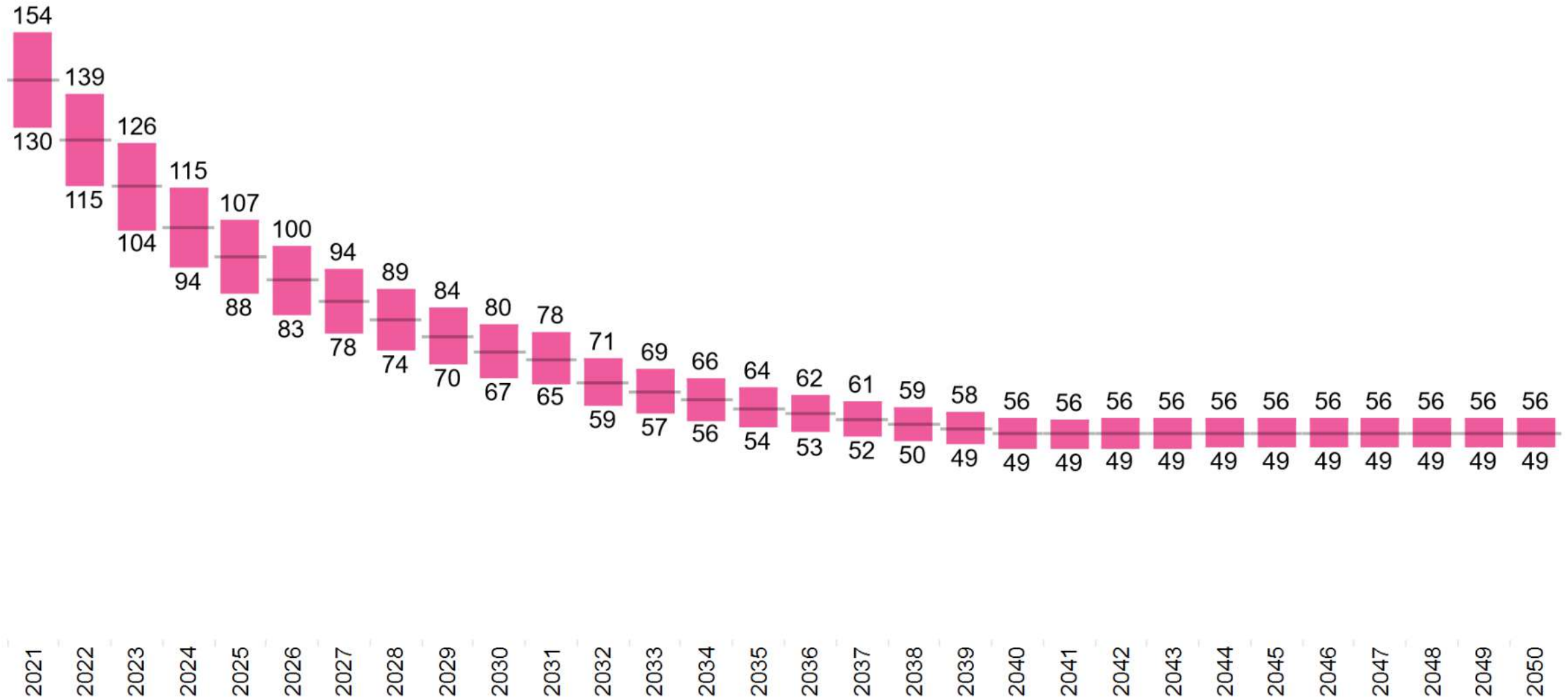


LCOE (USD/MWh, nominal) of 4h Utility Storage, 1st Half 2021

Current LCOE of coal is based on calculations with PLF above 50 %

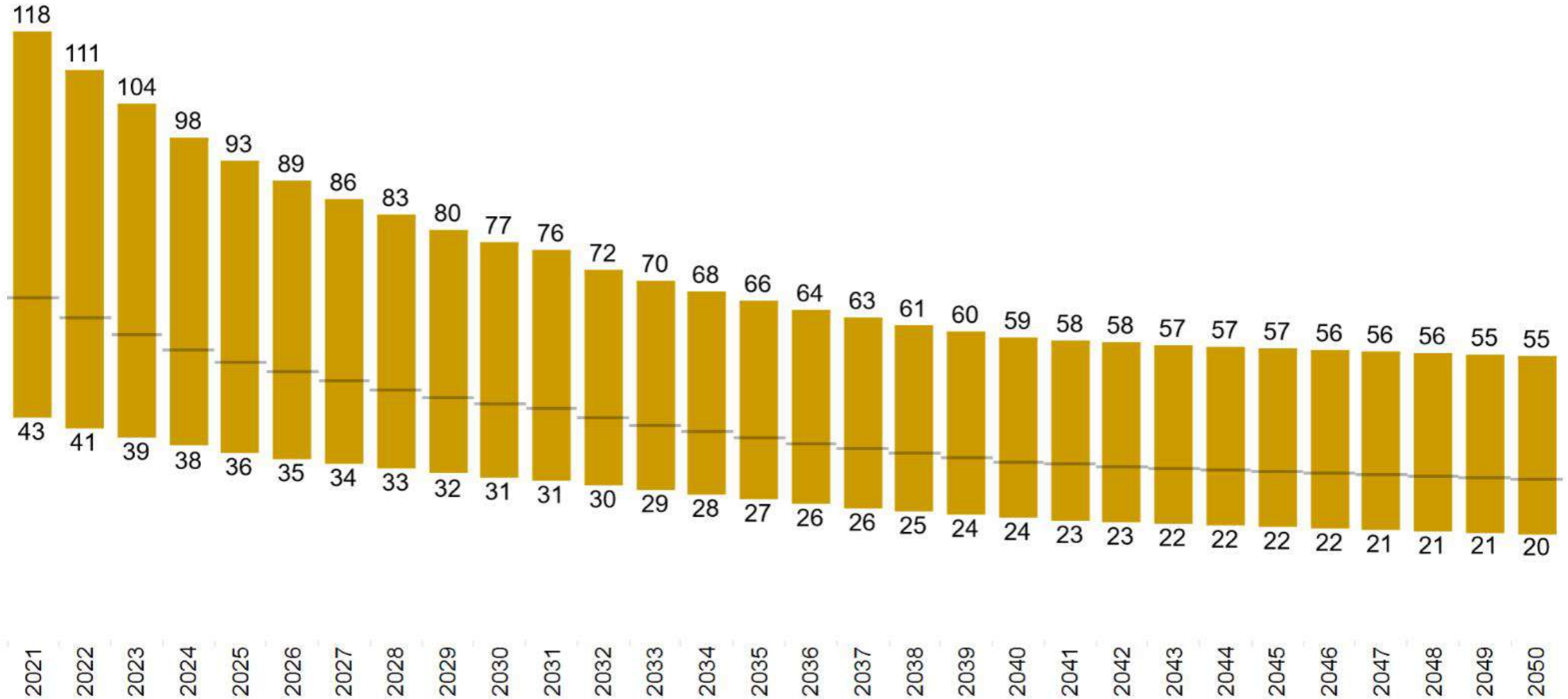


Forecast LCOE (USD/MWh, nominal) for 4h battery in India



Forecast LCOE (USD/MWh, nominal) for PV+battery in India

4h utility scale battery at 25% of PV capacity



Import batteries instead of oil?!

Single use of oil vs. 1st & 2nd life of batteries followed by recycling and reuse.

First life of battery in EV (10 years), then second life (5-15 years) as power storage or e.g. distribution grid booster at EV charging stations then recycling (n-number of time) vs. single use of oil. [Umicore](#), [Duesenfeld](#), Lithium Australia, [Li-Cycle](#), Fortum and others already claiming being able to recycle around 95% of the material of a battery in large scale. Dozens of international players mainly auto mobile manufacturers entering the space.

Recovery rate of metals for various recycling methods

	Lithium (%)	Cobalt (%)	Nickel (%)	Aluminum (%)	Manganese (%)	Iron (%)	Steel (%)	Copper (%)
Hydrometallurgy	100	100	100	100	100	100	100	100
Pryometallurgy	0	100	100	0	0	91	100	100
Pyro-hydro	90	100	100	0	0	91	100	100

Source: BloombergNEF, American Manganese, OnTo recycling, Umicore, Duesenfeld

More info here:

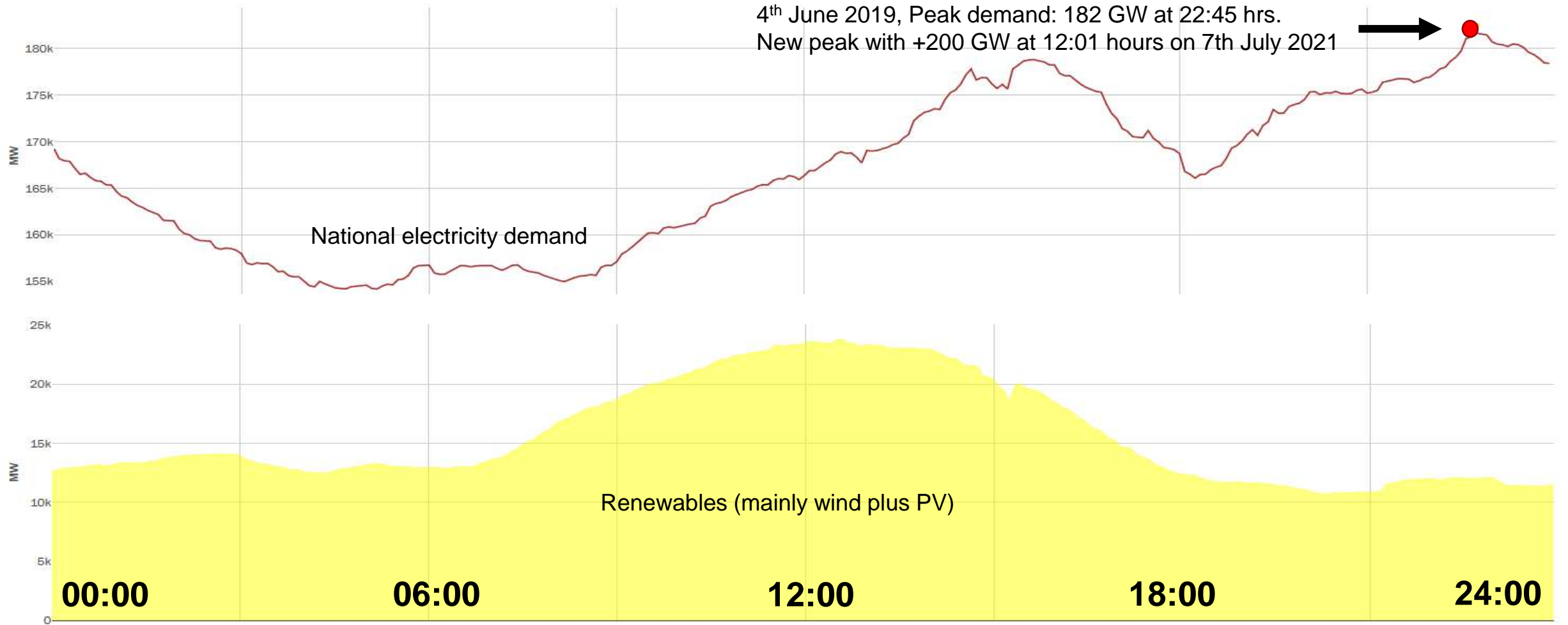


BNEF: "For large format EV batteries, recyclers are still working to improve the recovery rate of lithium. Using current technology, lithium is likely to be recovered in the form of lithium carbonate." Several companies have achieved recovery rates of up to 100% of Cobalt, Nickel and Lithium. "Recycling used batteries is gaining ground as the car-industry grapples with finite supplies of raw materials. China plans to boost its recycling capacity to 1 million tons annually by 2030, from about 60,000 tons, according to BloombergNEF."

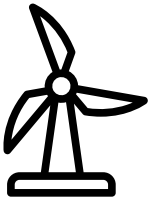
But (BNEF in 2019): "We expect the lithium market to be in surplus until 2024. This could discourage recyclers from recovering lithium unless they can offer lithium that is cheaper or of a higher quality than that available from mining."

Example: "China's EV battery recycling program covers batteries of lithium-ion, nickel hydride and oxide chemistries (...) Recycling of second-life EV batteries are covered by the current policy (...) Mandated collection rate is 100% for EV batteries. Auto manufacturers bear full legal responsibility of tracking every single battery cell through its life cycle." Already today "recyclers must recover 98% of contained nickel, cobalt and manganese and 85% of the lithium."

But: No PV Generation at night! Peak demand will remain at night?



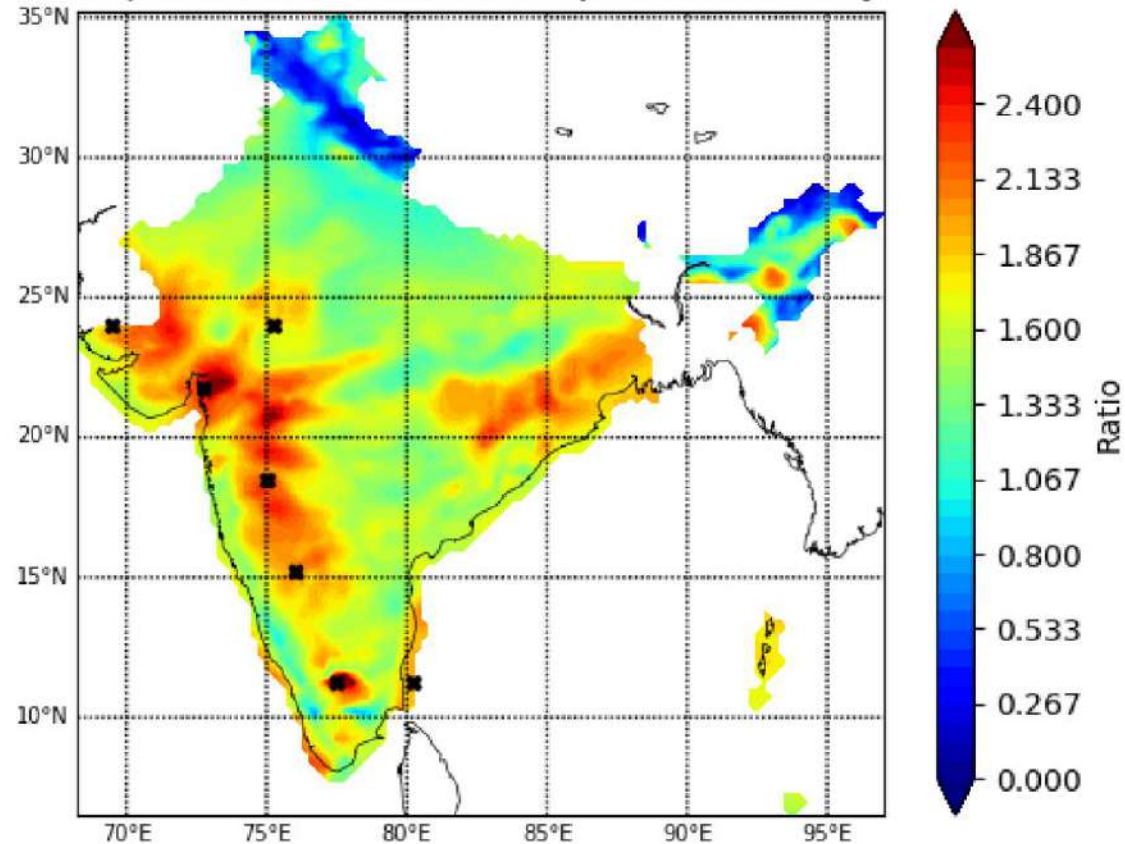
Source: <https://carbontracker.in>, based on data from MERIT India, last accessed 16th June, 2020



India can rely on wind during peak demand at night

German WindGuard has screened India for wind sites which constantly deliver power during peak demand between 7-11 pm with focus on May - August as well as Sep - April. Commercially highly valuable sites have been identified.

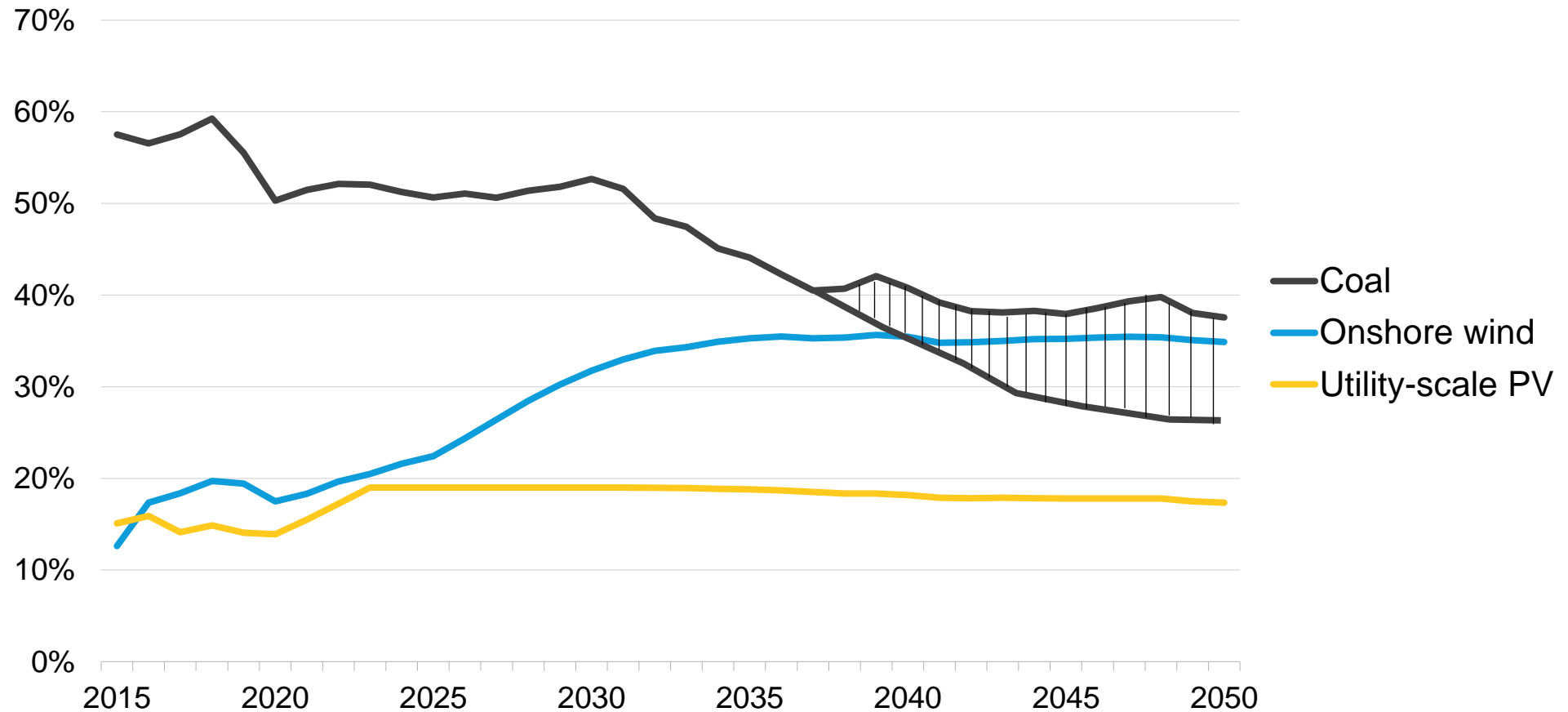
Ratio peak hours summer compared to entire year



Above: Ratio between mean power during the evening hours during the summer months May – August, and the annual mean power. Highest value sites are different from regular sites and highlighted by a black X.

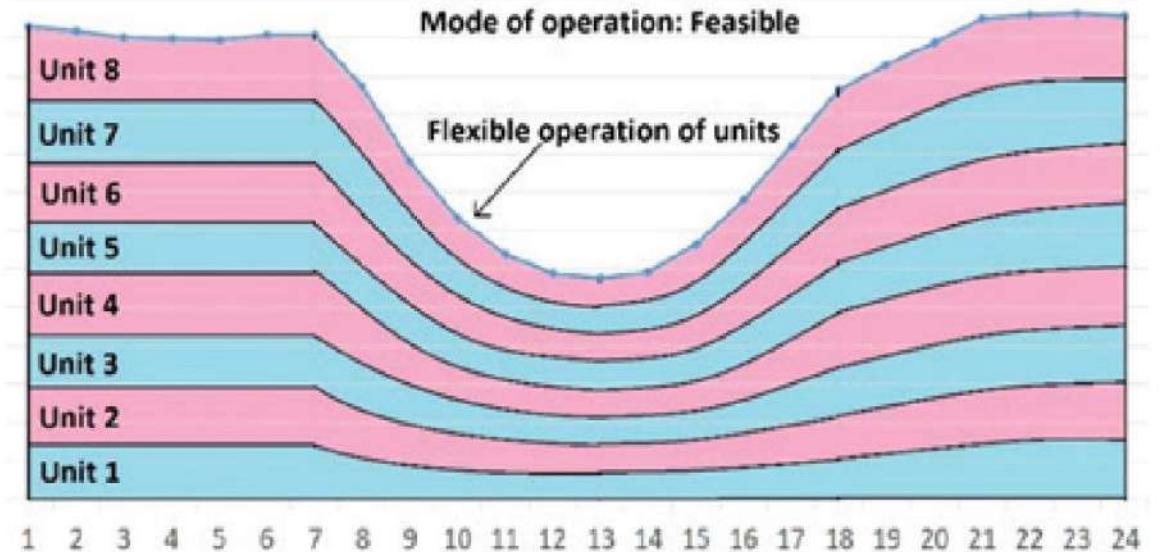
With increased PV+Wind PLF of coal will fall

Current LCOE of coal based on calculations with PLF above 50%. Calculations may consider a PLF of <40%



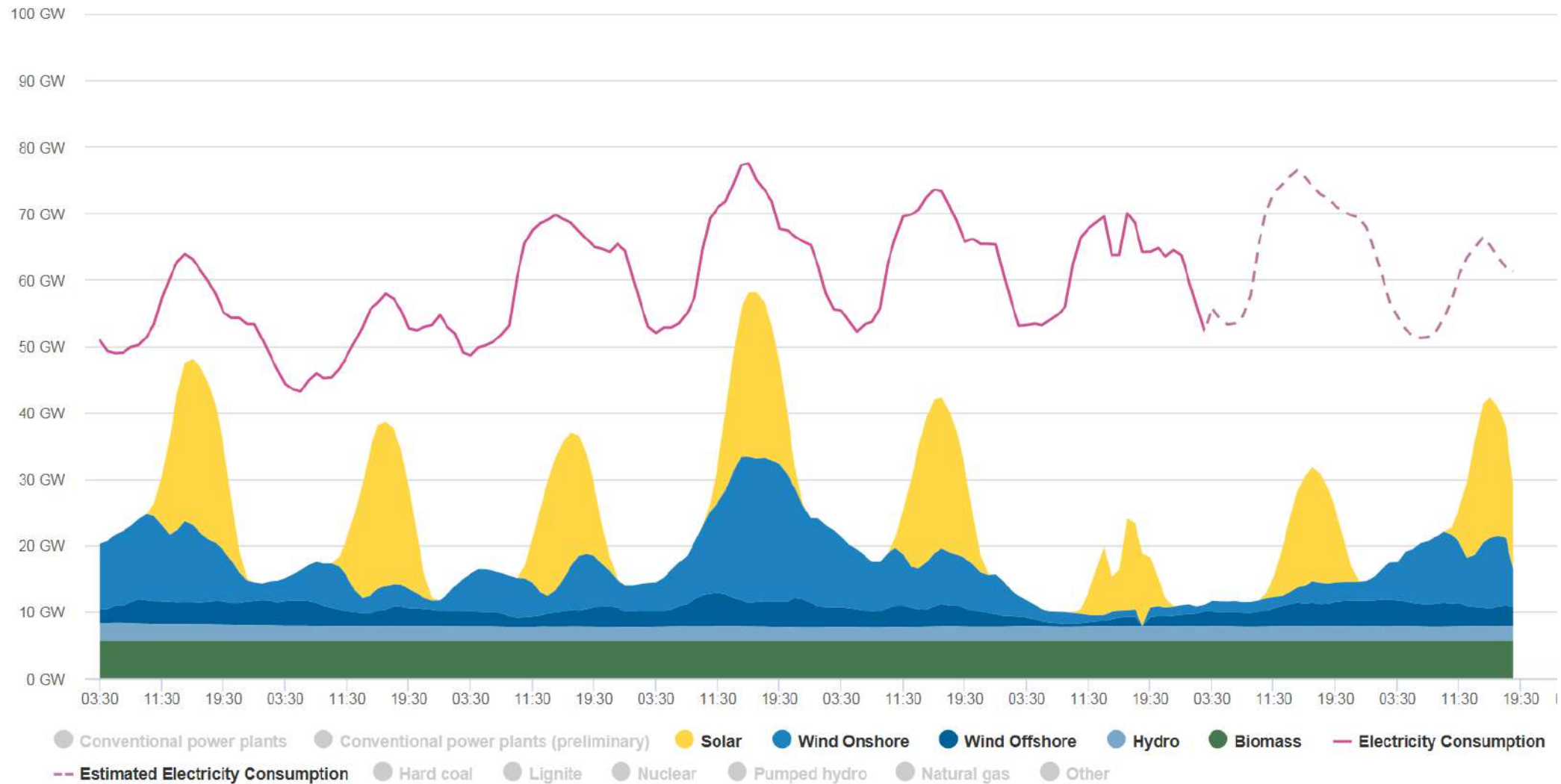
Flexible Operation Mode with low Minimum Load most Feasible

Start Stop Operation of TPS very expensive. Flexible Operation most feasible.



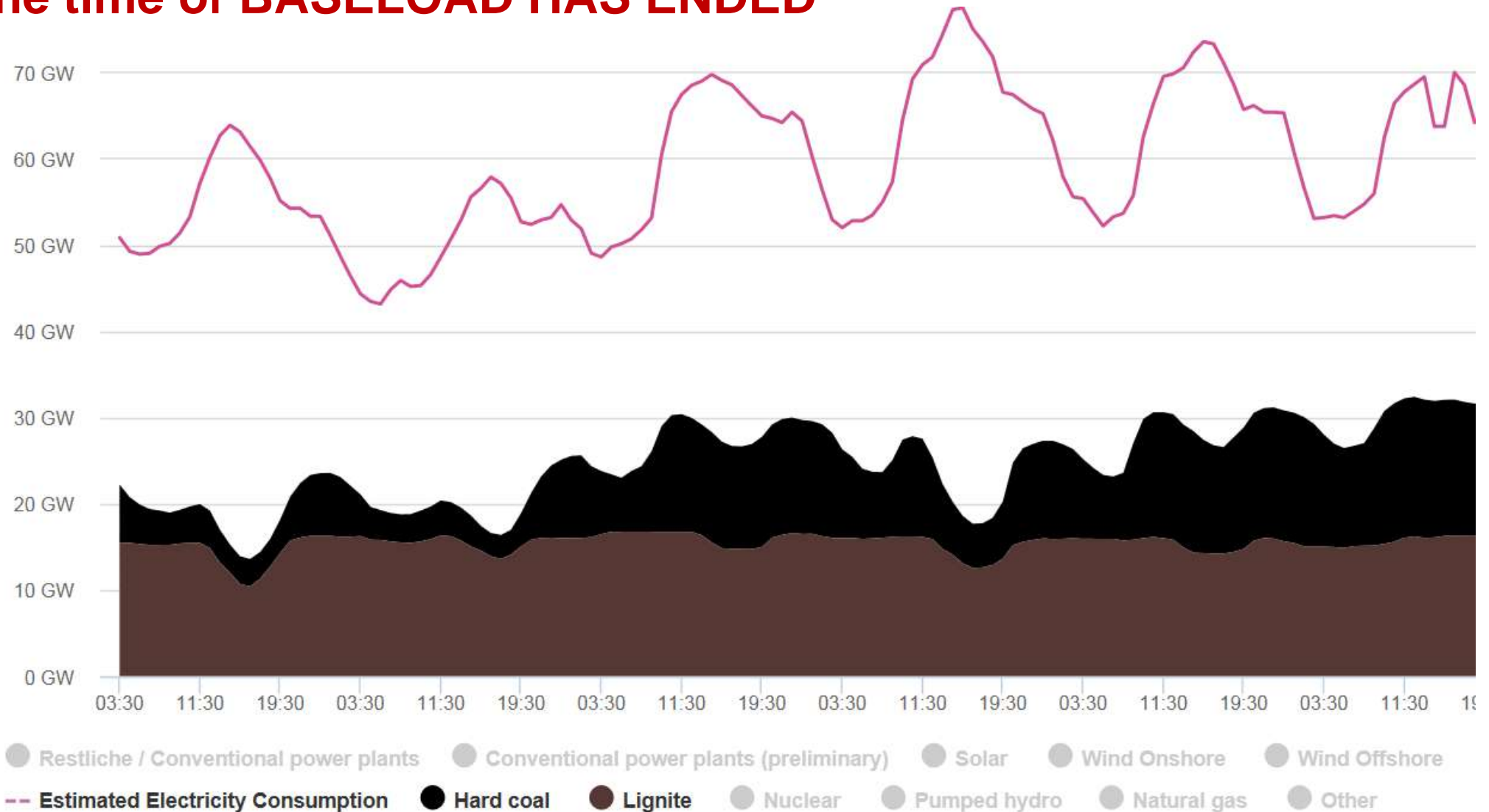
धन्यवाद

Renewables and load in Germany – a week in September

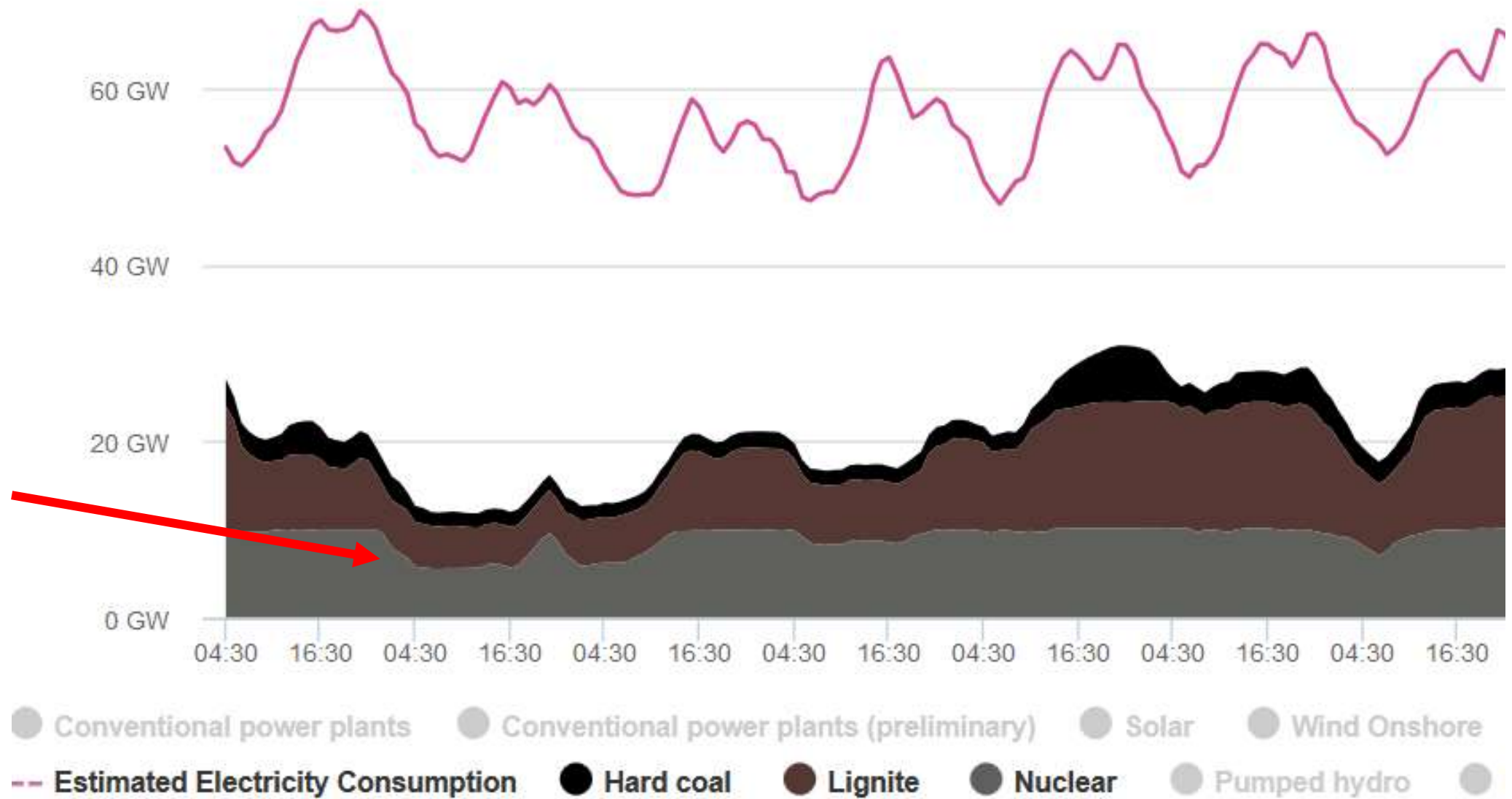


Coal and load in Germany – same week in September

The time of BASELOAD HAS ENDED

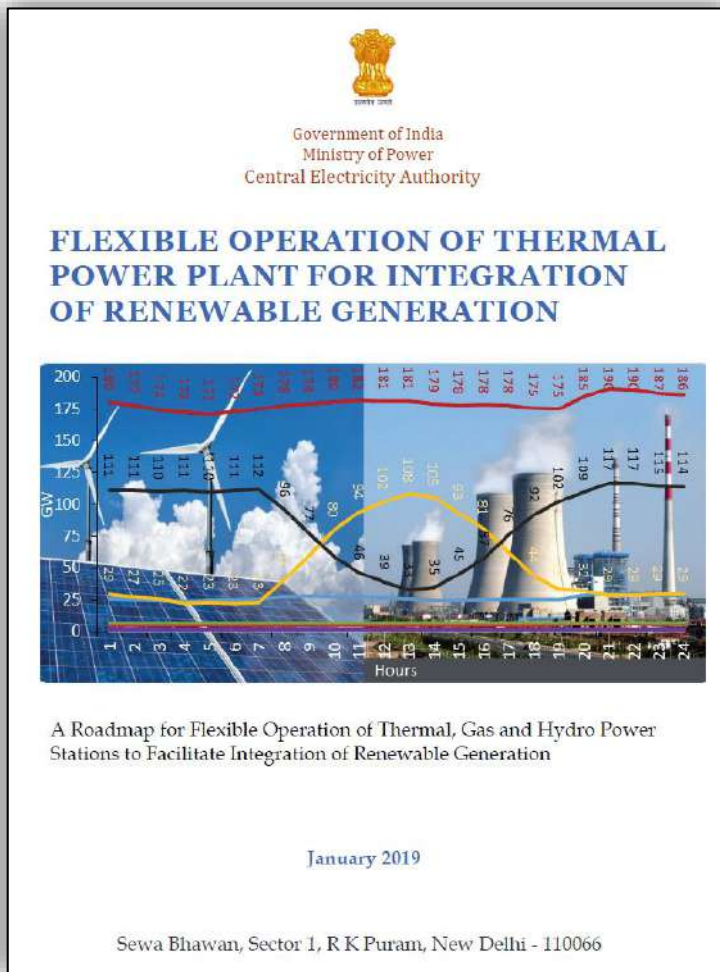


Even NUCLEAR is ramping up and down – a week in December



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