The race to climate neutrality in Germany by 2045

What we can learn from recent studies

Aurora provides data-driven intelligence for the global energy transformation

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Power markets

Renewables

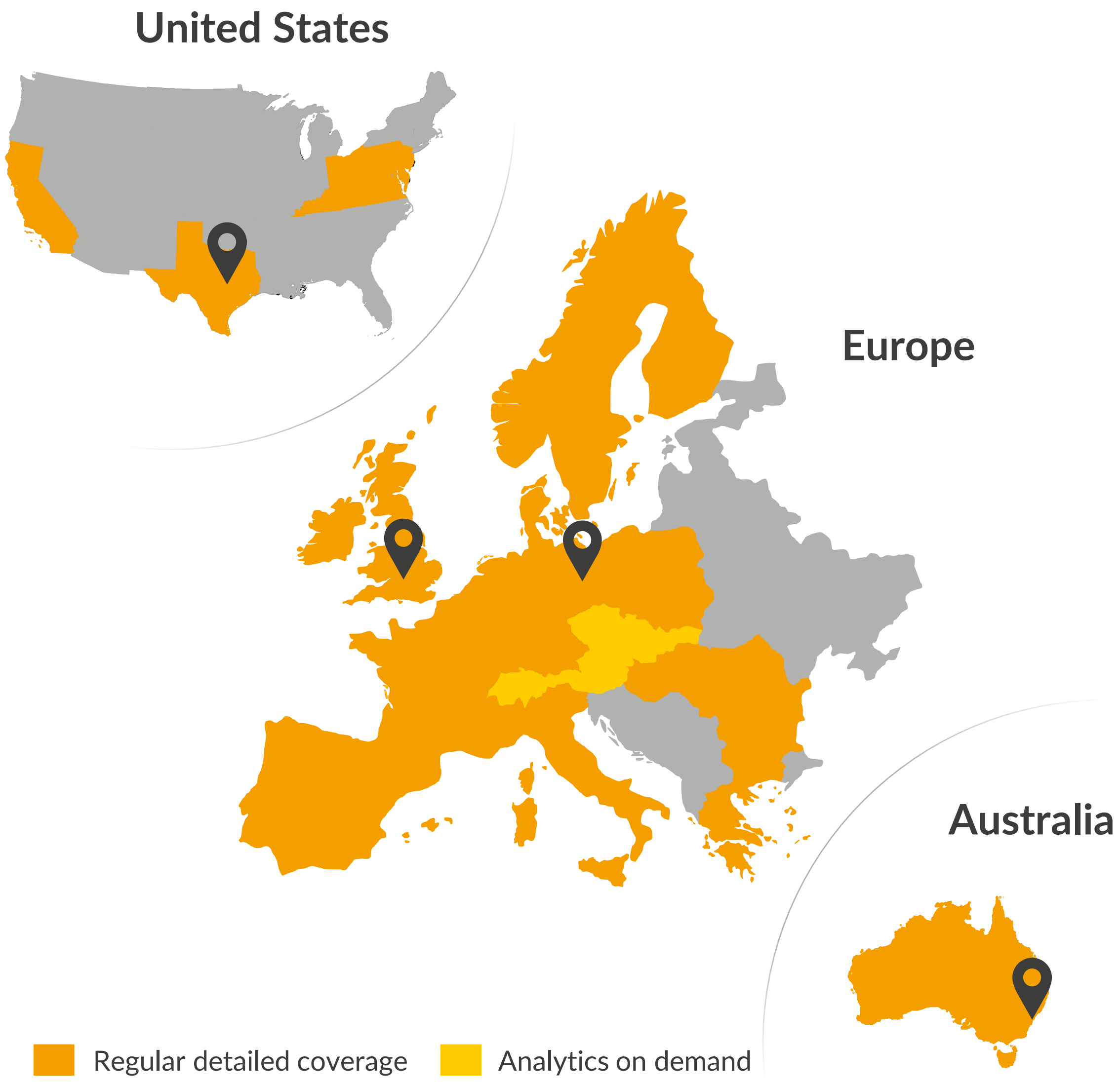
Storage

Electric vehicles

Hydrogen H_2

Carbon CO_2

Natural gas



4 Offices
Oxford | Berlin | Sydney | Austin

200+
market experts

350+
subscribing companies

100+
transactions supported in 2020

Source: Aurora Energy Research

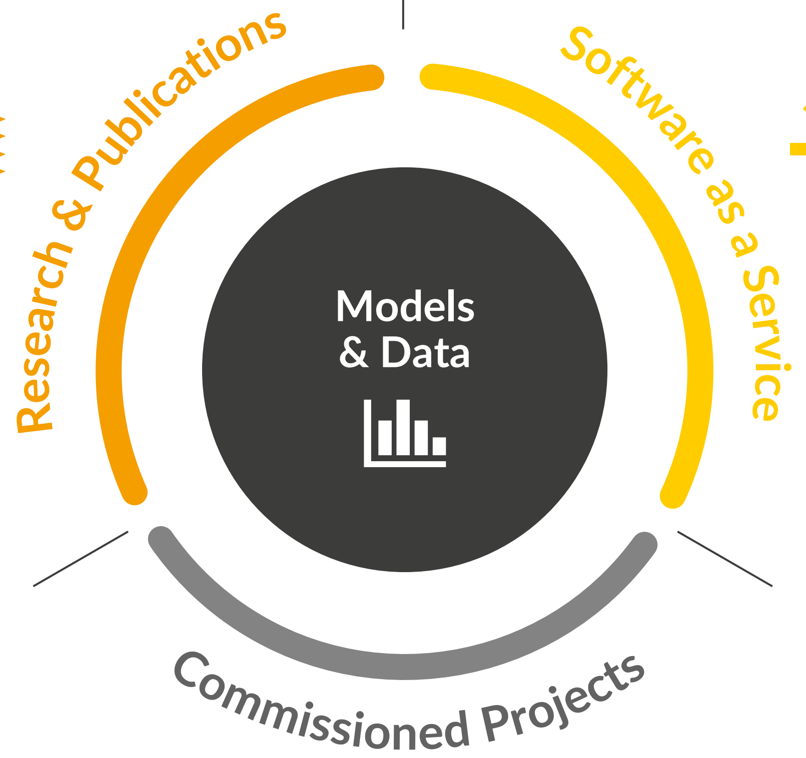
Aurora brings a sophisticated approach to the provision of analysis and insight to the energy industry

Research & Publications

- Industry-standard market outlook reports and bankable price forecasts for power, gas, carbon and hydrogen markets
- Strategic insights into major policy questions and new business models
- Read and constantly challenged by 350+ subscribers from all industry sectors

Software as a Service

- Out-of-the-box SaaS solutions, combining cutting-edge sophistication with unparalleled ease of use
- *Origin* provides cloud-based access to Aurora's market model, pre-populated with our data
- *Amun* automates asset-specific wind farm valuations for over 30 leading funds, developers and utilities



Commissioned Projects

- Bespoke analysis, drawing upon our models and data
- Trusted advice for all major market participants proven in 500+ projects: transaction support, valuations, strategy & policy engagement

Models & Data

- Market-leading long-term models for power, gas, hydrogen carbon, oil and coal markets
- Continuous model improvements to reflect policy and market developments

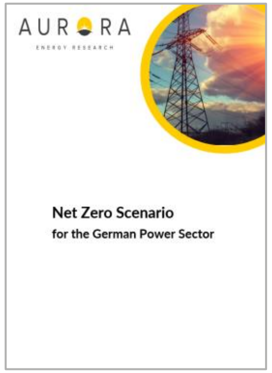
Source: Aurora Energy Research

Purpose of today's webinar

- Show the consensus regarding power sector development: Although Net Zero 2045 pathways depend heavily on politics and regulation, some trends are rather certain and market participants should be prepared for them
- Highlight the uncertain: Market participants might not want to base their strategies on open questions and uncertain technology trends

Scenarios considered	Agora KN2045	Dena KN100	Ariadne Mix Ariadne H2Imp	BDI Klimapfade 2.0	FZ Jülich 100KSG2045
Release	April 2021	October 2021	October 2021	October 2021	November 2021

- Evaluation of power market effects based on
  - Study comparison
  - Aurora Net Zero Scenario
  - Aurora power market studies



Disclaimer: Where no data backup was available, data was partly sourced from plots shown in the studies, potentially yielding some inaccuracies.

The race towards Net Zero: Power sector emissions must be at least halved over the next decade, requiring a speed-up in decarbonisation

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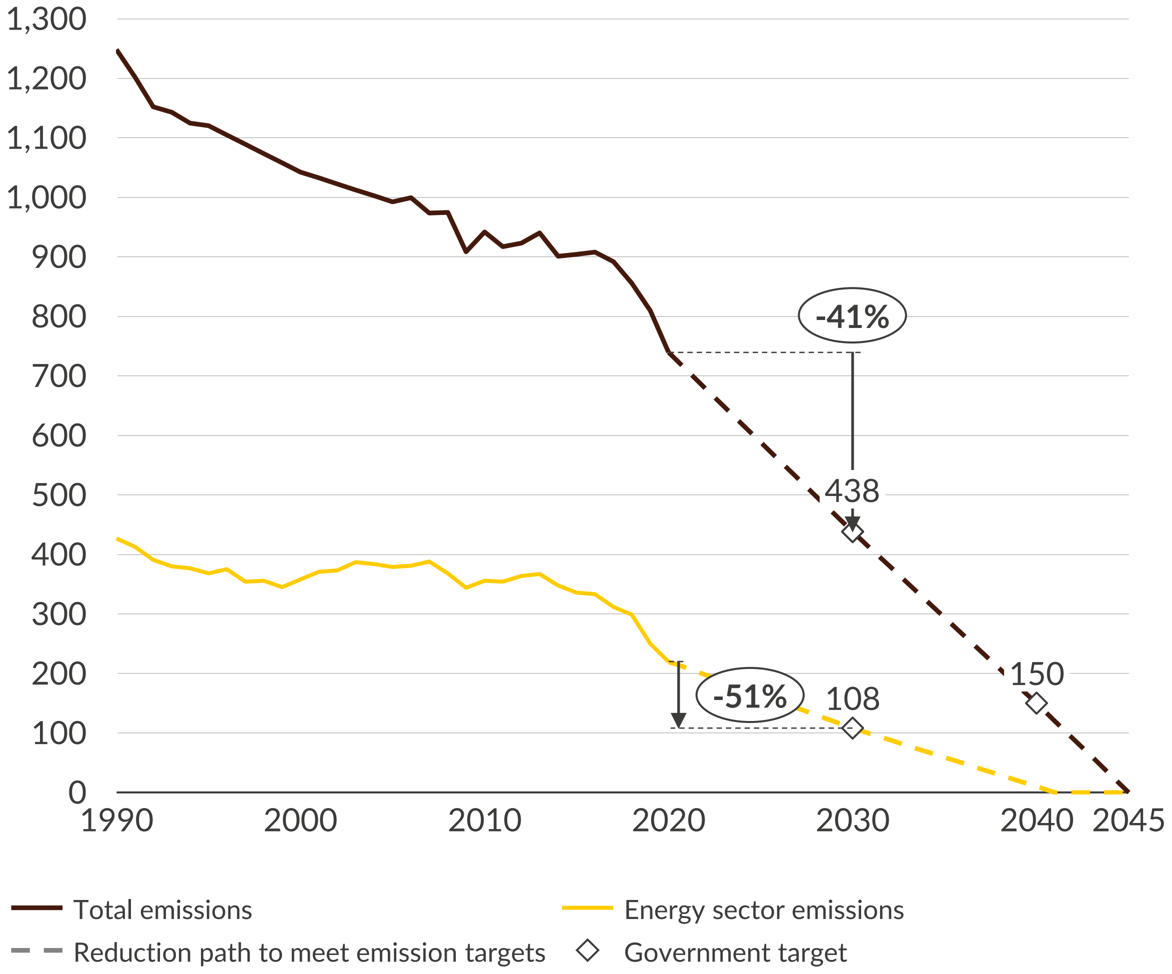
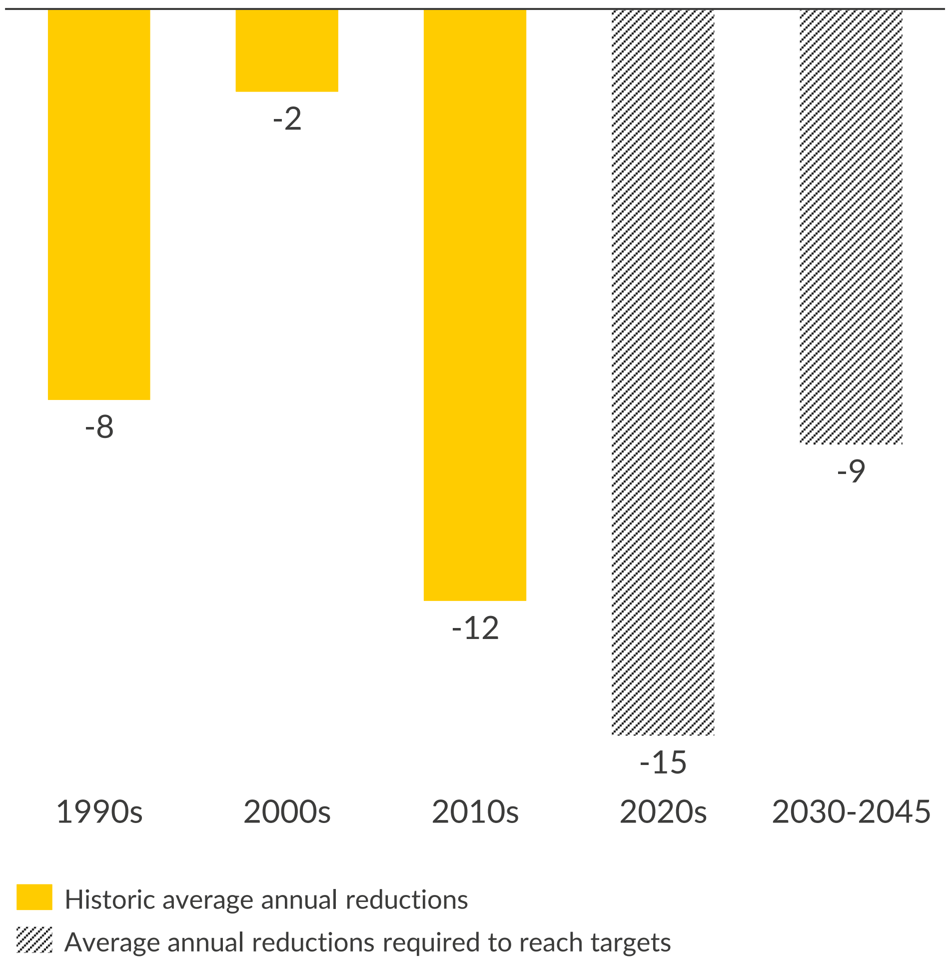
Historic emissions in Germany and Climate Act reduction targets[1]
$MtCO_2e$



Historic average annual emission abatement vs. required reductions to achieve power sector targets in 2030 and 2045[2]
$MtCO_2e$



1) Umweltbundesamt 2021, not including LULUCF. 2) Excluding the year 2020 because of the impact of the Covid-19 pandemic and assuming net zero emissions in the energy sector are reached in 2042.

For climate neutrality in 2045, the power sector needs to be decarbonised several years before

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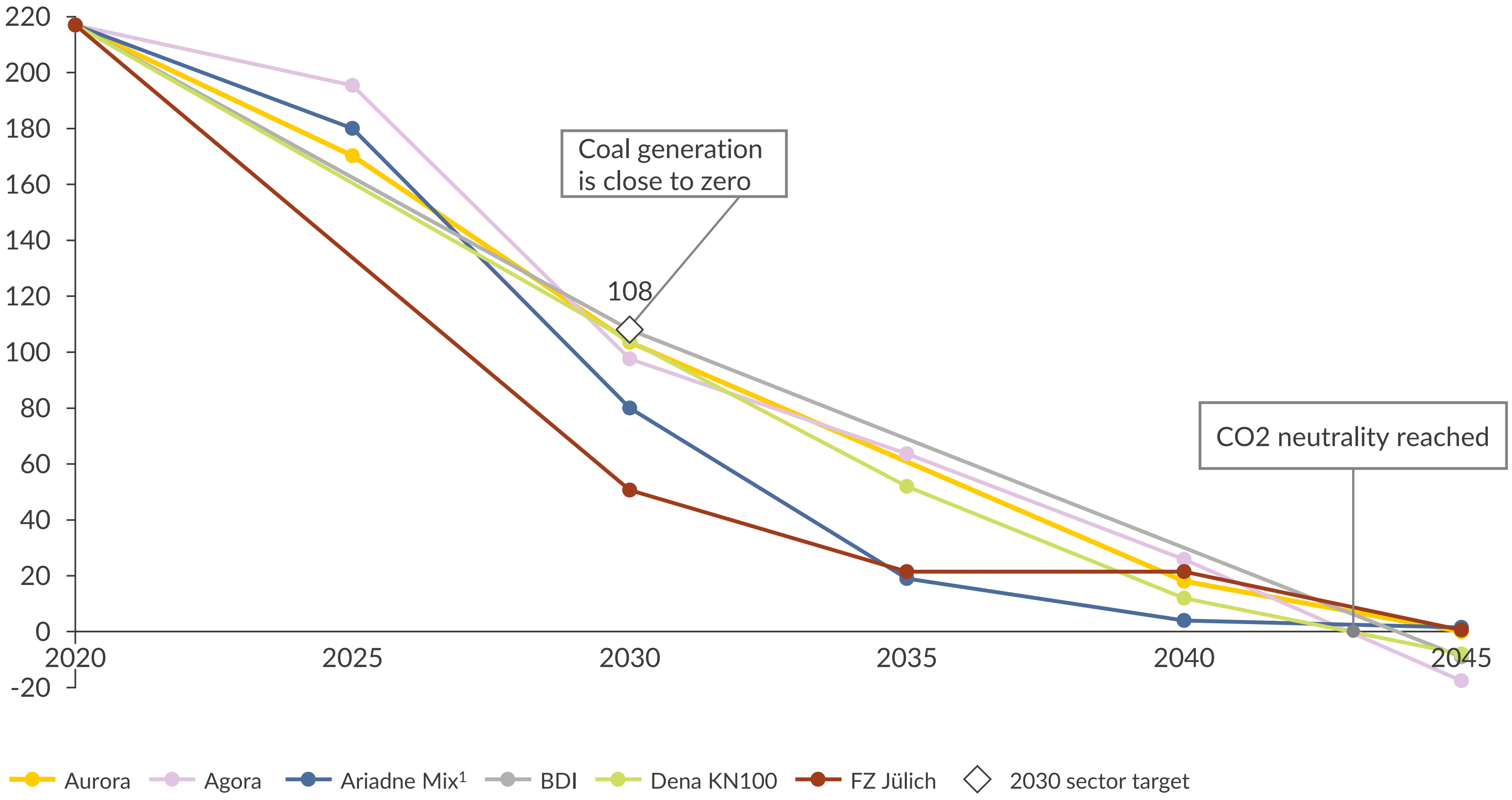
Power sector emission projections

Mt CO2 eq



1) Unless specified otherwise, data is taken from REMIND model.

Energy sector emissions

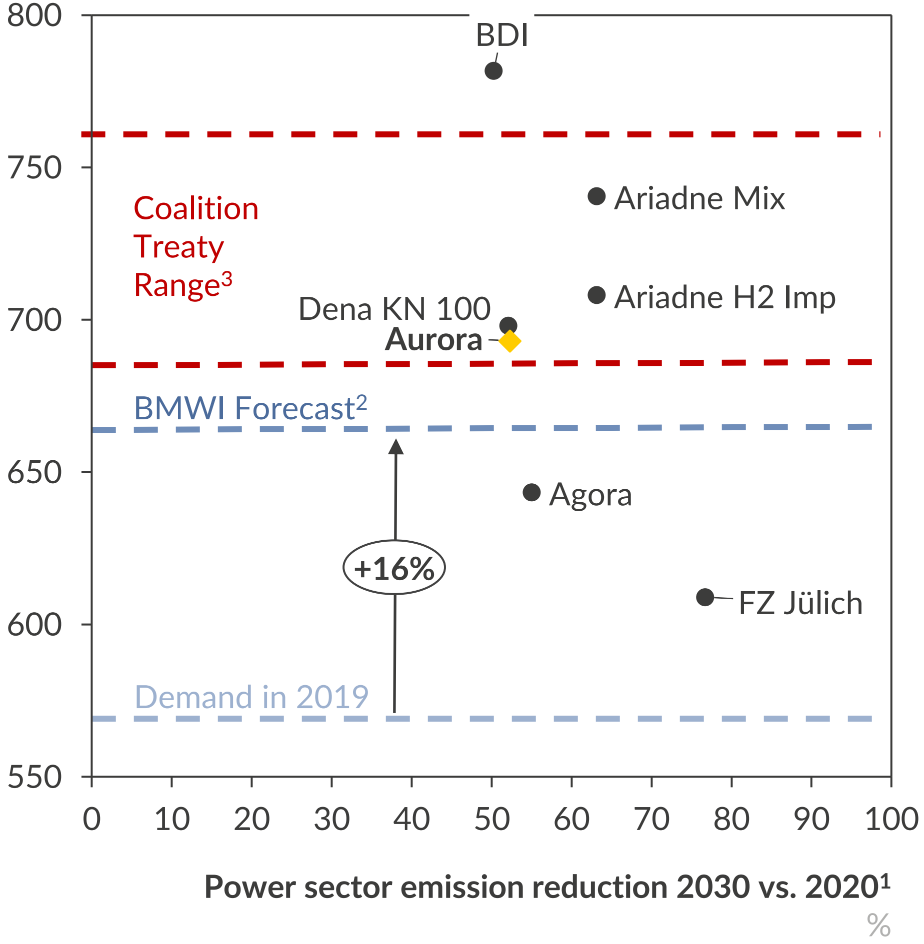
- To reach climate neutrality by 2045, power sector emission reductions need to meet the 2030 goal or be even significantly lower
- As other sectors are much harder to decarbonise and CCS potential is limited, the power sector must tackle emission reductions faster: Reviewed studies foresee it reaching net zero CO2 before 2045. This is roughly in line with ETS1 reform proposals pushing for an annual cap decrease of 4.2%.

Open questions ?

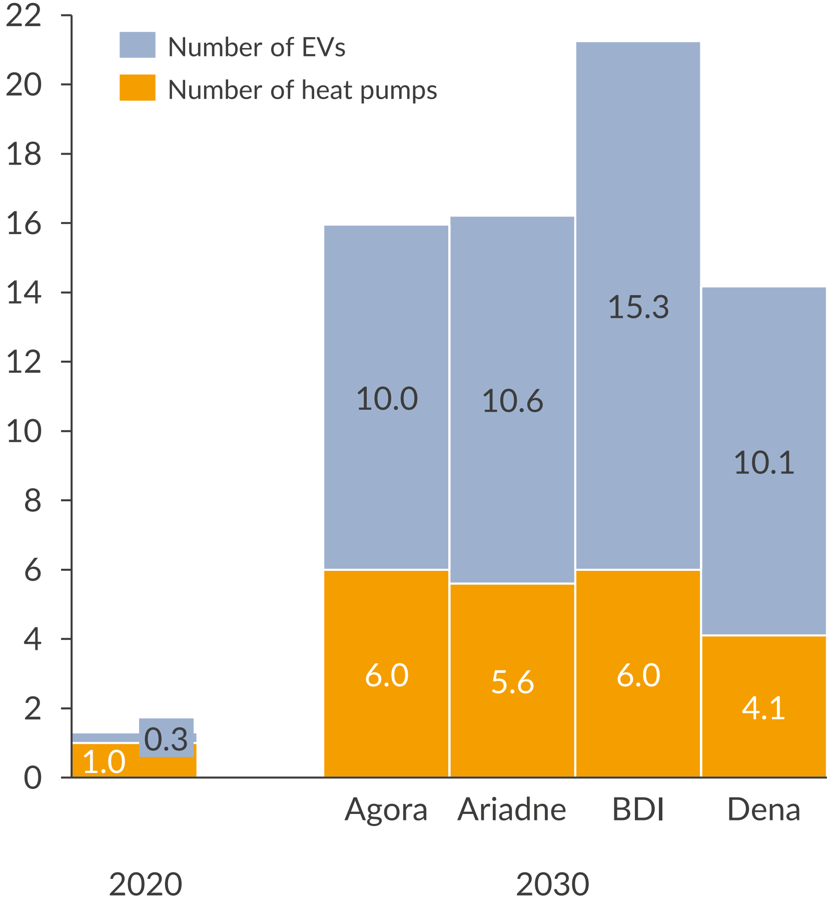
- Will the energy emission targets for 2030 be revised downwards compared to Climate Act Law?
- Can the fast reduction pathway be delivered mainly by carbon prices?

By 2030, power demand is expected to increase by 16% according to BMWi, but most studies see a big upside potential

Gross power consumption in Germany 2030
TWh



Number of electric vehicles and heat pumps
Mio



Power demand until 2030

- Gross power consumption is likely to increase to 650-750 TWh until 2030, where uncertainty is driven by
  - Electrification speed
  - Energy efficiency
  - Ramp up of green hydrogen production

Power sector implications

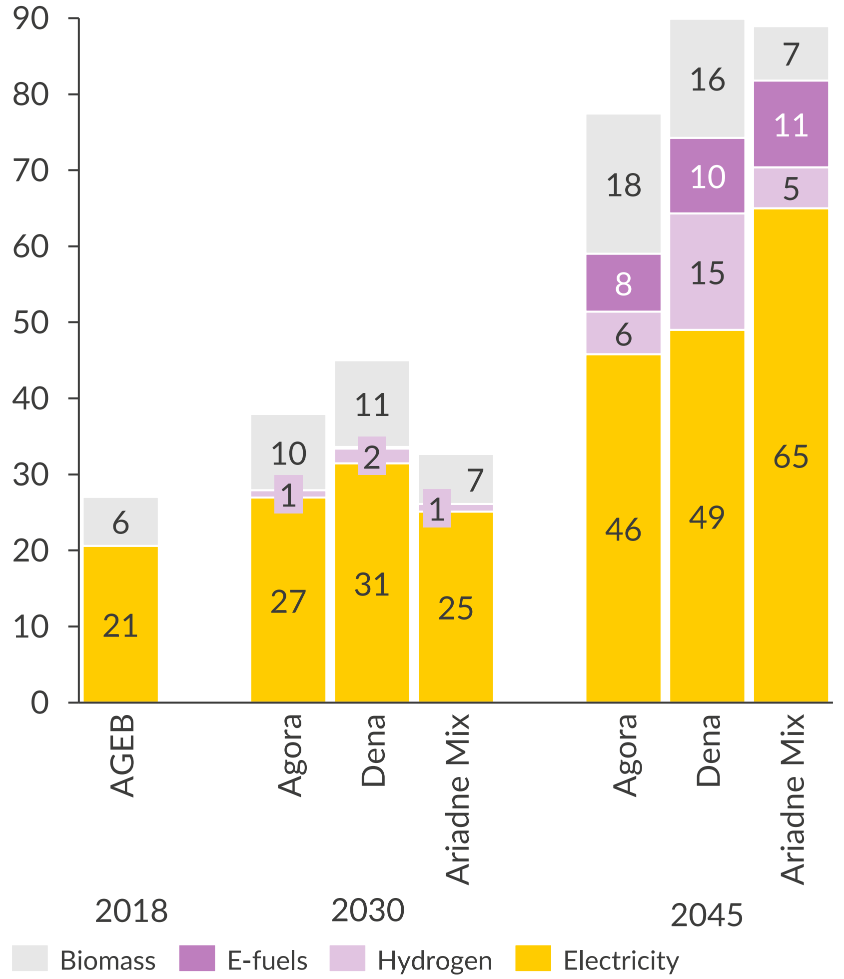
- Demand from new sources combined with higher RES generation leads to strong increase in power price volatility
- Power price volatility and rising demand for flexibility can be used as business opportunity for aggregators and innovative RES developers
- Additional dispatchable capacity will be necessary for security of supply

1) Defined as power sector emission reduction achieved by 2030 compared to 2020 level. 2) Projection released by BMWi on Nov 16, 2021. 3) Draft version published on Nov 24, 2011.

Hydrogen plays a minor role until 2030, while its long-term usage could reach 500 TWh

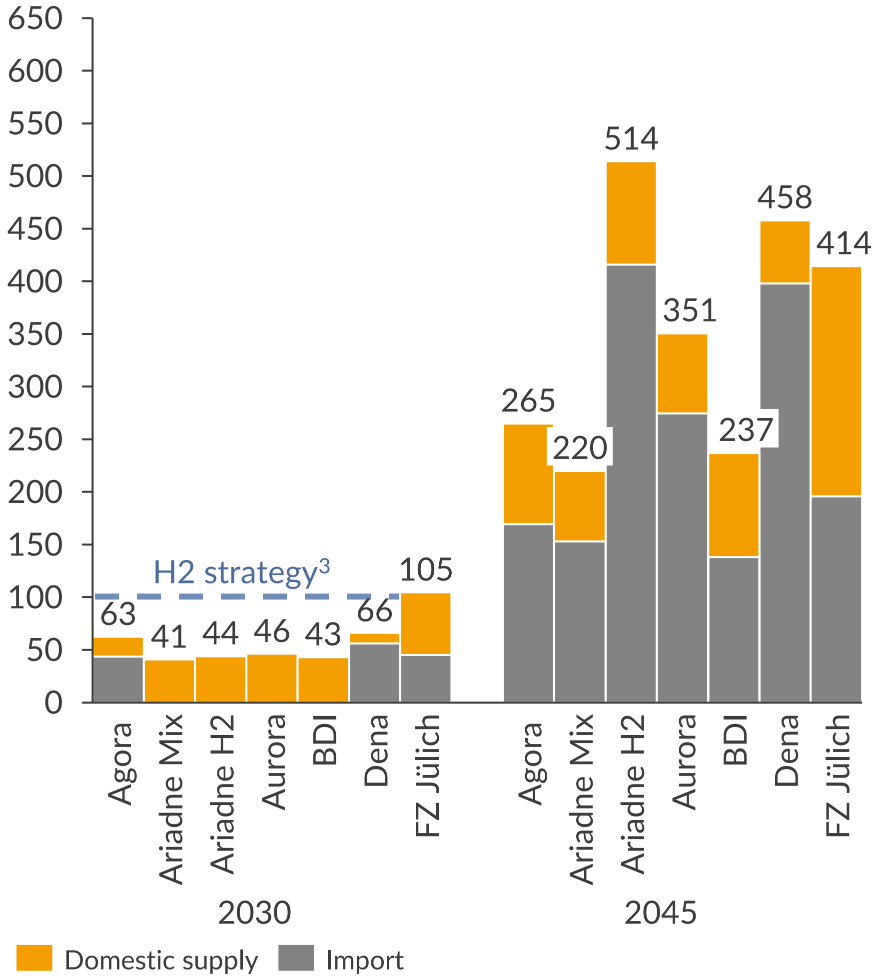
Final energy demand share[1]

%



Hydrogen supply[2] in Germany

TWh



1) Agora and Dena excluding material use, Ariadne including material use 2) Excluding grey hydrogen. 3) German national hydrogen strategy. The 100 TWh target for 2030 does not specifcy hydrogen colour and could potentially include grey hydrogen.

Source: Ueckerdt et al. (2021), Kurzdossier: Durchstarten trotz Unsicherheiten – Eckpunkte einer anpassungsfähigen Wasserstoffstrategie.

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Power sector implications

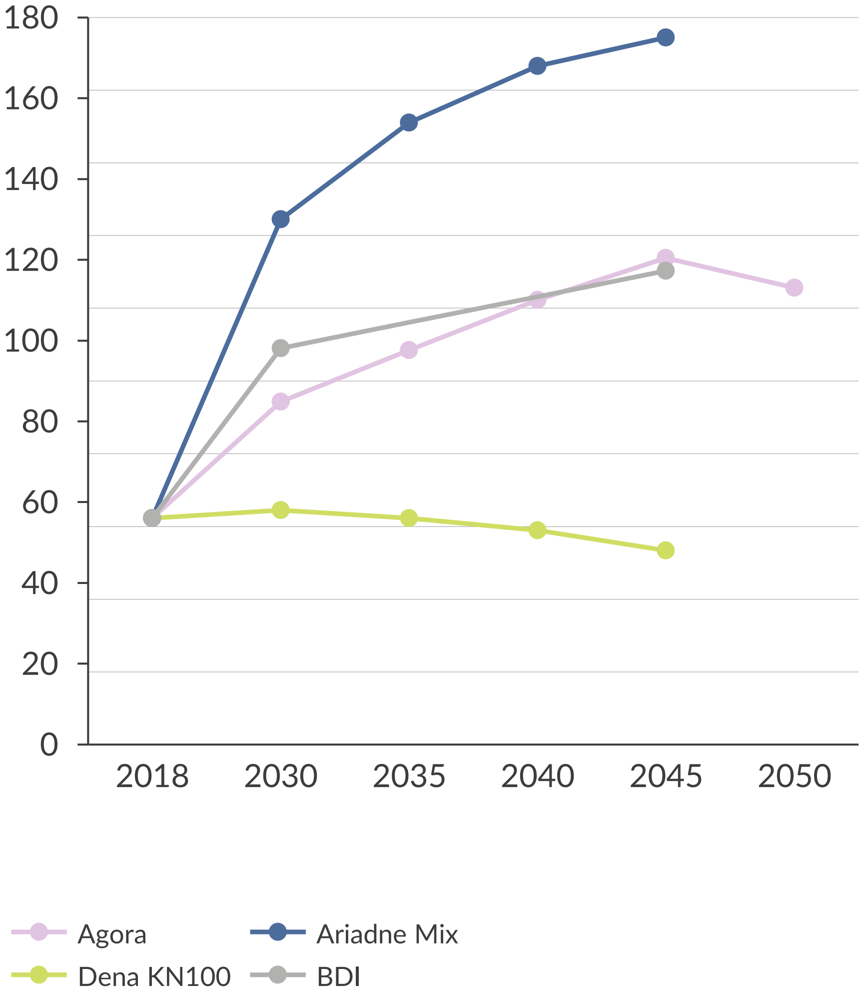
- Electricity will be the most important energy carrier, followed by hydrogen and e-fuels, which both require electricity to be produced
- Domestic green hydrogen production and imports will be limited. Green hydrogen can be expected to be scarce and price-intense until 2030/2035
- RES developers should start thinking about electrolyser business models.

Open questions

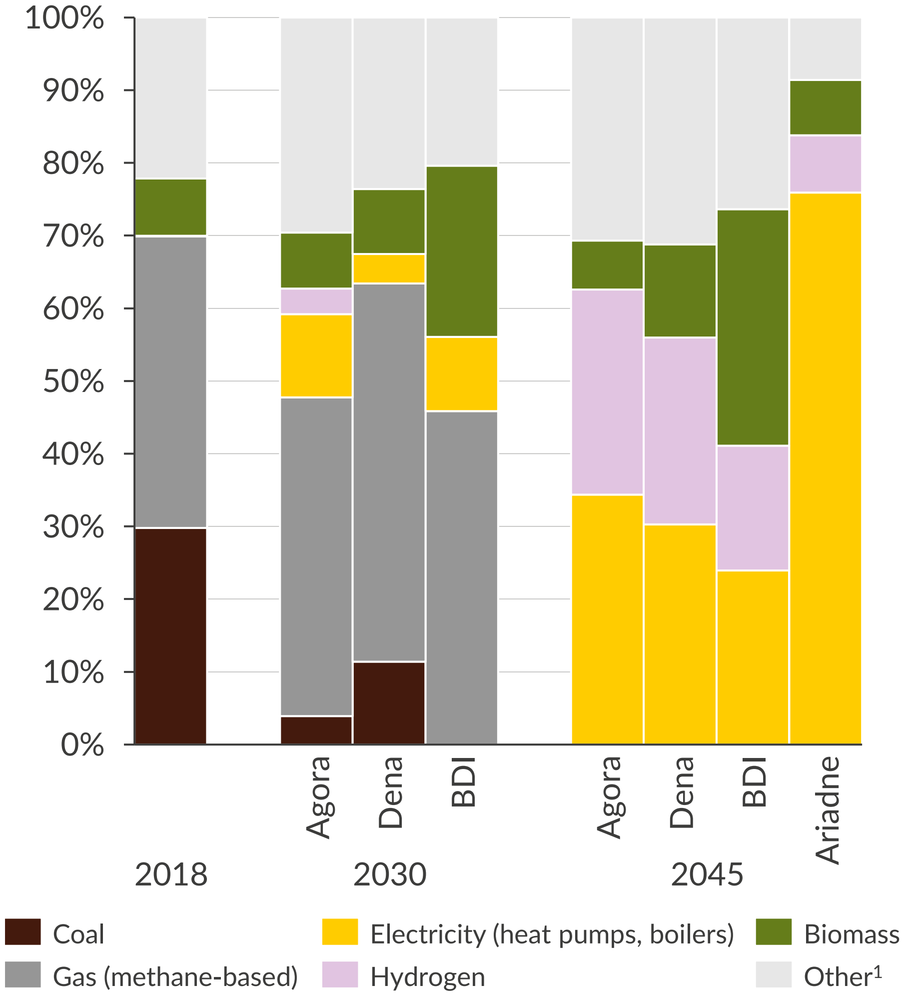
- How much hydrogen can Germany import and at what price?
- What will be the role of blue hydrogen?
- How much hydrogen will be used in transport, industry and heating in the longterm?

A less obvious driver of hydrogen and power demand is likely to be district heating, though heat generation mix for 2045 is uncertain

Trajectories for final district heating demand of buildings
TWh



Heat generation mix for district heating
%



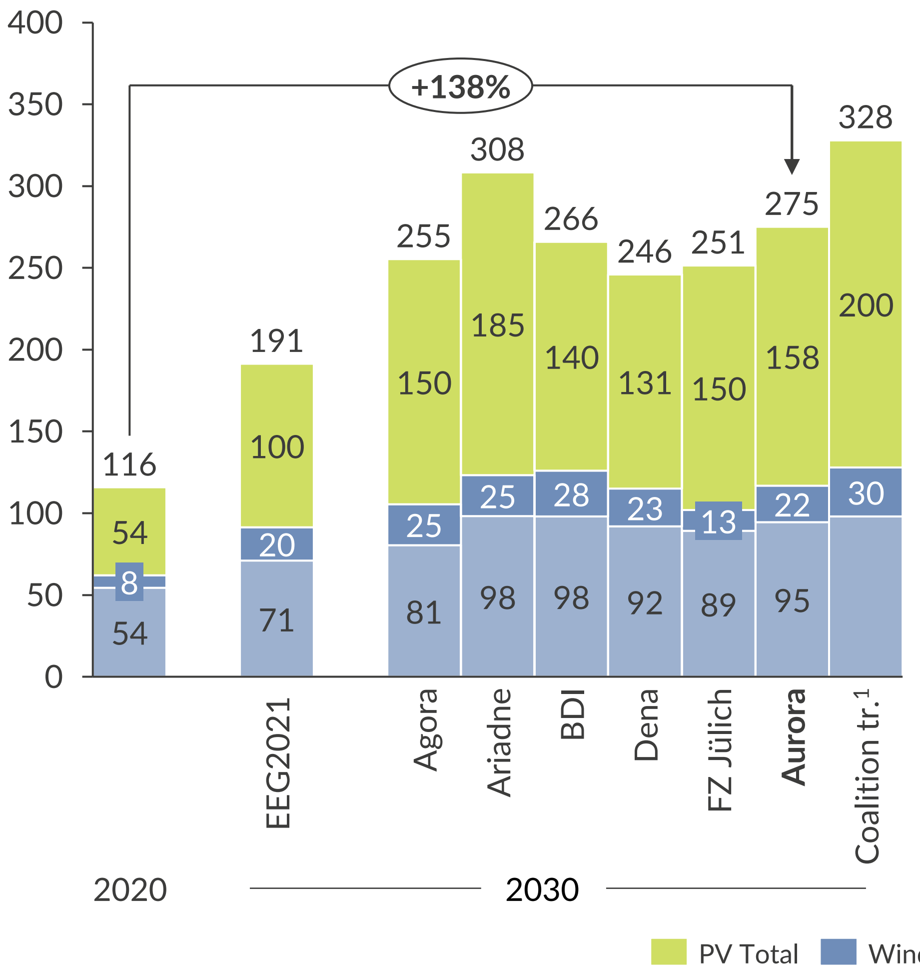
1) Including waste, industrial waste heat, solar thermal and geothermal.

Trends and uncertainties

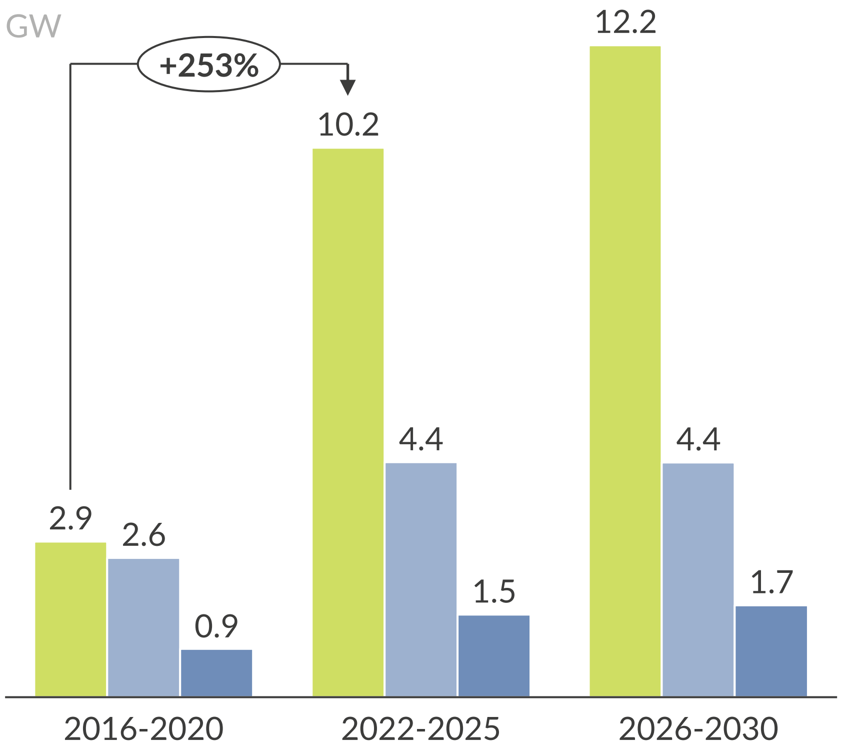
- District heating is a major source of heat in Germany and the majority of NZ2045 studies predict a further expansion, as fossil fuel-based decentralised heating needs to be replaced
- Most district heating is thermal today and needs to be replaced due to the coal exit – however, investment options & their regulatory support are unclear: Gas investments could result in sunk cost as pathway for H2 conversions is not defined yet
- In addition, heating grids are diverse and require individual solutions depending on local circumstances
- These uncertainties are reflected in the large discrepancies between studies: Shares of biomass, hydrogen, electric boilers and heat pumps range from major to marginal

To satisfy increasing demand and decreasing power from coal, solar and wind capacity is expected to more than double by 2030

Wind and PV capacity installed
GW



Average annual net buildout of solar and wind capacity historic and Aurora Net Zero
GW



1) Draft version published on Nov 24, 2011. The treaty does not mention a specific target number for onshore wind.

Source: BMWi

Wind and PV capacity buildout

Consistent trends

- For 2030, all studies project a significant wind and solar capacity increase of 112-166% compared to 2020

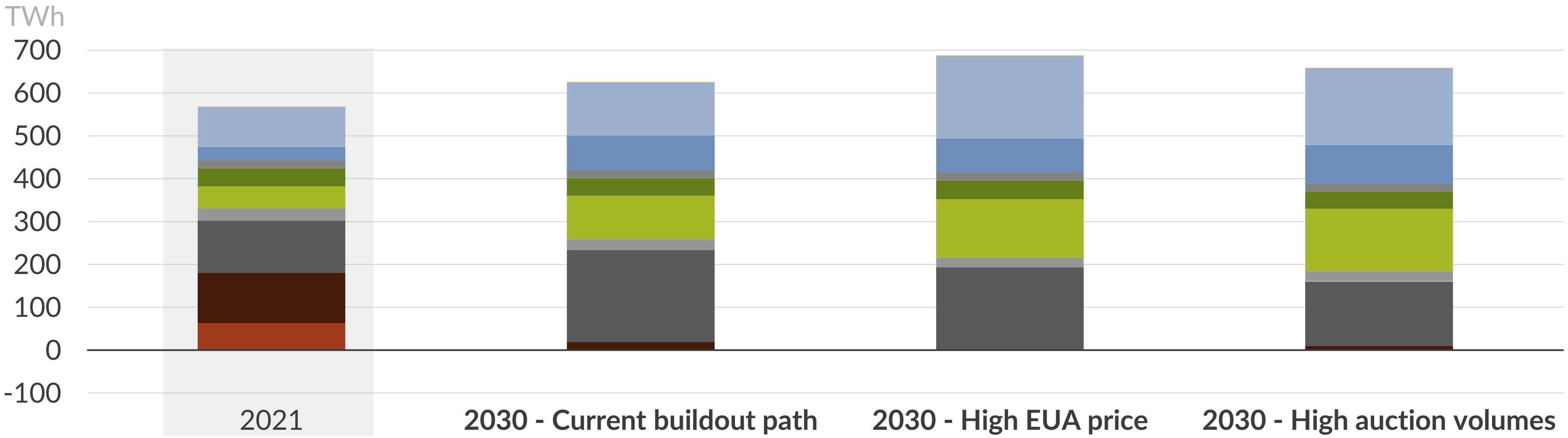
Open question

- Can the public acceptance issue for wind onshore be solved and buildout speed-up materialize?

Implications for RES developers

- Large auction volumes can be expected in the next decade
- Assets with merchant exposure suffer from low capture prices due to high cannibalisation caused by rapid RES buildout
- PPA-based business model will remain an attractive option as German PPA market will remain undersupplied

2030 renewables capacity requires either a rise in EUA prices to 130 EUR/tCO2 or a strong increase in the EEG tender volumes



Scenario overview			
EUA price [EUR/t]	60	130	60
Share of renewables	54%	69%	69%
CO_2-emissions [Mio t]	149	121	116

Average annual net capacity buildout			
PV	6,1	10,0	11,5
Wind onshore	1,1	4,2	4,4
Wind offshore	1,2	1,2	1,6

DSR · Wind onshore · Hydro · Solar PV · Electrolysers · Coal
Battery storage · Wind offshore · Biomass / other RES · Other thermal · Natural gas · Nuclear

Source: EPICO (2021). „Der Weg zu einem klimaneutralen Stromsystem – Aufbruch zu einem marktwirtschaftlichen Erneuerbaren-Zubau in Deutschland“, Berlin.

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EPICO analysis by Aurora: renewables buildout

- Current buildout pathways for renewables combined with a EUA price expectation of 60 EUR in 2030 is not sufficient to reach required 2030 renewables capacity
- Under a high EUA price of at least 130 EUR in 2030, merchant renewables buildout can bridge the gap between EEG buildout paths and climate targets
- Alternatively, higher EEG auction volumes will be required to ensure high gross build out

For security of supply, Aurora estimates that 65 GW dispatchable capacity is needed in 2030, but investment case is uncertain

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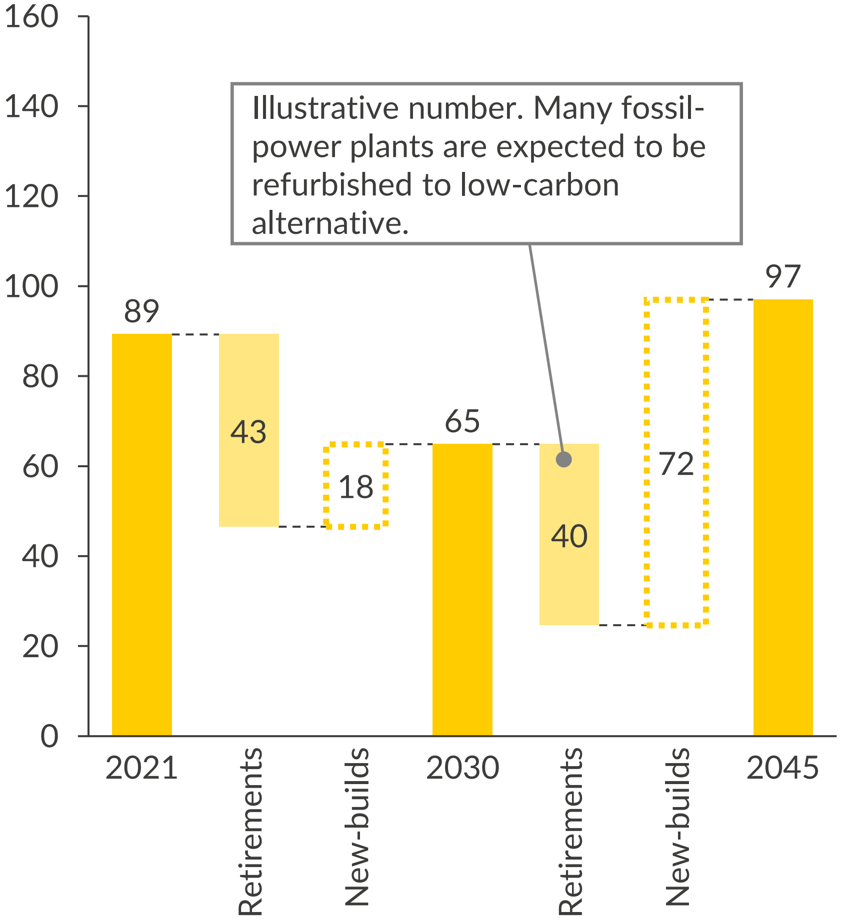
Dispatchable[1] capacity in Aurora Net Zero Scenario
GW



Technology options for dispatchable capacity

Nuclear	✗	Exit by the end of 2022
Coal	✗	Exit by the end of 2038 at the latest
Gas	✗	Exit required by 2045 at the latest to reach Net Zero
CCS	✗	Currently banned
Hydrogen	✓	Hydrogen strategy supports decarbonisation via hydrogen
Synfuel	✓	To be produced from hydrogen or from biomass, hence same constraints apply
Biomass	✓	Limited due to sustainability concerns and area constraints

Dispatchable capacity needs will increase until 2045

- Dispatchable capacities of 65 GW in 2030 and 97 GW in 2045 are needed to ensure security of supply during extreme residual load peaks
- Reasons for high buildout post 2035 are the higher demand due to increasing electrification, and replacement/refurbishment of natural gas assets by low-carbon alternatives
- Based on energy payments alone dispatchable investments likely to be insufficient. Security of supply could be incentivised by e.g.
  - Enforcing balancing responsible parties to have enough reserve capacity
  - Capacity payments
- Investments into gas capacities bear risk of stranded assets - transition to low-carbon unclear

1) Includes hard coal, lignite, combined cycle gas turbines (CCGT) running on gas or H_2, open cycle gas turbines (OCGT) running on gas or H_2, oil peakers and biomass. Includes all kinds of combined heat and power plants (CHPs).
Source: Aurora Energy Research

Studies agree that the largest part of dispatchable capacity will be provided by gas by 2030 and its low-carbon alternatives by 2045

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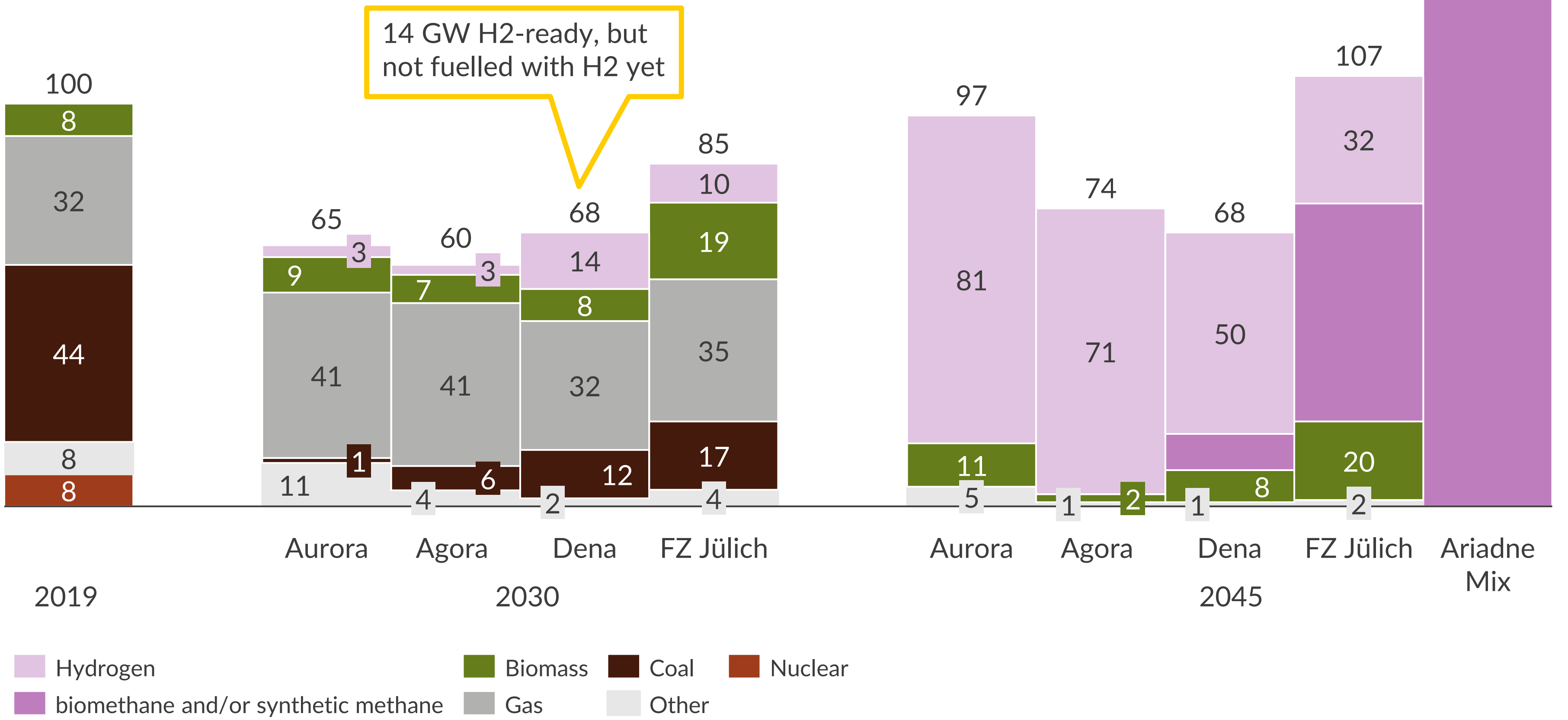
Dispatchable capacity by fuel[1]
GW



1) Includes hard coal, lignite, combined cycle gas turbines (CCGT) running on gas or H_2, open cycle gas turbines (OCGT) running on gas or H_2, oil peakers and biomass. Includes all kinds of combined heat and power plants (CHPs).
Source: Aurora Energy Research

Dispatchable capacity needs will increase until 2045

- Gas & its low carbon alternatives will play the largest role in providing flexible supply
- Consensus that >60 GW of its capacity is needed by 2030; span in 2045 much larger
- While H2 will play a major role in most studies, methane is favoured by some

Implications

- New gas capacities will need to be ready for refurbishment
- Co-existence of H2 & gas will be required for a transition phase – gas-fired plants will benefit from price-setting of more expensive technologies, unless fuel support payments are used to make H2 competitive

Key takeaways

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1. For reaching Net Zero in 2045, the power sector needs to decarbonise faster than any other sector and reach carbon neutrality several years before 2045.

2. Mainly driven by the electrification of other sectors, power demand will increase by at least 16% until 2030 - therefore, to reach climate targets, wind and solar capacity need to more than double. Given government‘s credible ambition, market participants should prepare for higher RES auction volumes and the resulting higher RES cannibalisation and power price volatility.

3. Security of supply requirements will rise especially post 2035. The current market design cannot be expected to deliver the required capacities as wholesale margins alone are too low and uncertainty regarding the substitution of gas with low-carbon alternatives discourages investments. Market participants should prepare for a reform.

4. Green hydrogen supply from both domestic sources and imports will still be scarce in 2030, with potentially high prices. Market participants should favor direct electrification options where possible for reaching emission reductions in the next decade. In the long-run, it is still unclear what role hydrogen will play in heavy transport and heating. Market participants should watch out for technology lock-ins in strategic decisions.

5. Operators of district heating grids should seek individual strategies for decarbonising them, as it is still unclear which technolgies will be most economic and optimal solutions will strongly depend on local conditions.

Details und Haftungsausschluss

The race to climate neutrality in Germany by 2045. What we can learn from recent studies.

Public Webinar, November 25 2021.

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