AURORA ENERGY RESEARCH

Net Zero in Poland: pathways and security of supply

Aurora Public webinar

21 April 2021

Agenda

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I. Introduction

II. Transformation to a carbon neutral power system

III. Security of supply

IV. Hydrogen and its role in the power system

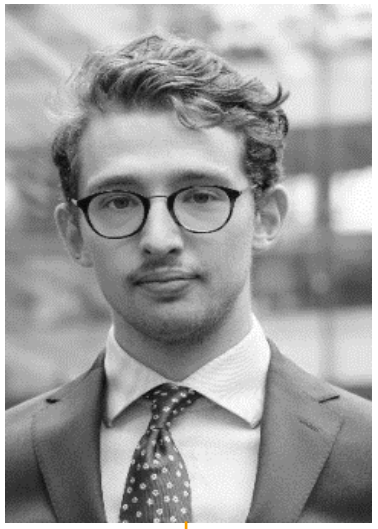
V. Closing remarks

Introducing Aurora's speakers

Hanns Koenig

Head of Commissioned Projects – Central EU

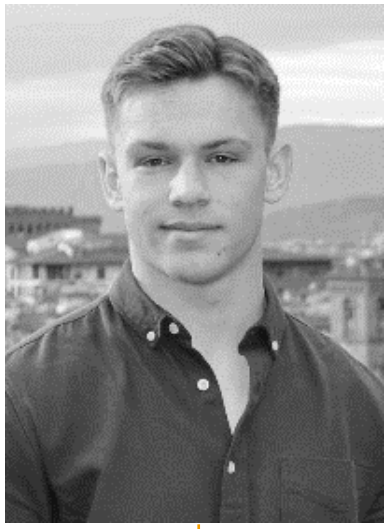
hanns.koenig@auroraer.com



Filip Piasecki

Associate Poland

filip.piasecki@auroraer.com



Grzegorz Walkowski

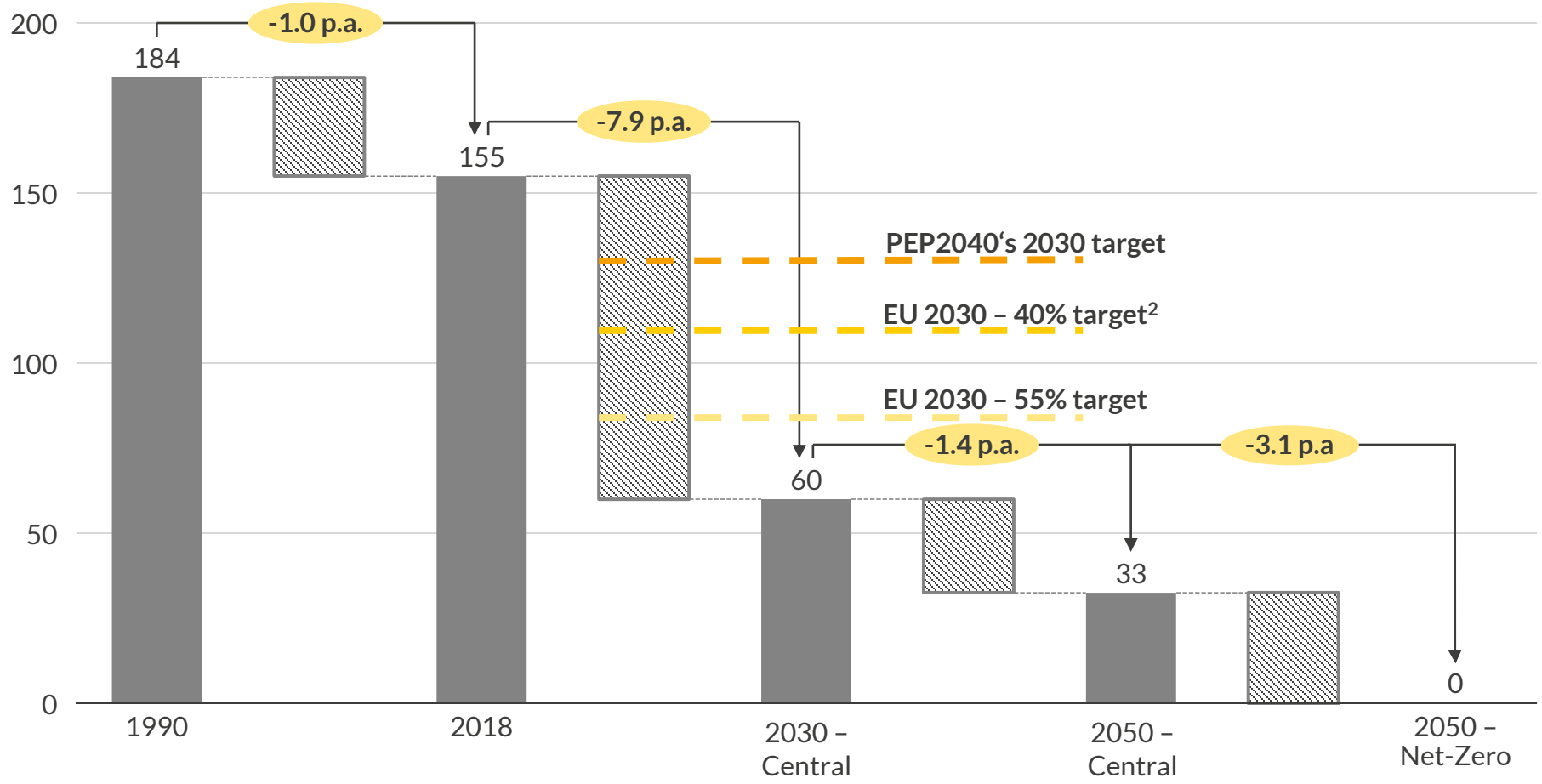
Commercial Associate Poland

grzegorz.walkowski@auroraer.com

Source: Aurora Energy Research

Without further policy interventions, the Polish power sector will not reach Net Zero by 2050

Polish power sector[1] emissions
Mt CO_2e



1) Includes power generation and CHPs. 2) Europe does not have a sector specific target yet, this is the target as a whole – range shows 40 to 55% reduction. 3) Compared to 1990 levels.

Sources: Aurora Energy Research, Polish Ministry of Climate and Environment, European Commission

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Polish climate commitments

- Poland's most up to date PEP2040 outlines a target of 30% emissions reduction[2] by 2030 which translates to 129 Mt CO_2e power sector emissions in 2030
- The Aurora Central scenario foresees an emissions reduction of 70% by 2030
- This reduction is driven an aging coal power fleet and rising ETS prices
- Nevertheless, Poland still fails to achieve Net Zero, emitting 33 Mt CO_2e in 2050; these emissions will be the hardest to abate

Today we will discuss the development of power prices & asset economics in a Net Zero Poland, highlighting the impact of nuclear

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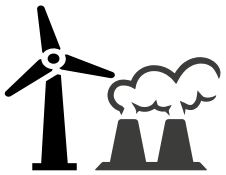
1 How can carbon neutrality be reached by 2050?

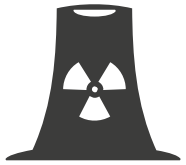
- How will electrification and the hydrogen switch affect power demand?
- How will power prices develop in a Net Zero world?
- What role can nuclear play and how will it affect the generation mix?

2 How can security of supply be ensured in a Net Zero power system?



- How much renewable capacity will be needed to match demand?
- How large will peak demand be and which thermal technologies will meet it?
- To what extend can nuclear buildout reduce the demand for new capacities?

3 What role will hydrogen play in achieving decarbonisation?



- How will the gas to hydrogen switch affect prices in scarce hours?
- How do electrolysers affect the economics of renewables?
- Can electrolysers improve the business case of nuclear?

Source: Aurora Energy Research

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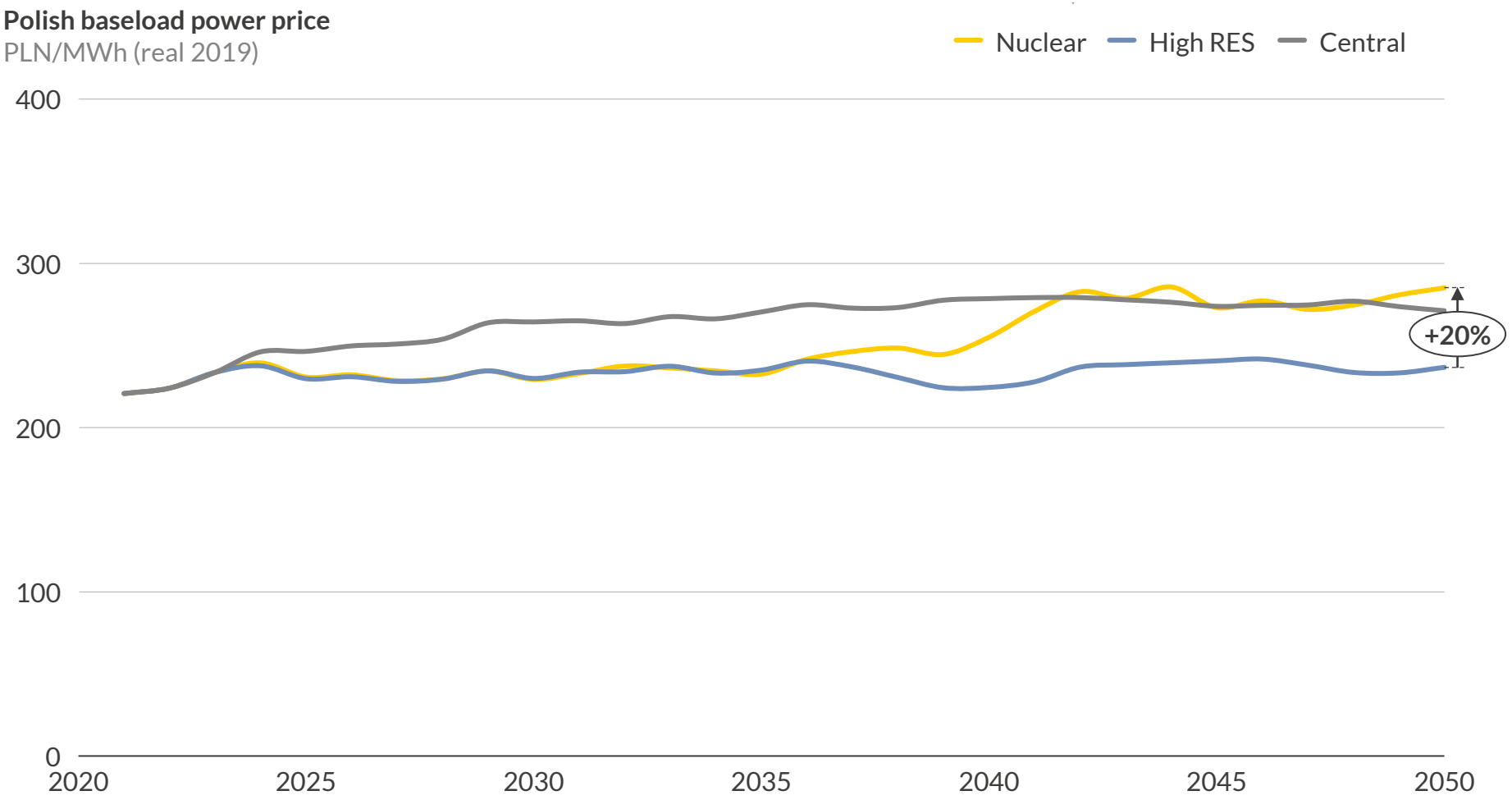
Lower RES generation in the Nuclear scenario raises the baseload price by 20% relative to the High RES scenario

Polish baseload power price
PLN/MWh (real 2019)



Source: Aurora Energy Research

High buildout of renewables can mean low power prices in a Net Zero world

- Nuclear generation reduces system intermittency meaning cannibalisation is reduced in periods of high RES production
- Less excess generation is available for hydrogen production and electrolysers are forced to buy more expensive power, with units higher up the merit order becoming marginal
- Electrolysers can raise power prices until the cost of the green H2 the produce exceeds the cost of blue H2, imposing an upper limit
- The price of hydrogen is consequently higher in the nuclear scenario, making dispatchable generation more expensive
- The two effects combine to cause higher baseload prices than in the High RES scenario

Poland's power demand will more than double in a Net Zero world, driven by electrification and electrolyser demand

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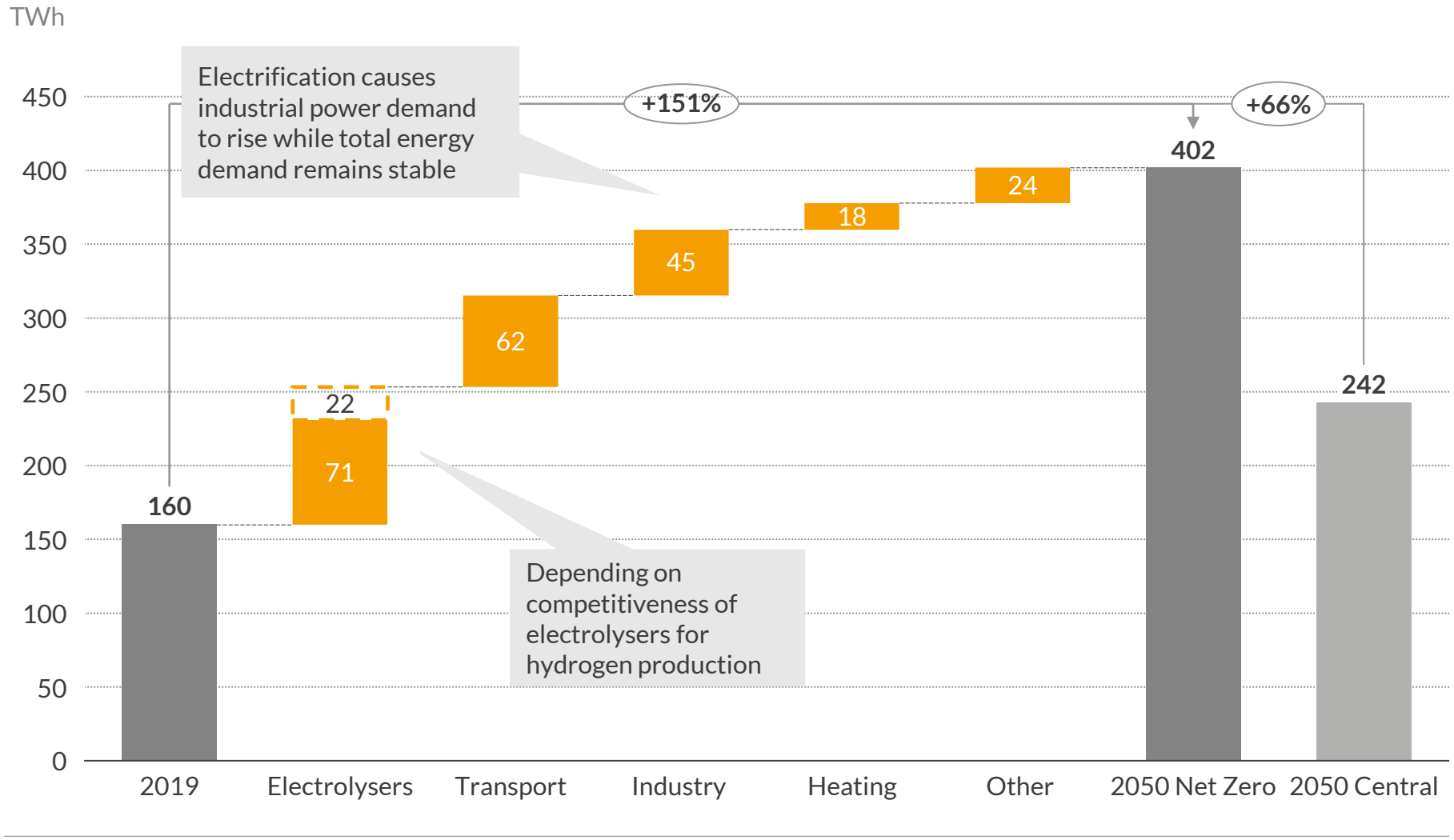
Total net zero power demand

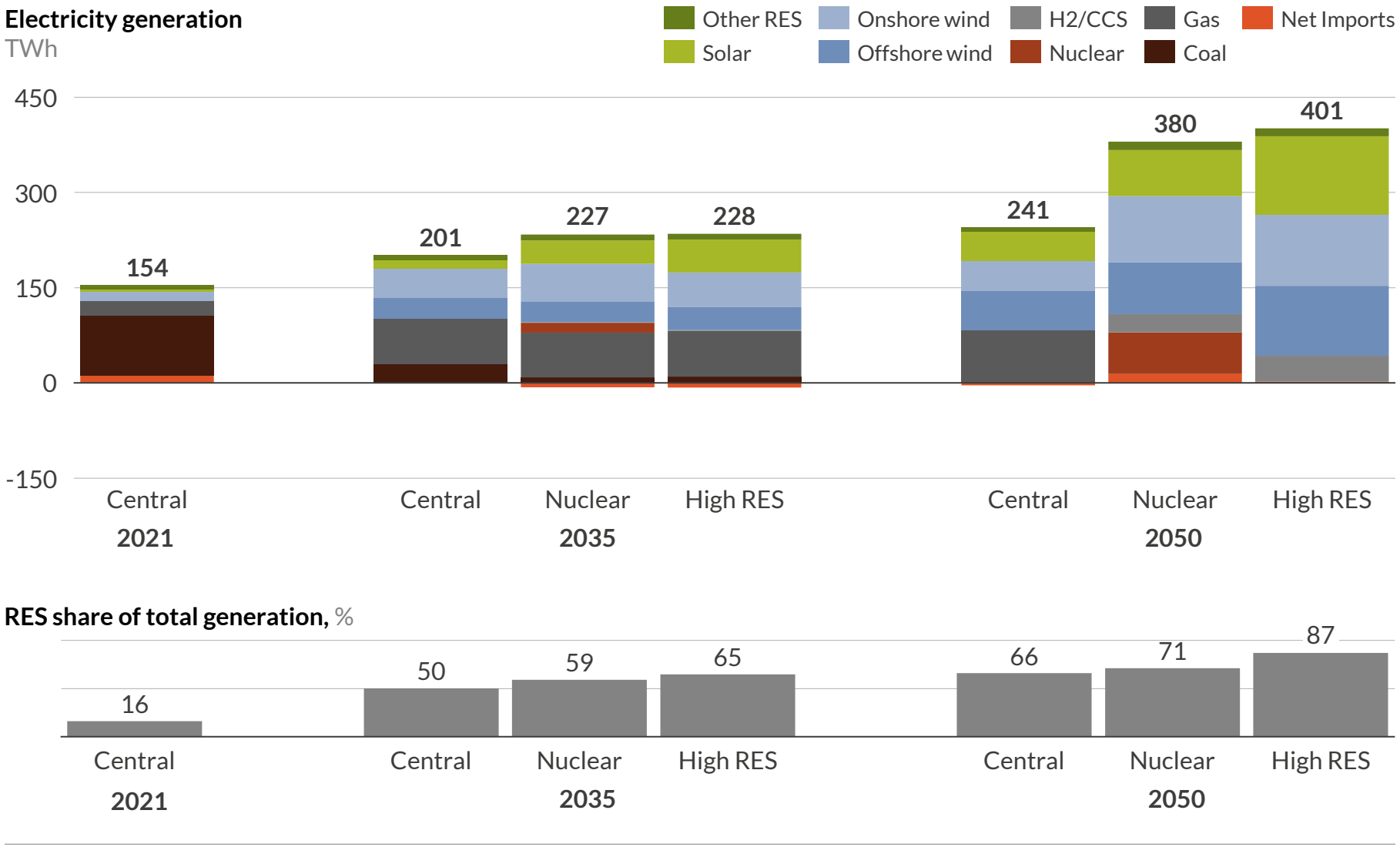


Rise in power demand is driven mostly by electrolysers and electrification

- To achieve carbon neutrality, Poland's power demand will rise by 150%, reaching 402 TWh in 2050
- Industry will add 45 TWh, driven by electrification
- Hydrogen demand will require up to 95 TWh of additional power generation
- Electrolysers and EVs transform the nature of power demand, providing flexibility and improving the integration of renewables
- Base power demand rises by just 69 TWh, with 45 TWh from industry and 24 TWh from the commercial sector and households

Source: Aurora Energy Research

Dispatchable generation remains necessary to cover scarce periods; nuclear reduces RES share of generation by running at baseload



Dispatchable generation is needed to cover around 10% of demand in 2050, the rest can be met by RES

- RES generation rises more than fifteen fold compared to current levels
- Thermal generation does not decline completely, falling by around 65 percent by 2050
- This is due to hours of low RES generation, as well as the importance of CHPs in Poland.
- CHPs decarbonise largely through hydrogen switching as biomass potential is limited and CCS is not a viable long-term solution for high LF plants
- 9 GW of nuclear is enough to cover 17% of demand in 2050
- Imports are higher in the Nuclear than the High RES scenario due to higher wholesale prices

Source: Aurora Energy Research

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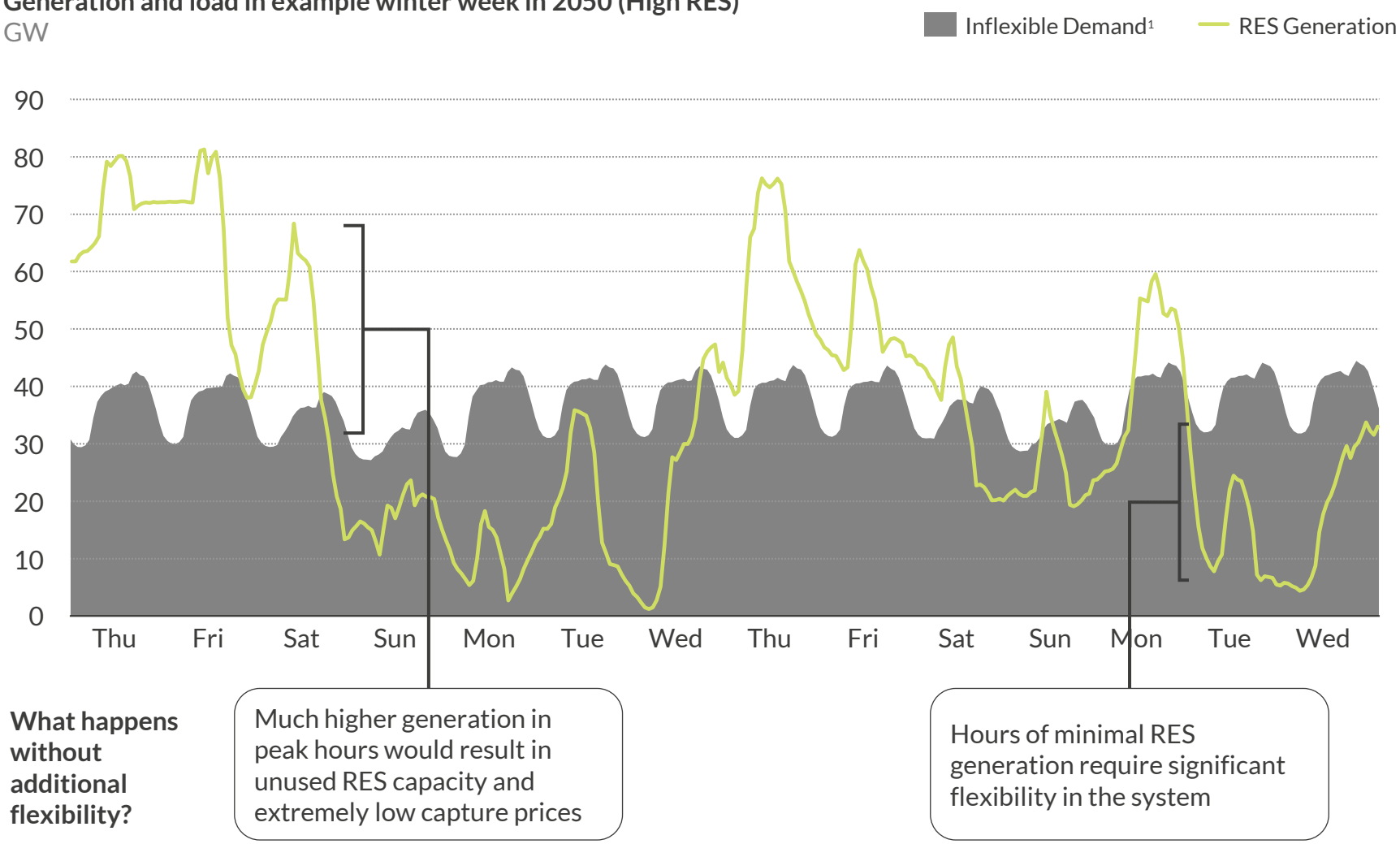
The high share of renewables needed for Net Zero creates a significant mismatch between RES generation and base demand

Generation and load in example winter week in 2050 (High RES)
GW



1) total demand minus power demand from electrolysers, EVs, heat pumps, and exports.

Source: Aurora Energy Research

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- The inherent variability of renewable resources means that significant flexibility is necessary to match supply and demand
- Two base types of flexibility are necessary:
- Fast ramping, backup capacity to cover hours of low RES generation
- Flexible demand that will utilise surplus power produced during peak RES generation hours
- Failure to do so both underuses invested assets and decreases capture prices

Hydrogen, interconnectivity and flexible demand all help to match supply and demand

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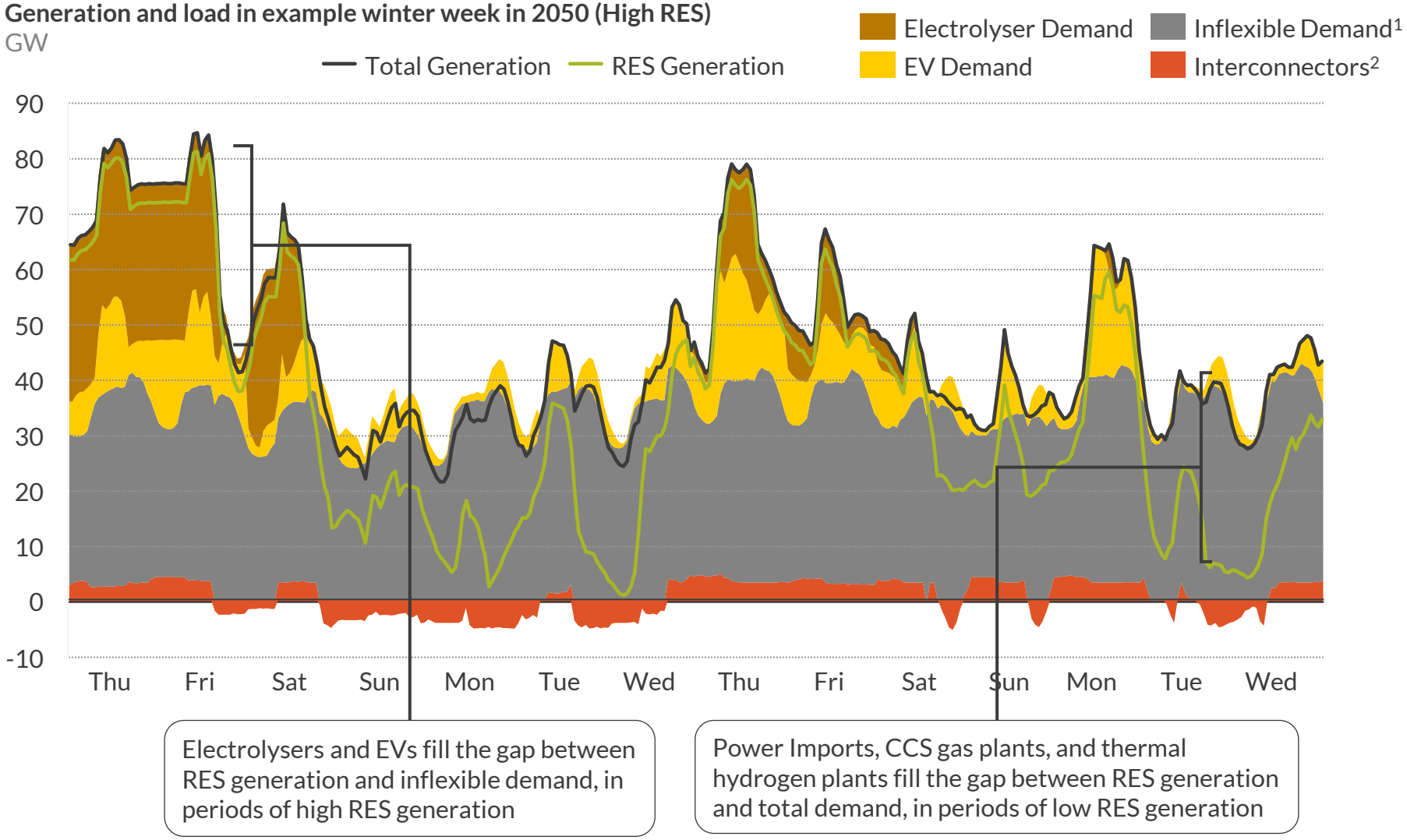
Generation and load in example winter week in 2050 (High RES)



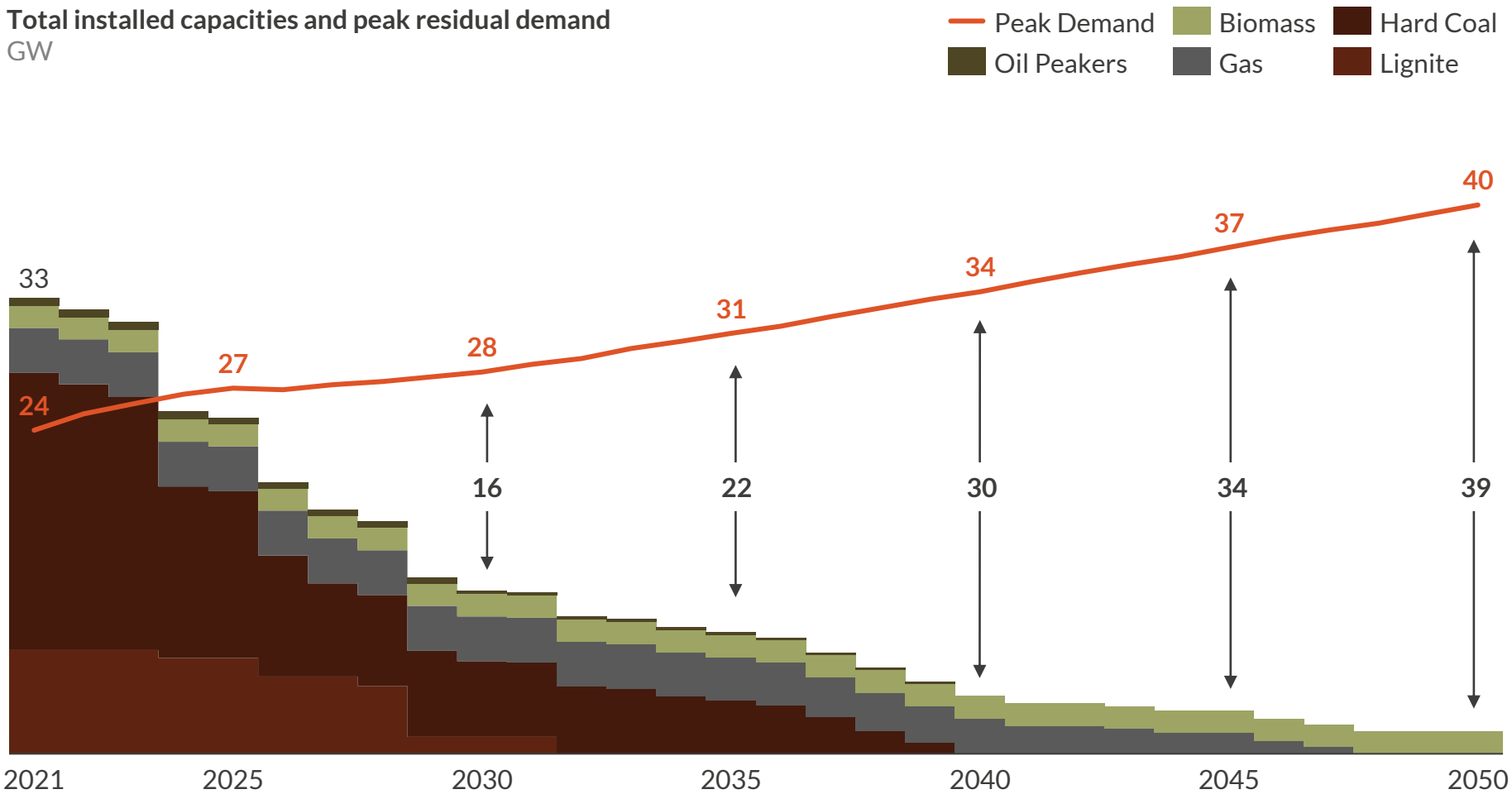
- EVs, electrolysers, and heat pumps (HPUs) provide an enormous amount of flexible demand, allowing effective use of renewables' generation curves.
- Thermal capacity, primarily hydrogen, and interconnectors provide flexible supply, covering any residual demand[3] and providing fast ramping capacity.

1) Including heat pumps. 2) Net import/export balance. 3) Total load net of RES production.

Source: Aurora Energy Research

Peak demand rises to 40 GW; as existing assets leave the market, new dispatchable capacities are required to ensure security of supply

Total installed capacities and peak residual demand
GW



Source: Aurora Energy Research

The Capacity Market will need to remain in place to ensure security of supply

- Without substantial new investments, there will be a capacity gap from 2025 onwards
- Most hard coal and lignite plants become unprofitable once their capacity market contracts expire in 2025-7.
- The capacity market target will reach 44 GW by 2050, demanding a full rebuilding of the dispatchable system
- Peak residual demand occurs when RES production is almost zero, meaning the capacity market must procure dispatchable capacities
- Certainty over the future of the capacity market and policy support for a gas to hydrogen switch is needed to enable new investments

Around 9 GW of nuclear capacity reduces system needs for other clean dispatchable technologies such as hydrogen and gas CCS

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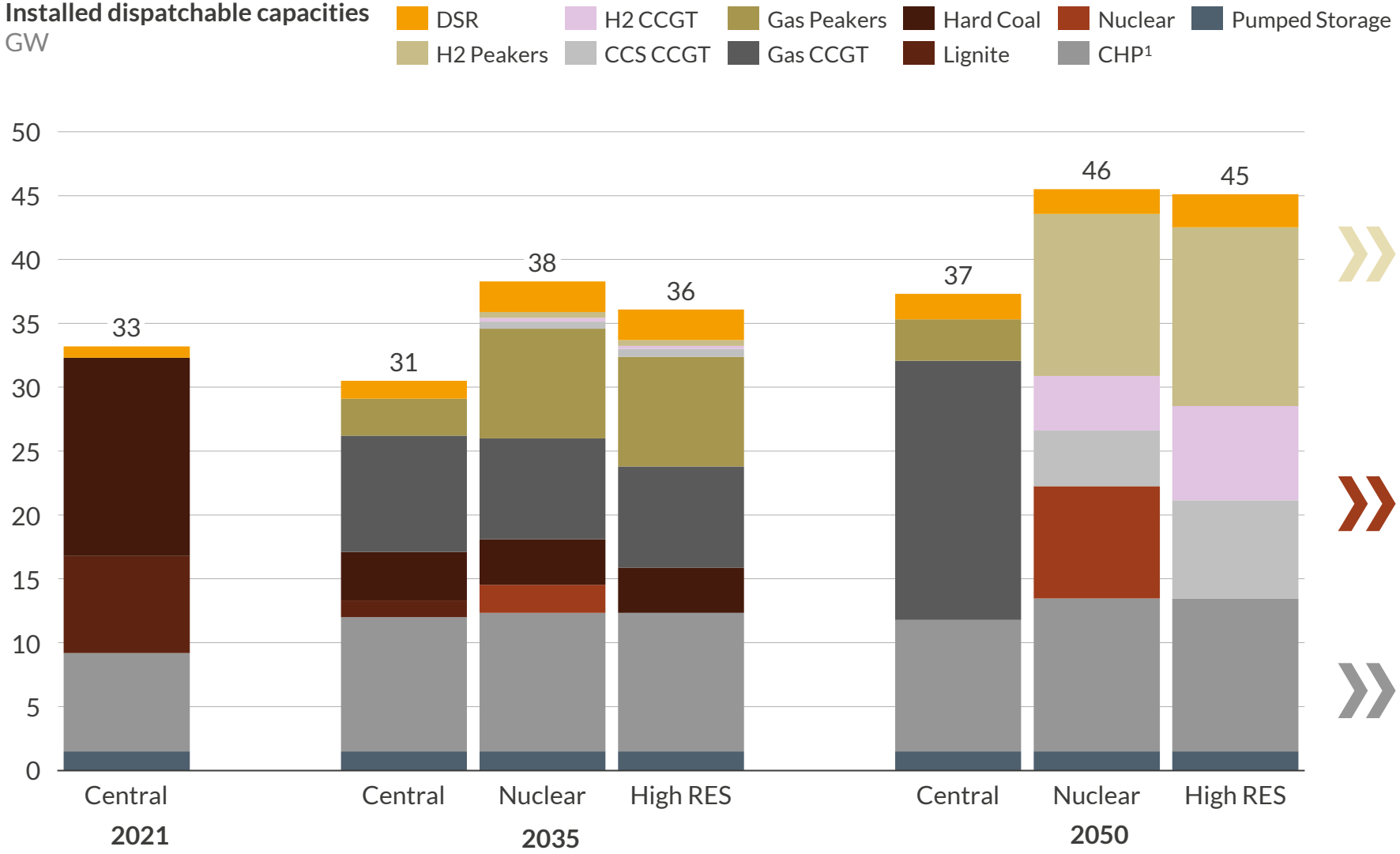
Installed dispatchable capacities
GW



Peakers

- OCGTs cover increasingly large residual demand peaks but have very low full load hours
- Less solar in nuclear scenario reduces the peak residual load

Nuclear

- Nuclear runs close to baselaod
- Reduces load factors for CCS
- Reduces amount of hydrogen capacity required

Combined Heat and Power

- CHP capacity is set by district heating demand
- CHPs will become increasingly electricity-led, providing additional flexibility

1) CHPs in 2050 Net Zero run on hydrogen and biomass. In central view CHPs in 2050 run on gas

Source: Aurora Energy Research

Both Net Zero scenarios require a significant acceleration of renewable buildout compared to historical levels

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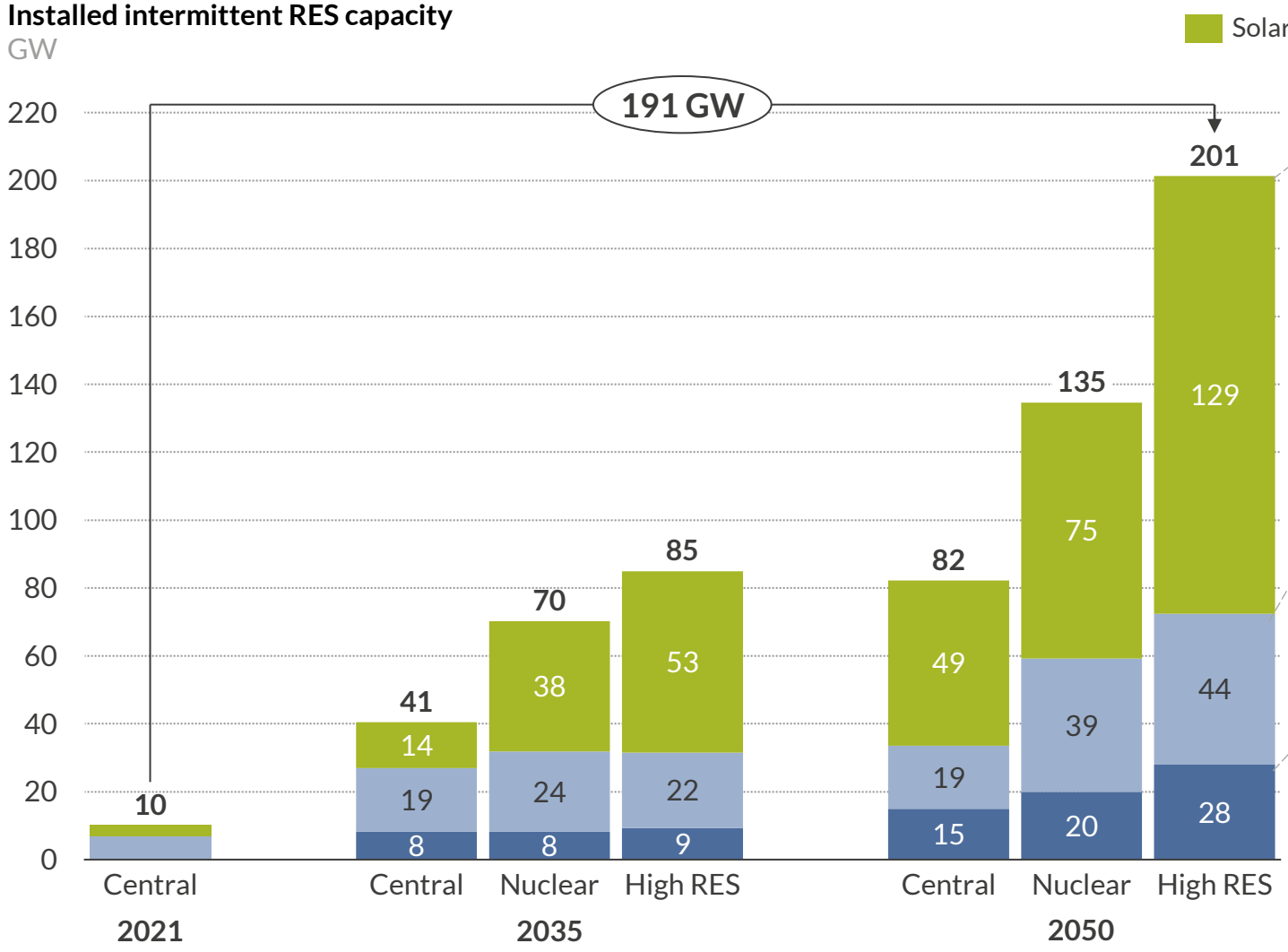
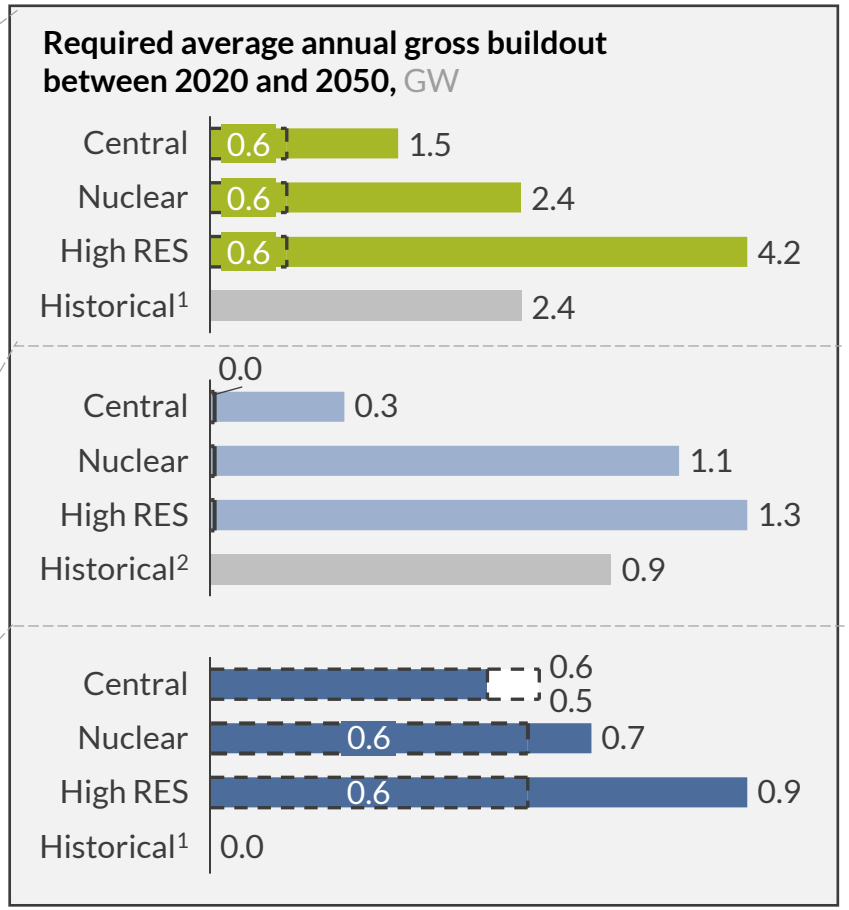
Installed intermittent RES capacity
GW



Required average annual gross buildout between 2020 and 2050, GW



1) Based on 2015-2020 data from GUS and Forum Energii. 2) Historical data prior to the introduction of the "10h" rule in Poland in 2016.

Sources: Aurora Energy Research, Polish Ministry of Climate and Environment, GUS, Forum Energii

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Integrating electrolysers and hydrogen turbines into a market raises power prices in periods both with high and low renewables production

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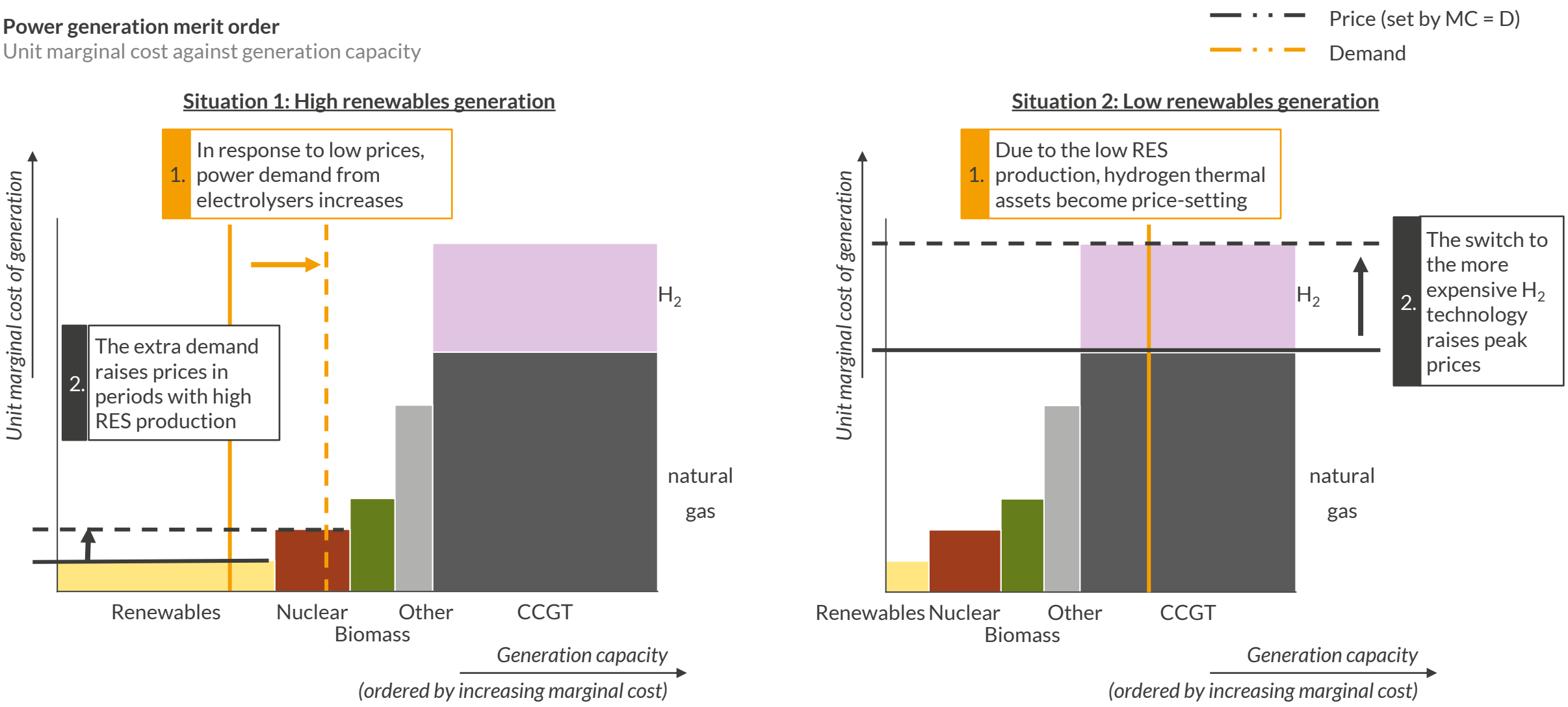
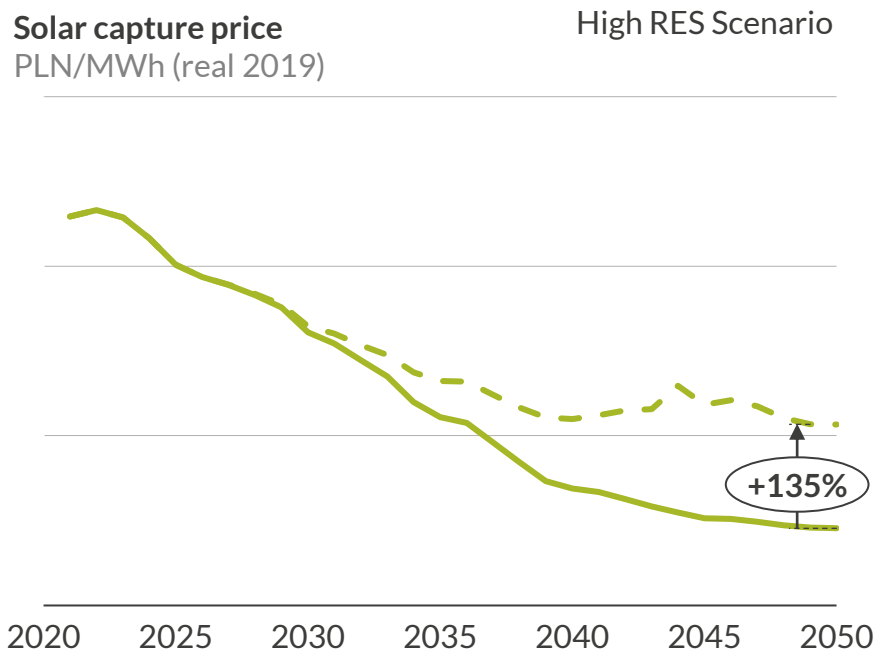
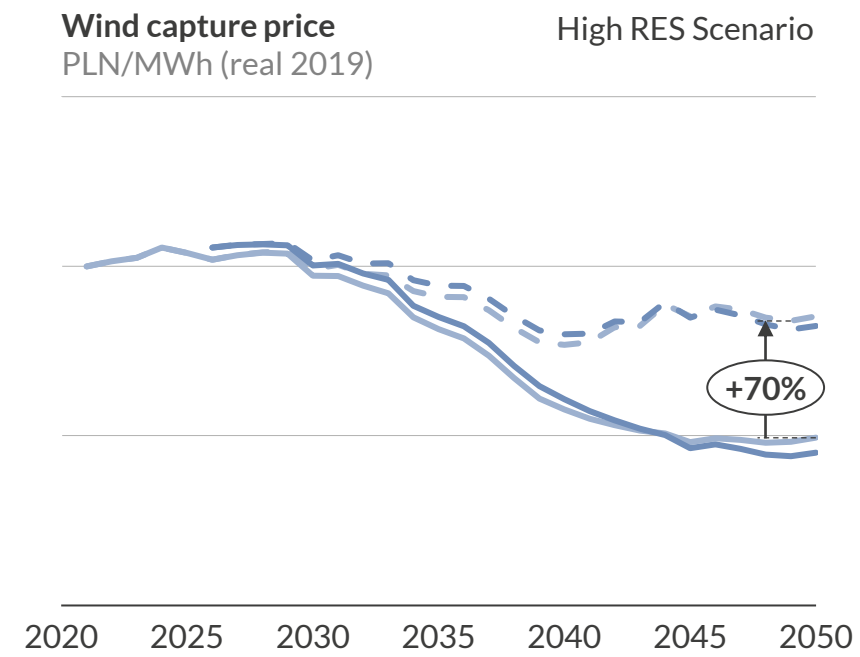
Power generation merit order
Unit marginal cost against generation capacity

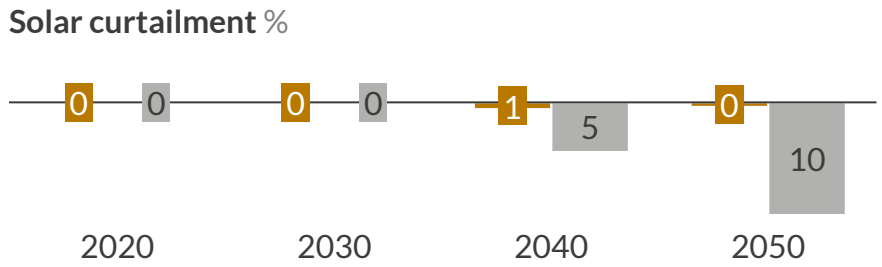


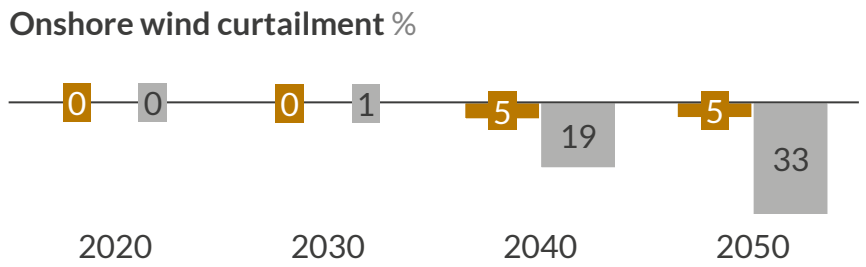
Source: Aurora Energy Research

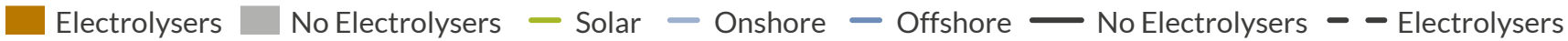
Electrolysers prevent curtailment and support capture prices, improving RES revenues by over 150%











Source: Aurora Energy Research

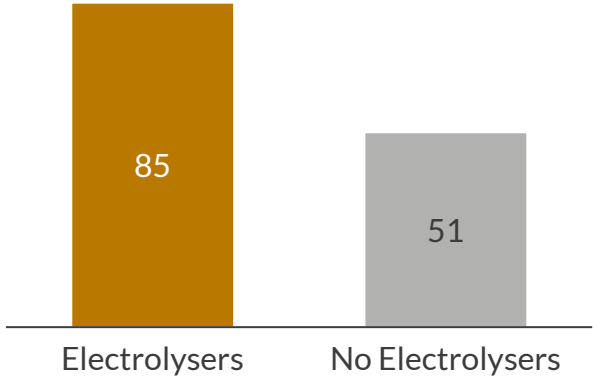
By providing flexible demand, electrolysers prevent curtailment in all but the highest RES generation hours

- Electrolysers, together with smart charging EVs, provide flexible demand to match RES intermittency
- Electrolysers buy electricity to meet H2 demand until they are no longer competitive with blue H2 production
- This shifts the marginality higher up the merit order and RES benefits from higher prices
- Reduced curtailment prevents 73 TWh of wasted renewable generation
- Electrolysers produce cheaper hydrogen than is available through imports but raise baseload prices by making RES generation more expensive

Electrolysers improve nuclear load factor by creating additional demand in high RES hours, increasing revenues by 46%

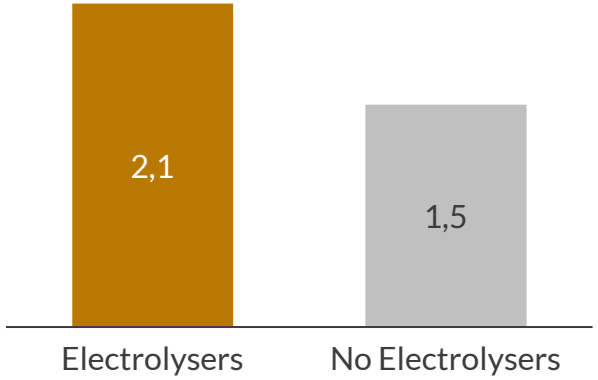
Load Factor in 2050[1]

%



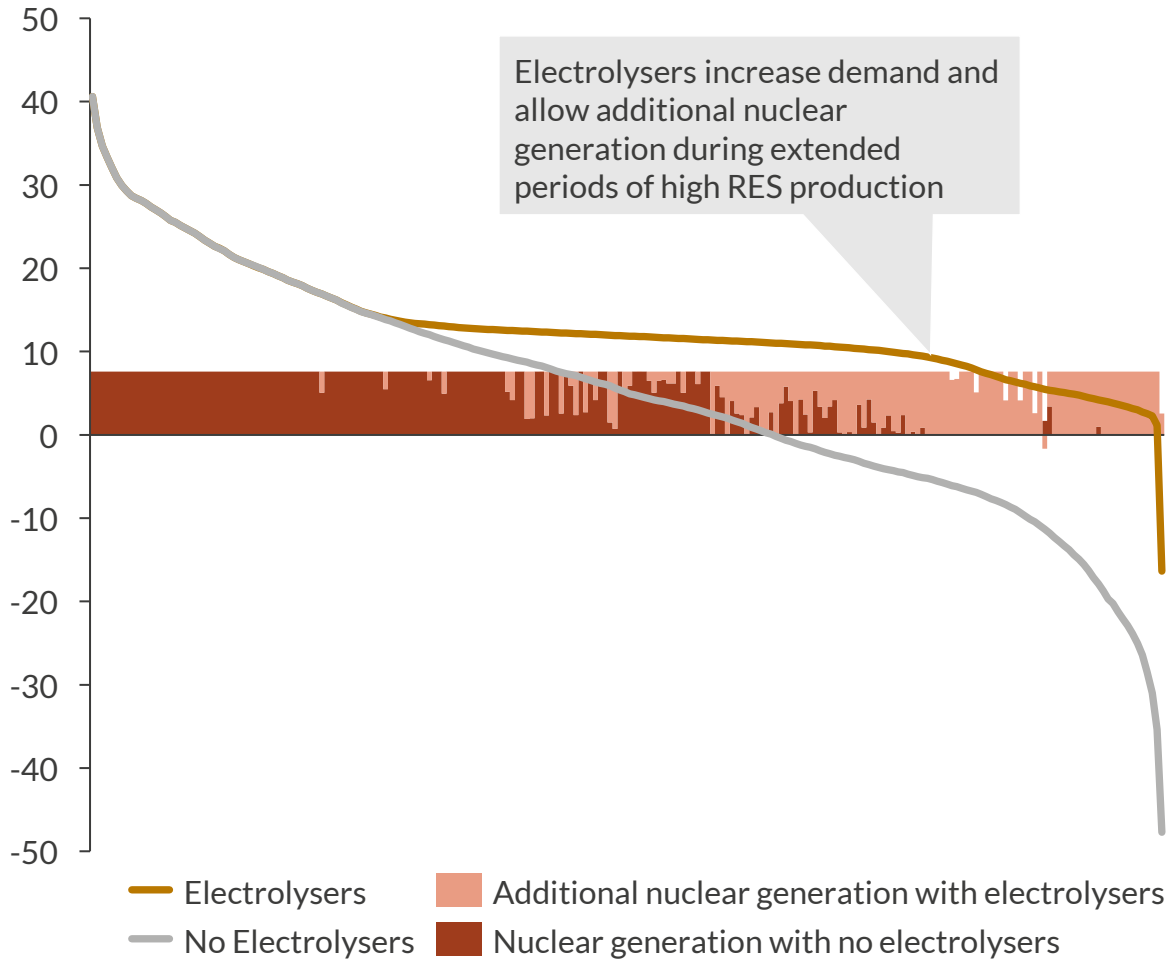
Annual revenue in 2050

mPLN/MW (real 2019)



Residual load and nuclear generation in 2050

GW



1) Nuclear is assumed to have an availability of 86%

Source: Aurora Energy Research

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Electrolysers allow nuclear to fit into the system much more effectively

- Electrolysers flatten the residual load curve, making it more suitable for high load factor technologies such as nuclear
- Electrolysers provide demand side responsiveness which compensates for nuclear's inflexibility
- In hours where it is not marginal nuclear benefits from high prices set by hydrogen and CCS
- Electrolysers provide cheaper hydrogen than imports, lowering nuclear capture prices – however this is a much smaller effect compared to curtailment

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Key take-aways

- Net zero more than doubles Polish power demand to ~400 TWh, driven by electrification in industry, heating and transport, as well as due to demand from electrolysers
- Net zero wholesale power prices are lower or similar to non-net zero power prices; the addition of nuclear to the system leads to a 20% increase in power prices over RES based decarbonisation
- 201 GW of renewable capacity will be needed in 2050 to achieve Net Zero without nuclear power
- 45 GW of dispatchable capacity will be needed to ensure security of supply in an increasingly intermittent system. Even with nuclear in the system, most of this will need to be in the form of flexible hydrogen-burning capacities
- Flexible demand from electrolysers will significantly improve the economics of renewables and nuclear alike, by increasing capture prices and effective running hours

Source: Aurora Energy Research

Polish Power Market Service

Key market analyses and forecasts for all participants in the Polish power market

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Quarterly data & bi-annual market reports to assess business models

- **Forecasts with annual granularity** under central, low, high and Net Zero scenarios reaching 2050
- **Wholesale prices** and price distributions
- **Capacity development** and generation mix,
- **Capture prices and further analytics** for wind and PV
- **Utilisation rates** of key thermal technologies along different efficiencies, dark and spark spreads
- **Capacity market clearing price** forecast
- **Commodities** and ETS carbon price forecasts
- **Additional packages** with monthly and hourly data granularity

Group Meetings and Strategic Insight Reports

- **In-depth thematic reports** on topical issues
- **Three multi-client roundtable discussions** per year in Warsaw to discuss reports with actors across the Polish power market (utilities, developer, investors, project finance, government, regulation)
- **Upcoming topics:**

1- European Green Deal and EU-ETS reform

2- Opportunities and risks for Polish renewables

  - The structure of Poland‘s CfD scheme leaves merchant exposure and provides the opportunity to maximise revenues through spot market participation

Interaction through workshops and ongoing support

- **Bilateral workshops** at your office discuss specific issues on the Polish market
- **Ongoing availability** (calls, access to market experts, modellers) to address any questions across European power markets
- Discounted invitations to Aurora’s annual **Spring Forum**

All intelligence for a successful business, based on bankable price forecasts

For more information, please contact
Grzegorz Walkowski, Commercial Associate
✉ **Grzegorz.walkowski@auroraer.com**
☎ **0044 7939 260 763**

Source: Aurora Energy Research

Our Polish research agenda continues… get in touch if you have any questions or would like to discuss in detail

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Next topics in Aurora's Polish Power Market Group

European Green Deal and ETS Reform (August)

- Investing in renewables: risks and opportunities under the CfD and Green Certificate schemes
- The unique structure of Poland's CfD scheme leaves merchant exposure and provides the opportunity to maximise revenues through spot market participation
- We analyse the risks and potential upsides for RES developers, investors and financiers

Opportunities and risks in Polish renewables (November)

- Investing in renewables: risks and opportunities under the CfD and Green Certificate schemes
- The unique structure of Poland's CfD scheme leaves merchant exposure and provides the opportunity to maximise revenues through spot market participation
- We analyse the risks and potential upsides for RES developers, investors and financiers

- Email grzegorz.walkowski@auroraer.com for more information

Multi-client study on Hydrogen in Poland: additional deep dives on the emerging Polish hydrogen economy in two workshops

1st Workshop: Demand & Technologies

- Detailed hydrogen demand development by sector (industry, transportation, households, power)
- Technology outlook for hydrogen technologies (electrolysers, blue, turquoise)
- The potential for hydrogen storage in Poland
- Possibilities for the transmission and distribution networks

2nd Workshop: Regulatory & Investment Opportunities

- Discussion of existing policy frameworks and their impact on the hydrogen economy
- Policy recommendations based on Aurora's modelling results
- Quantitative analysis of the foreseen effects of such policies

- Study commencing in mid April
- Email hanns.koenig@auroraer.com for more information

Source: Aurora Energy Research


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