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ENERGY RESEARCH

Unveiling Tomorrow: The Swiss Power Market until 2060

REDACTED VERSION

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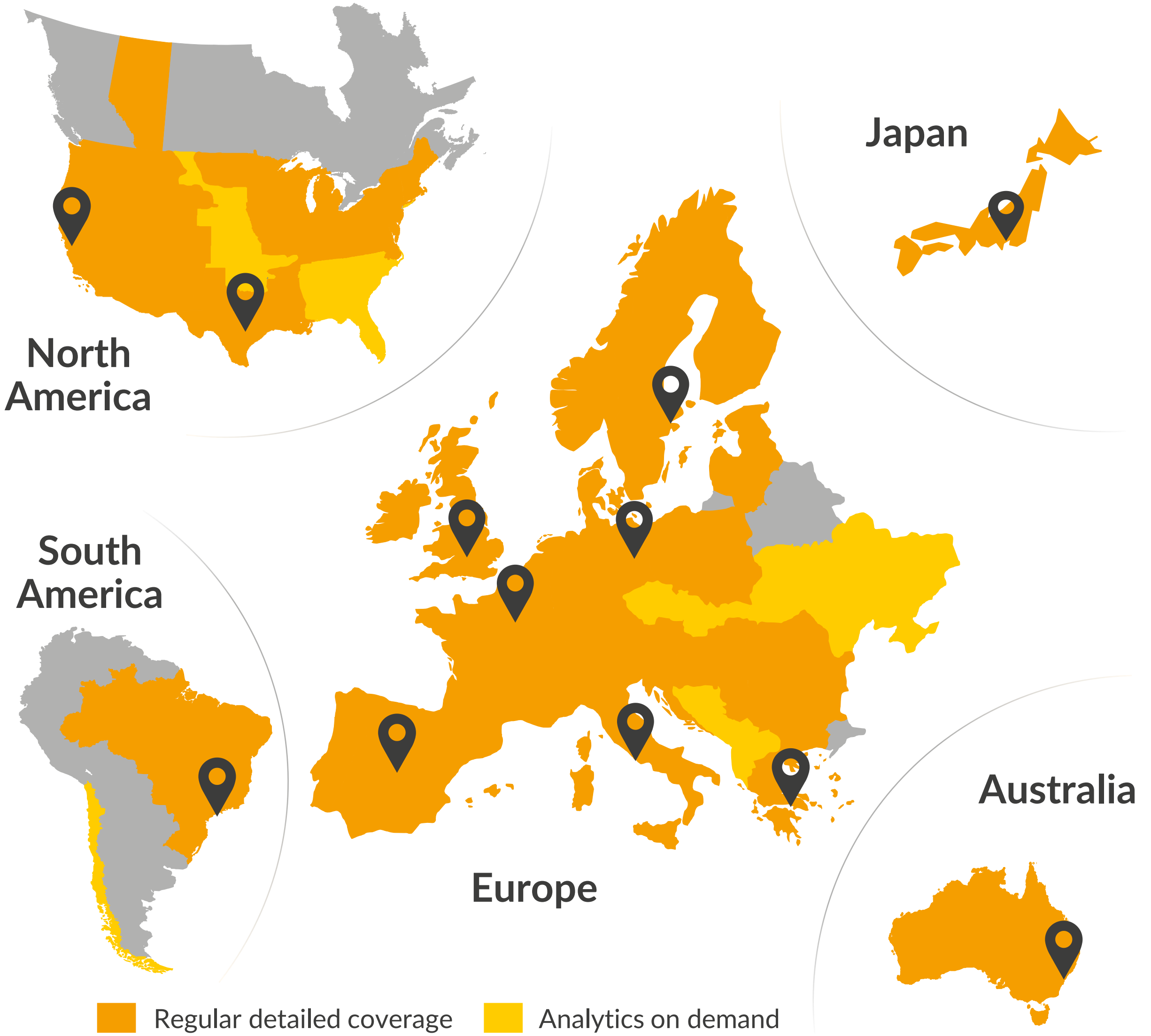

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> *"With its capabilities, intellect and with its credibility Aurora plays an essential role bringing the dialogue [in the global energy transition] to a different plane"*
>
> **Ben van Beurden, CEO, Shell**

> *"Aurora analysis and the provision of reliance was crucial for our debt funding. Their ability to explain market logics and revenue streams was vital for this successful financing."*
>
> **Jeremy Taylor, Director, Green Frog Power**

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Policy & regulation

Source: Aurora Energy Research

Agenda

After a rapid decline post-2024, Swiss baseload prices continue to gradually decrease from [redacted] €/MWh in 2030 to [redacted] €/MWh in 2060

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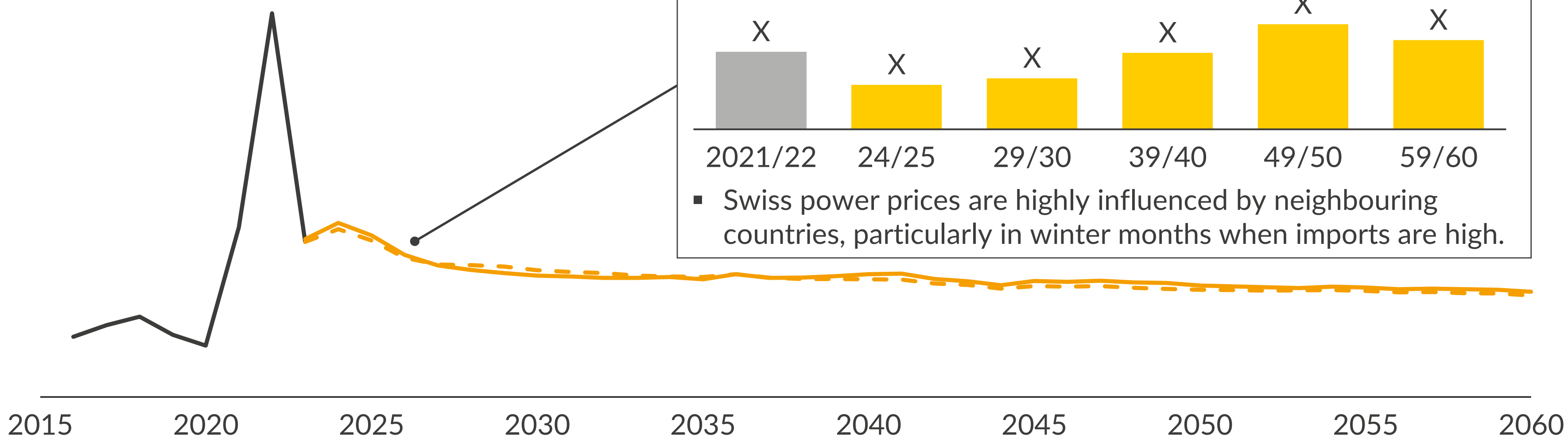
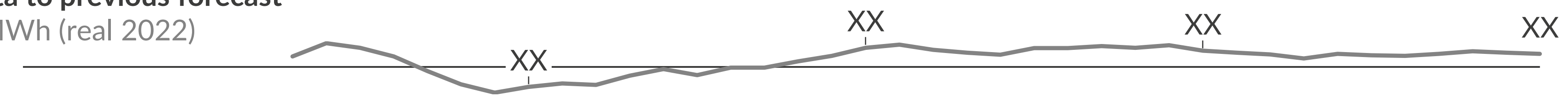
Baseload wholesale electricity price
€/MWh (real 2022)



- Swiss power prices are highly influenced by neighbouring countries, particularly in winter months when imports are high.

Delta to previous forecast[1]
€/MWh (real 2022)



- After a price increase until 2027, driven through higher gas prices reflecting an increase in futures prices, baseload prices fall below our previous forecast until 2035, with the average delta of -[redacted] €/MWh ([redacted]%) reflecting lower gas prices in this period.
- Post-2035, power prices slightly rise above our previous forecast, with prices being [redacted] €/MWh ([redacted]%) higher on average. While updated power demand and load factor assumptions for ground-mounted solar lead to slight downward price pressure, these effects are overcompensated by lower solar capacity in neighbouring countries (due to higher CAPEX costs) and lower availability of batteries in the Swiss wholesale market, driving up power prices.

Historical baseload — Baseload — Previous baseload[1] — Delta

2023-30

- Baseload prices drop to [redacted] €/MWh by 2030, as declining gas prices depress power prices in neighbouring countries, causing a knock-on effect in Switzerland during the import-intensive winter months.

2031-45

- Baseload prices fall from [redacted] €/MWh by [redacted] €/MWh ([redacted]%), as upward pressure from increasing power demand and the gradual phase-out of nuclear is overcompensated by increasing RES buildout, in particular solar.

2046-60

- Power prices decrease further to [redacted] €/MWh by 2060 due to continued renewables deployment in Switzerland and neighbouring countries, even as demand increases with decarbonisation.

1) Refers to Aurora's preliminary market outlook for Switzerland, presented during the 2nd workshop of the Swiss Multi-Client Study in Zurich on 5 September 2023. 2) Winter half-years are considered from 1 October to 31 March.
Sources: Aurora Energy Research, ENTSO-E

Solar capture prices are on average [redacted]% below baseload prices until 2030, with the discount increasing to [redacted]% post 2050

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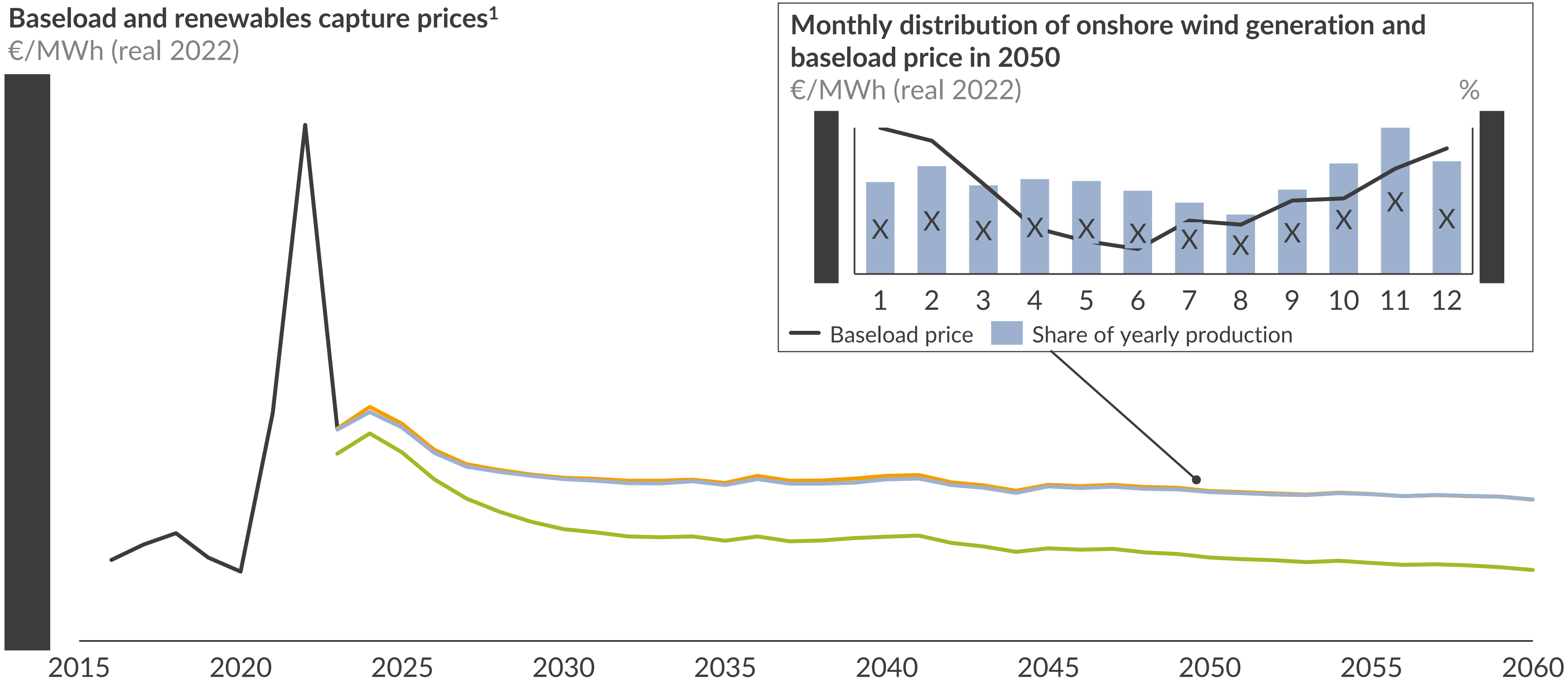
Baseload and renewables capture prices[1]
€/MWh (real 2022)



Average discount to baseload	2023–2030	2031–2040	2041–2050	2051–2060
Solar	XX	XX	XX	XX
Onshore wind	XX	XX	XX	XX

Historical baseload — Baseload — Onshore wind — Solar

1) Uncurtailed generation-weighted capture prices.

Source: Aurora Energy Research

Outlook for renewables

Solar

- As we forecast significant solar buildout, capture prices decrease from [redacted] €/MWh in 2023 to [redacted] €/MWh in 2060 reflecting rising cannibalisation. Discounts to baseload prices increase continuously from [redacted]% in 2023 up to [redacted]% in 2060.
- Given these capture price levels, solar buildout will largely rely on subsidies. Taking a conservative view on discount rates ([redacted]% real, pre-tax) and a moderate view on load factors ([redacted] % for ground-mounted assets), we expect merchant buildout to be unprofitable.

Onshore wind

- Due to very small buildout and increasing benefits from high power prices in winter, onshore wind capture prices are largely aligned with baseload prices.

Growing intermittent capacity results in high price volatility, with standard deviation in prices exceeding [redacted] €/MWh by 2050

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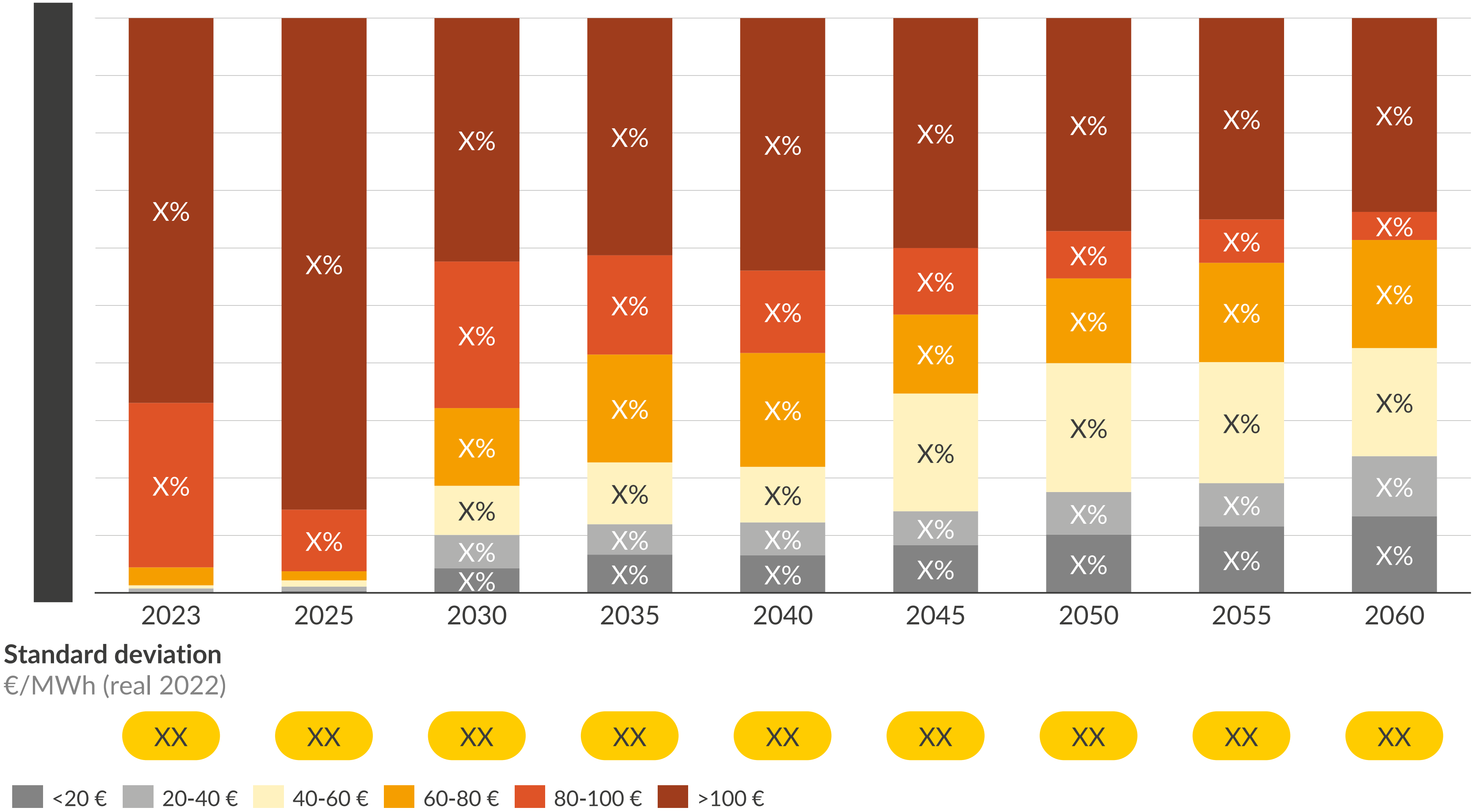
Frequency distribution of the electricity price (real 2022)
%



1) Short-run marginal costs.

Source: Aurora Energy Research

Outlook on price distributions

- Following the rebalancing of prices until the mid-2020s, power price volatility increases significantly in the long term, with the standard deviation doubling between 2025 and 2060.
- Volatility is mostly driven by the increase in low-price hours (<[redacted] €/MWh), whose frequency grows by [redacted] p.p. between 2025 and 2060, reflecting a high buildout of renewables with low SRMC[1], in particular solar.
- Benefitting from more low-price hours, flexible applications – batteries, EVs, and, to a lesser extent, electrolysers – increasingly penetrate the system, mitigating the growth in volatility in the medium term, where power prices in the medium range ([redacted]-[redacted] €/MWh) become more frequent.

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European gas prices drop through 2027 before rising steadily with global demand, as competition for LNG increases

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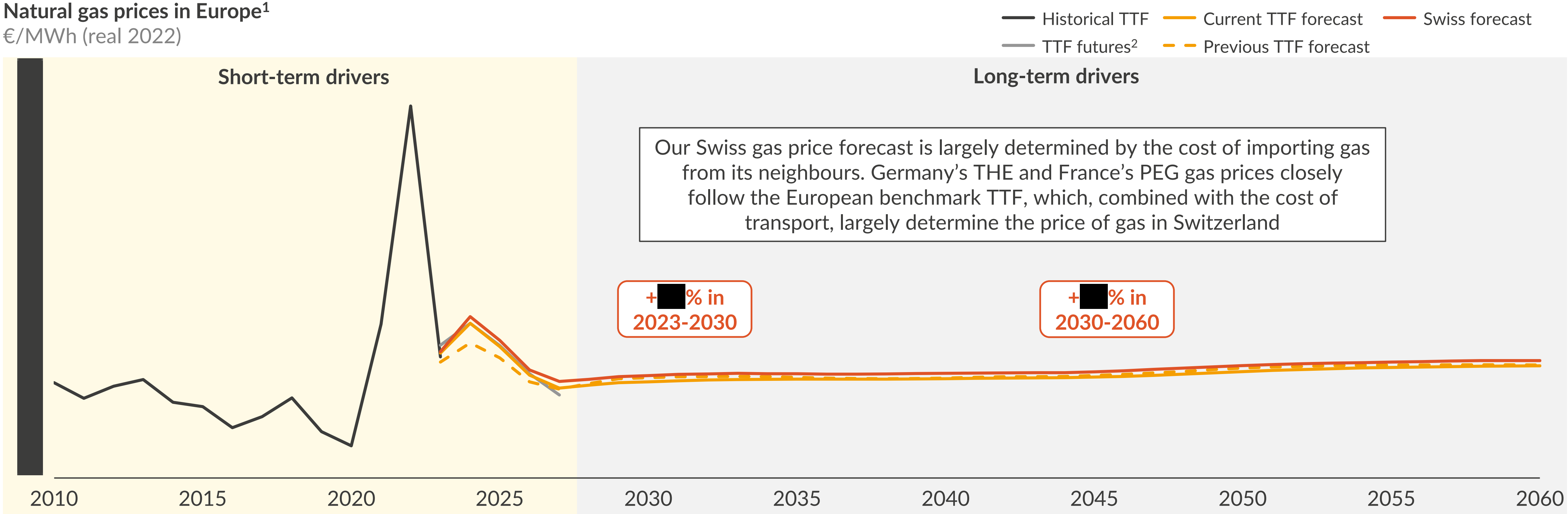
Natural gas prices in Europe[1]
€/MWh (real 2022)



Short-term drivers

1. The TTF gas price averages [redacted] €/MWh in 2023-2027, [redacted]% higher than the previous forecast.
2. By 2027, prices fall to [redacted] €/MWh as global liquefaction infrastructure expands. Competition from Asian importers supports global LNG prices, but the sharp rise in supply and decline in European demand keeps prices from climbing.

Long-term drivers

1. The gas price between 2028 and 2060 averages [redacted] €/MWh, [redacted] % lower than the previous forecast partly due to higher production than previously expected.
2. The global LNG market grows and becomes more spot-dominated as European production falls, increasing the continent's reliance on LNG.
3. Increasing Asian gas demand and appetite for LNG drive competition for cargoes with Europe.
4. Extraction costs rise as lowest-cost fields are depleted, supporting price growth.
5. Rapid renewables and electrification drive down European gas demand.

1) For years 2023-2028, the prices shown take into account current futures prices for the years in question, with declining weights. In 2023, forecast prices include historical prices up to Aug-23. 2) A rolling 14-day average as of 1 September 2023.

Sources: Aurora Energy Research, Refinitiv

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Swiss power demand remains closely aligned with our previous forecast, rising to [redacted] TWh in 2060, mostly driven through EV uptake

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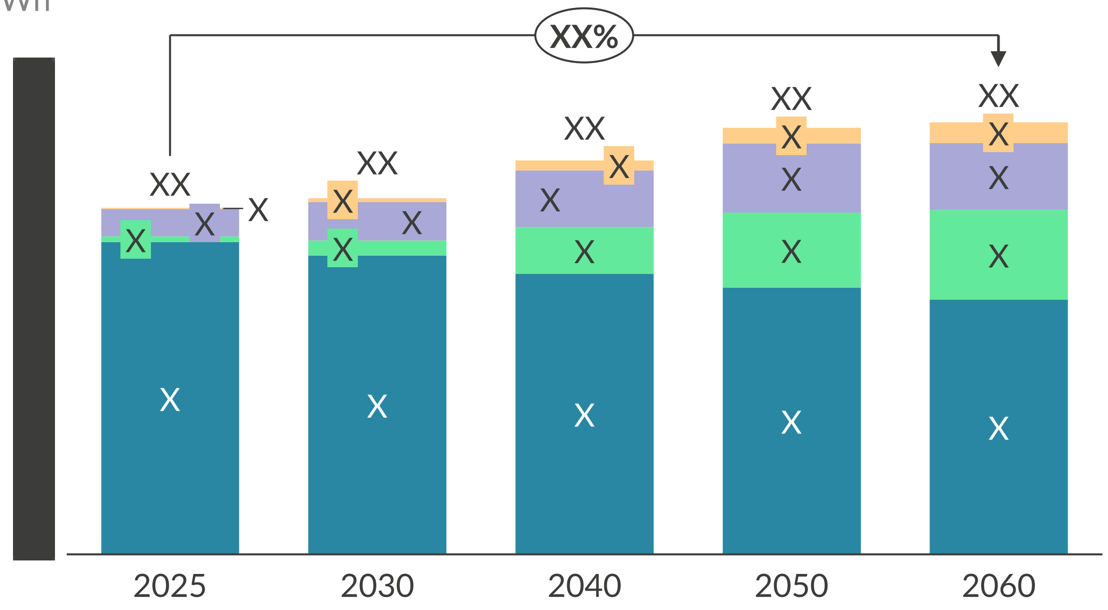
Net annual power demand by type[1]

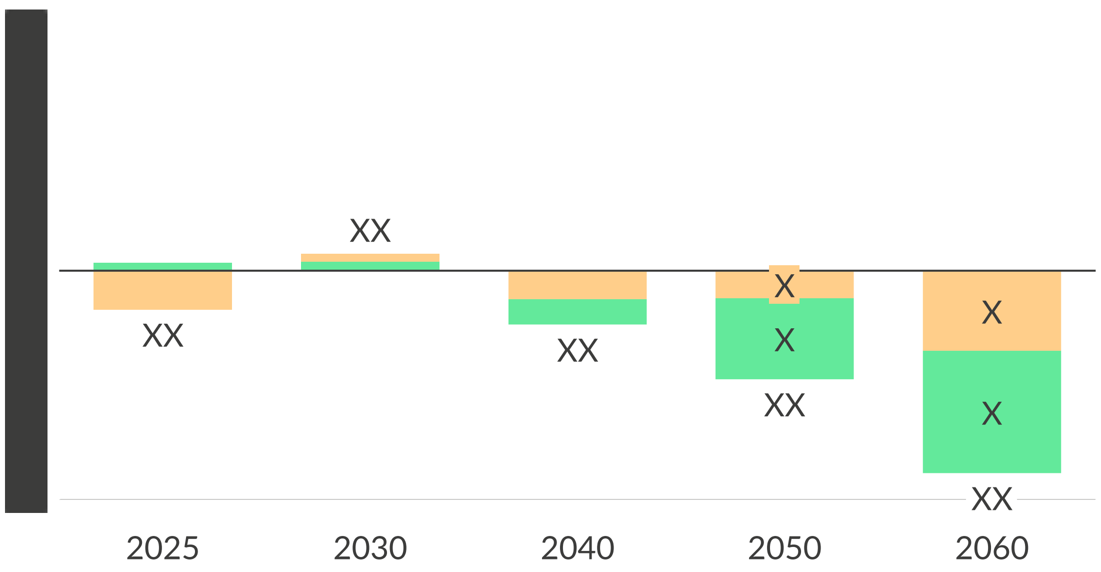
TWh



- Most demand growth comes from the electrification of transport, which rises to [redacted] TWh by 2060 due to a rapid EV uptake, as well as from heat pumps, whose demand doubles by 2040 and remains largely constant until 2060.
- We expect a weak buildout of electrolysers due to the lack of a hydrogen strategy. Power demand from electrolysers reaches only [redacted] TWh in 2060, with most H_2 demand being covered through imports.
- Base demand growth, driven mostly by economic activity, is expected to be overcompensated by improvements in efficiency.

Delta in net annual power demand compared to previous forecast[2]

TWh



- Total demand remains largely aligned with our previous forecast with an average demand delta of -[redacted]% throughout the forecast horizon.
- Our updated view on long-term vehicle efficiency leads to a slight decline of power demand from EVs by [redacted] TWh in 2060.
- Electrolyser demand decreases by [redacted] TWh in 2060 due to lower activity in response to higher baseload prices (i.e., [redacted] €/MWh delta to our previous forecast in 2060), making hydrogen production less profitable.

Base demand[1] | Electric vehicle (EV) demand | Electric heat demand | Electrolyser demand

1) Net power demand includes sectoral demand (i.e., industry, commerce, transport and households) as well as transmission losses. Power plant self-consumption and demand from efficiency losses of storage are excluded. 2) Refers to Aurora's preliminary market outlook for Switzerland, presented during the 2nd workshop of the Swiss Multi-Client Study in Zurich on 5 September 2023.

Source: Aurora Energy Research

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While hydro still provides almost half of Swiss power production until the 2050s, strong solar buildout is expected to overcompensate the nuclear exit

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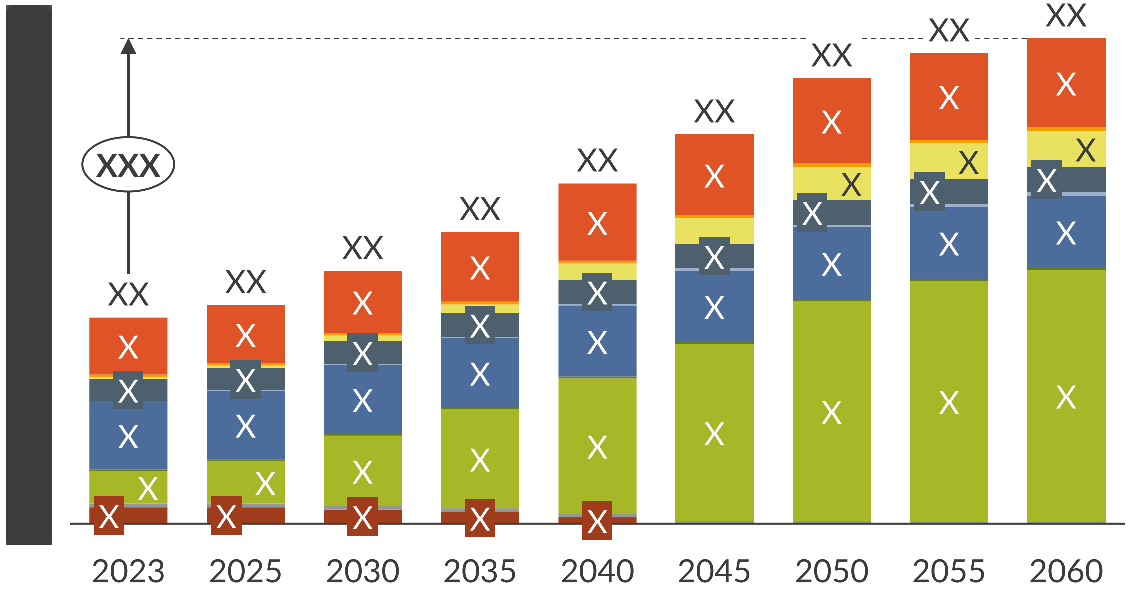
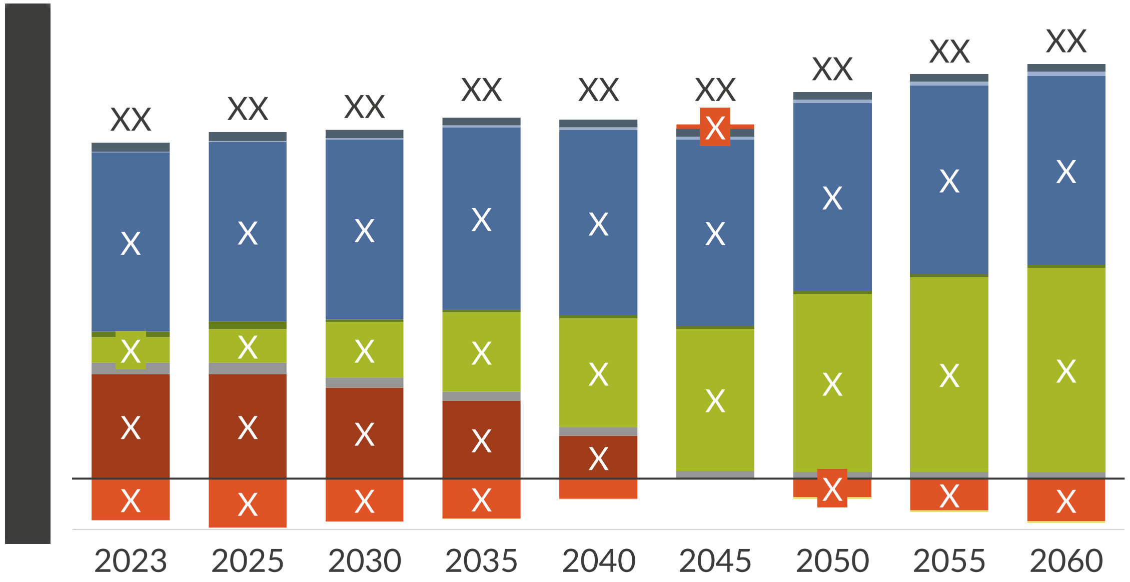
Installed capacity
GW



- Installed capacity rises up to [redacted] GW in 2060, driven by the rapid growth of solar and flexible capacities.
- Assuming a 60-year lifetime for the remaining nuclear capacities, we expect a full nuclear exit by 2045.
- As the potential for hydro plants is almost exhausted, capacity is expected to remain mostly constant, with hydro pumped and reservoir storage capacity increasing only by [redacted] GW by 2060.

Electricity production and net imports
TWh



- Hydro generation remains the most important power source in the Swiss power system. Although its relative importance decreases over time, it still provides almost [redacted] % of total generation in 2060.
- A strong solar buildout is able to overcompensate retired nuclear generation while simultaneously tackling a rising power demand.
- After the nuclear phase-out, Switzerland becomes a temporary net importer, yet ongoing solar buildout ensures it turns to a net exporter anew by 2047.

Nuclear | Other thermal[1] | Solar PV | Biomass / other RES[2] | Hydro | Onshore wind | Pumped storage | Battery storage | DSR | Interconnectors

1) Other thermal includes waste plants, natural gas CHPs, and on-site industrial thermal plants. 2) Other renewables include other gas renewables (e.g., landfill, sewage or mine gas).

Source: Aurora Energy Research

Solar PV capacity is expected to more than triple by 2035, driven mainly through subsidised rooftop solar

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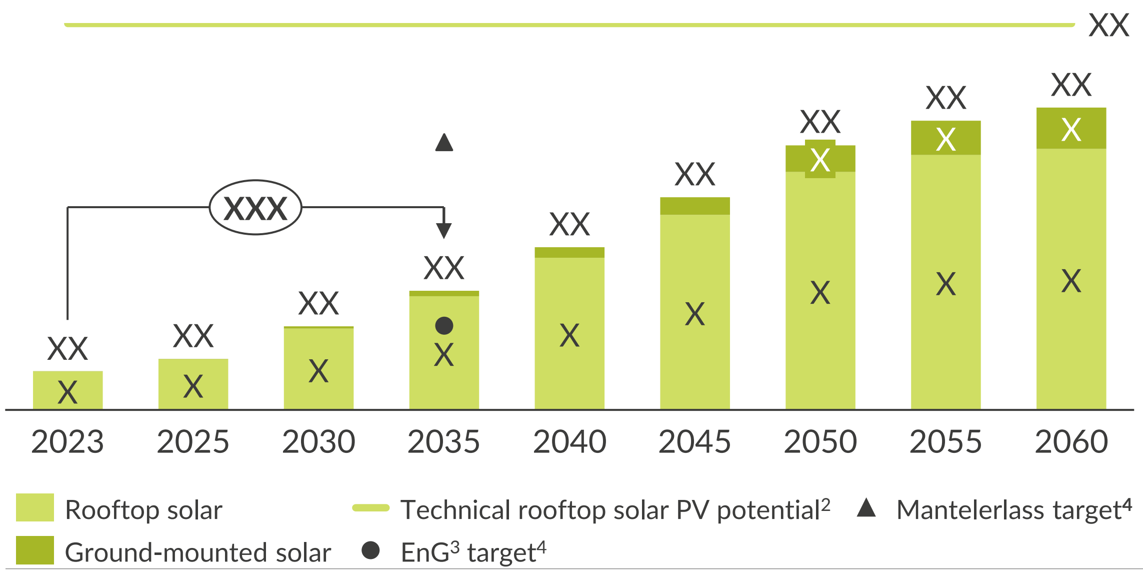
Overview

- Solar is beginning to play a significant role in the Swiss power sector and its decarbonisation, with 2022 seeing a buildout of over 1 GW solar capacity for the first time.
- Buildout is expected to continue across the forecast horizon with the harnessing of rooftop solar potential and an ambitious non-hydro renewables target in the Mantelerlass, supported by federal subsidy schemes.

Exogenous (subsidised) solar capacity timeline[1]
GW



Assumptions

Capacity timeline

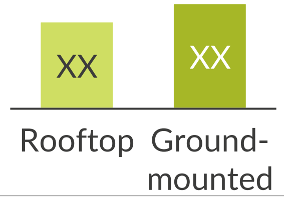
- While we expect solar capacity alone to exceed the 2035 non-hydro renewable generation target of the EnG[3], the target from the Mantelerlass[4] will only be fulfilled to less than [redacted] % by solar.
- In the long term, capacity increases to [redacted] GW by 2060, assuming a strong uptake in solar buildout post-2035 to make up for missing nuclear capacity.
- The fragmented Swiss policy landscape is the main hurdle for solar buildout. Permitting regulations vary at municipal level, taxation varies between cantons, subsidy rules differ between municipalities and cantons, and feed-in tariffs are set by the power provider, leading to large variations in the profitability of rooftop solar.
- Buildout is almost exclusively driven by subsidised rooftop solar due to a lack of incentives for merchant-scale buildout.

Generation profile

- Our generation profile is derived from typical insolation patterns for Switzerland and benchmarked against historical output.

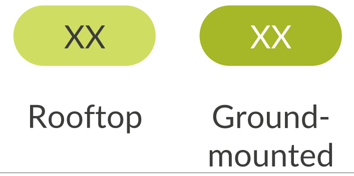
Load factor[5]

%



Plant life

Years



1) Assumed exogenous capacity timeline does not include merchant-risk buildout decisions of our model. 2) According to BFE, the technical rooftop solar potential lies at [redacted] TWh, equaling [redacted] GW of capacity assuming a load factor of [redacted]%. 3) Energiegesetz. 4) Generation target converted into capacity, assuming an average load factor of [redacted]% to account for 2035 split between rooftop and ground-mounted solar. 5) Fleet average.

Sources: Aurora Energy Research, Swisssolar, BFE, Pronovo

Deployment of embedded battery storage will aid in balancing supply and demand, with battery capacity increasing to [redacted] GW in 2060

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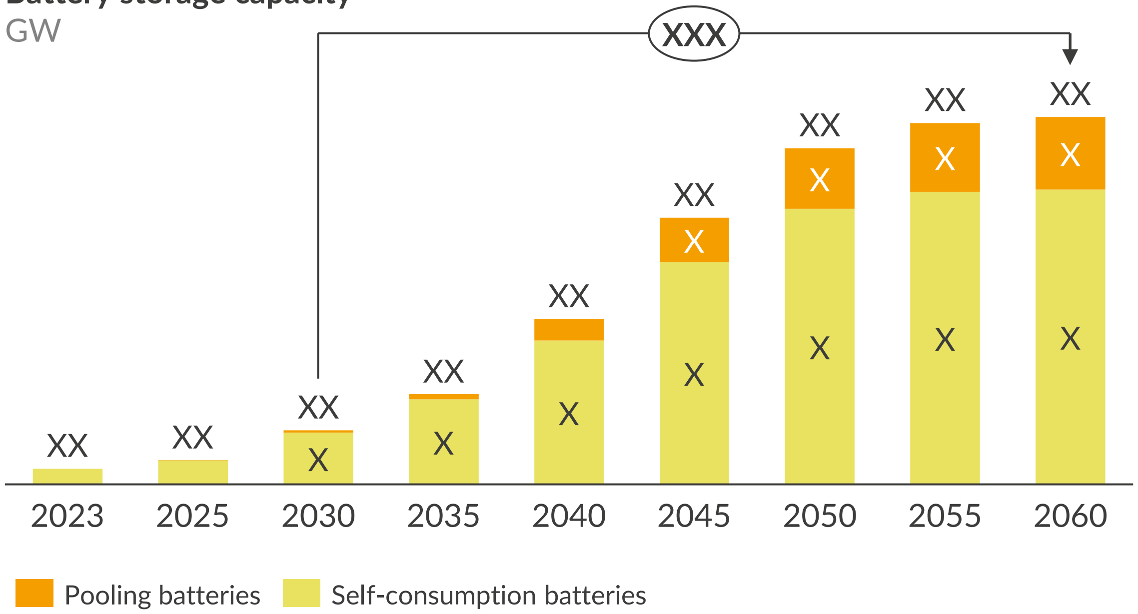
Overview

- Behind-the-meter batteries for home storage are the main driver of continued battery storage buildout, as they allow for optimisation of self-consumption in combination with rooftop solar PV panels.
- Large-scale battery development is not expected to play a major role in Switzerland due to pre-existing hydropower storage capacity providing system flexibility.

Battery storage capacity

GW



Assumptions

Capacity timeline

- Total behind-the-meter battery storage capacity is expected to increase slightly to [redacted] GW in 2030, before rising more than 6-fold to [redacted] GW in 2060.
- As the Mantelerlass promotes local electricity communities, we distinguish between batteries used for virtual pooling within these communities and pure self-consumption batteries, with the latter expected to dominate battery buildout.
- Continued buildout of rooftop solar and the expected decline of battery storage investment costs are the main drivers of accelerated buildout of battery storage capacity post-2030.

Generation profile

- We expect the charging behaviour of self-consumption batteries to be dependent on the generation profile of rooftop solar assets. Peak-shaving behaviour for these batteries is restricted due to increased emphasis on self-consumption at home.
- Pooling assets have more freedom to optimise outside of rooftop solar production patterns to provide local system flexibility services.

Lifetime[1]

Cycles

XXX	XXX
Self-consumption batteries	Pooling batteries

1) Alternatively, batteries can have a lifetime of 15 years.

Sources: Aurora Energy Research, BFE, EnergieSchweiz

While Switzerland is already closely connected to its neighbours today, we expect interconnector capacity to increase further by over [redacted]% by 2050

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Overview

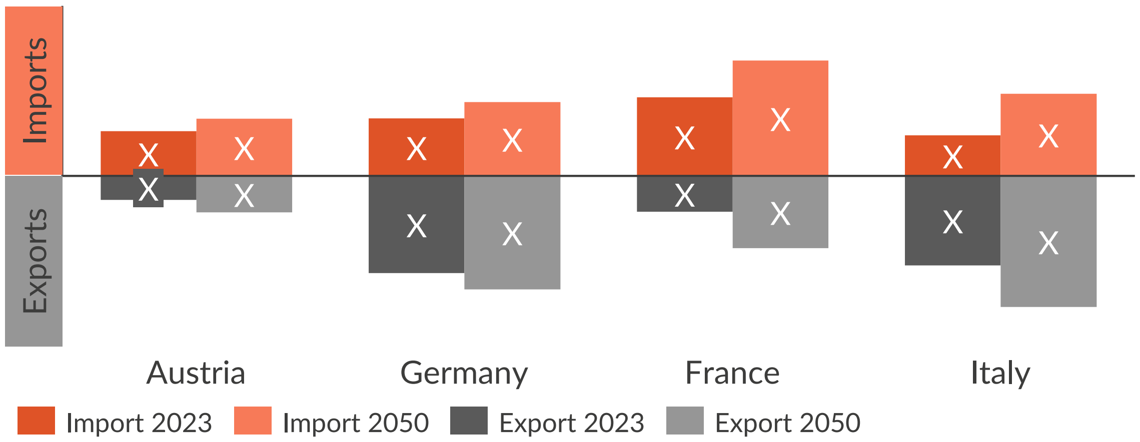
- Due to its location in Central Europe, Switzerland benefits from vast interconnection opportunities, with direct links to Austria, Germany, France and the North of Italy comprised of 41 international interconnection lines.
- Interconnectors will be key in ensuring security of supply in the future, especially since Switzerland plans to phase out its nuclear fleet.

Assumed capacity timeline

- Pre-2030 buildout timeline is based on announced projects whose capacity is weighted by the likelihood of realisation based on current project stage[1].
- Beyond 2030, projections are based on the System Needs analysis of the TYNDP[2], corrected for historical buildout rates, with interconnector capacities expected to increase by more than [redacted]% by 2050[3] relative to 2023.

Swiss interconnector capacity

GW



1) Success rates correspond to the following project statuses: 'under construction' (100%), 'in permitting' (70%), 'in planning but not permitting' (60%), 'under consideration' (30%). 2) Ten Year Network Development Plan (TYNDP) published every two years by ENTSO-E. 3) Average of all interconnections, applicable to both imports and exports.

Sources: Aurora Energy Research, Swiss Grid, Energy Community

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Compared to Central, Low gas prices are [redacted] % lower in 2060, while power demand is [redacted] % lower in the same year reflecting weaker economic growth

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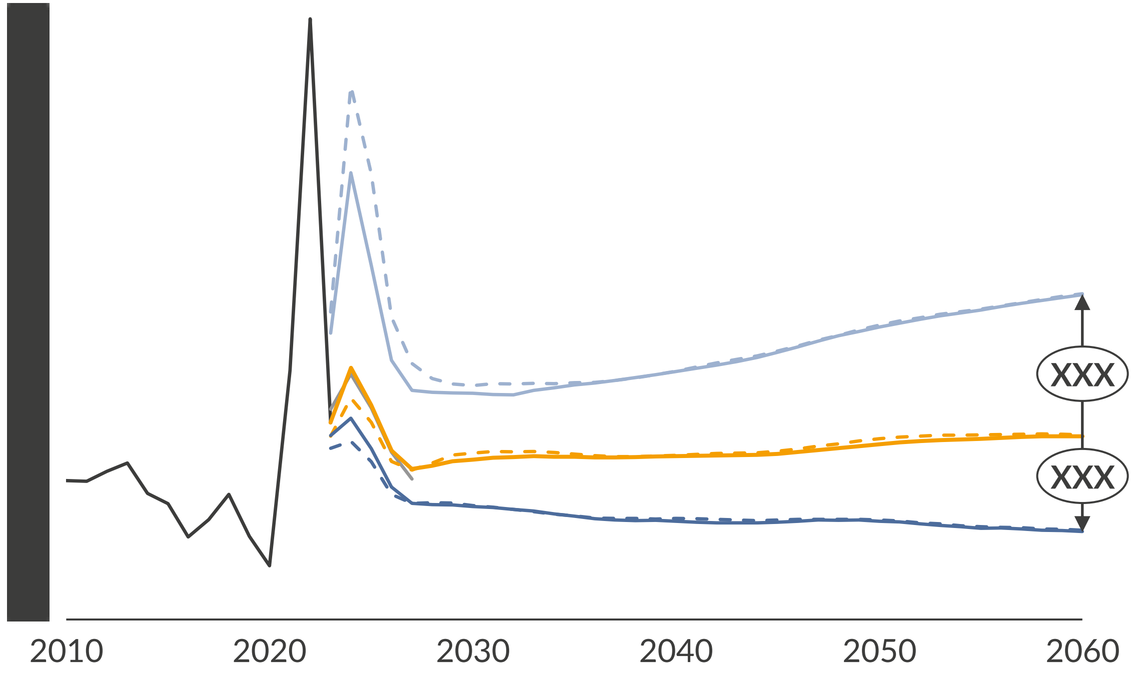
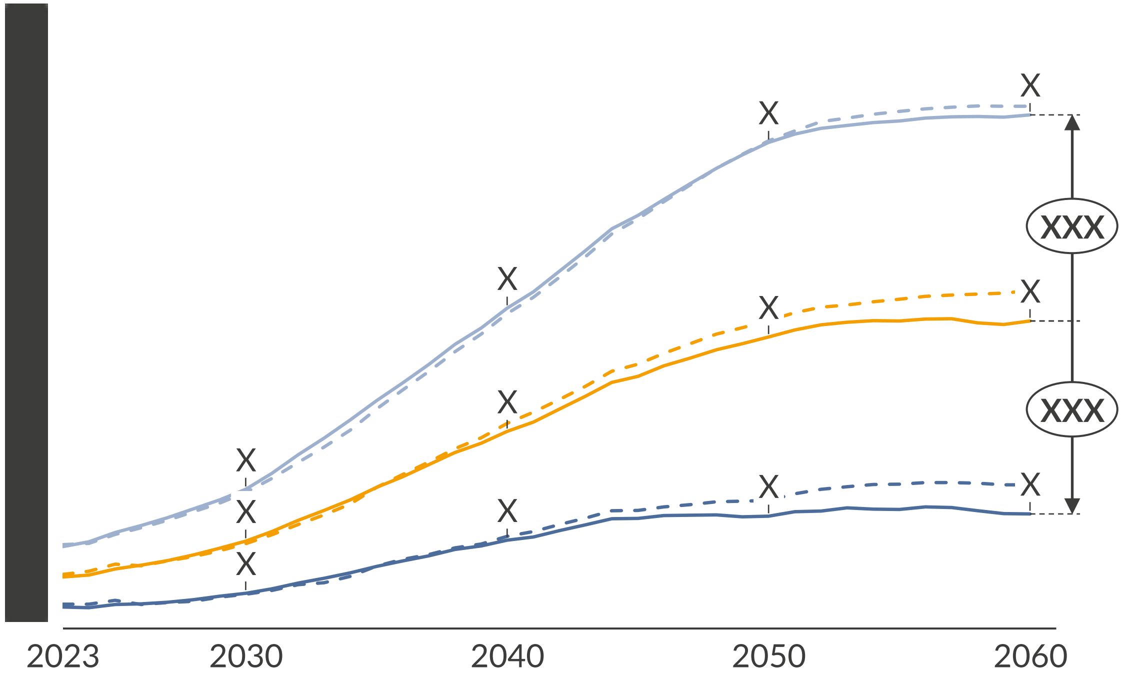
Natural gas price
€/MWh (real 2022)[1]



- In 2028-2060, Low gas prices are [redacted]% lower on average compared to our Central scenario, driven by a slower increase in extraction costs on the supply side, as well as lower GDP growth resulting in lower gas demand.
- High gas prices display the opposite price drivers and are [redacted]% higher on average than our Central scenario between 2028 and 2060.

Net annual power demand[2] – Central, High and Low scenarios
TWh



- Compared to our Central scenario, the Low case shows a reduction in net annual power demand of [redacted]% in 2060, at a level of [redacted] TWh. Key driver is weaker GDP growth compared to Central, which leads to lower economic output as well as slower electric vehicle and electric heating systems uptake.
- In our High case, demand sees a steeper growth trajectory and amounts to [redacted] TWh in 2060, i.e., [redacted]% more than in Central.

Historical — Futures[3] — Central — High — Low — Previous forecast[4]

1) For years 2023-2027, the prices shown take into account current futures prices for the years in question, with declining weights. In 2023, forecast prices include historical prices up to Aug-23. 2) Net power demand includes sectoral demand as well as transmission losses. Power plant self-consumption and demand from efficiency losses of storage are excluded. 3) A rolling 14-day average as of 01/09/2023. 4) Refers to Aurora's preliminary market outlook for Switzerland presented on 5 September 2023.
Source: Aurora Energy Research

Post 2030, power prices in the Low case are [redacted]% lower on average relative to Aurora's Central scenario, and [redacted]% above in the High case

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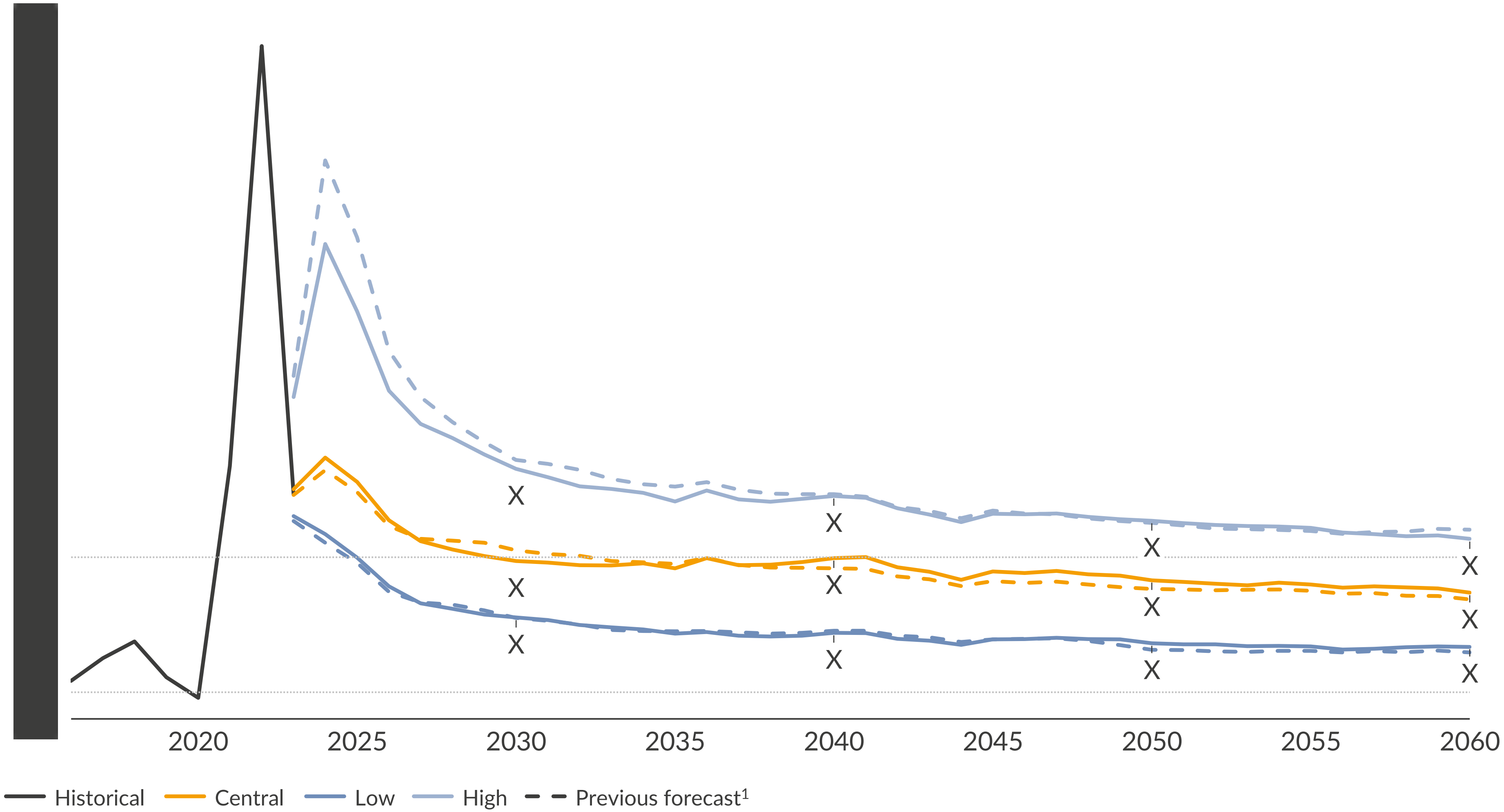
Baseload wholesale electricity price

€/MWh (real 2022)



1) Refers to Aurora's preliminary market outlook for Switzerland, presented during the 2nd workshop of the Swiss Multi-Client Study in Zurich on 5 September 2023.

Sources: Aurora Energy Research, ENTSO-E

Low scenario

- Baseload prices in the Low scenario fall quickly from the current high of [redacted] €/MWh to [redacted] €/MWh in 2030.
- They remain depressed at an average of [redacted] €/MWh post-2030 with baseload prices being on average [redacted] % below our Central forecast.

High scenario

- After a rapid surge from 2023 due to a spike in gas prices throughout Europe, baseload prices decrease sharply in the short term and remain at an average of [redacted] €/MWh post-2030 until the end of the forecast horizon.
- In the same period, baseload prices are [redacted] % above our Central forecast on average.

Post 2030, solar capture prices are on average [redacted]% lower in our Low scenario relative to Central, and in the High case [redacted]% above Central

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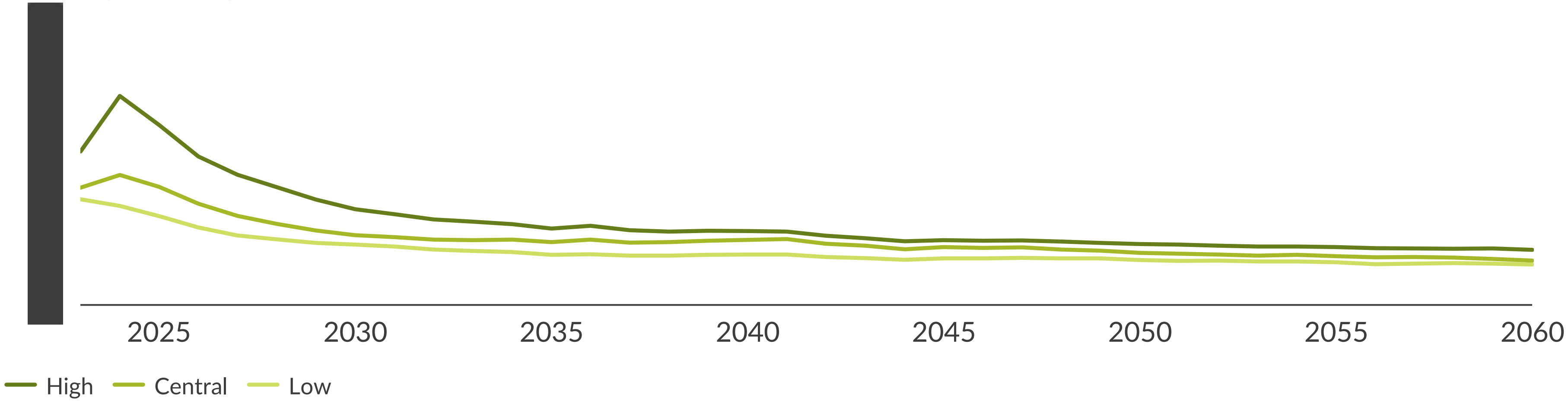
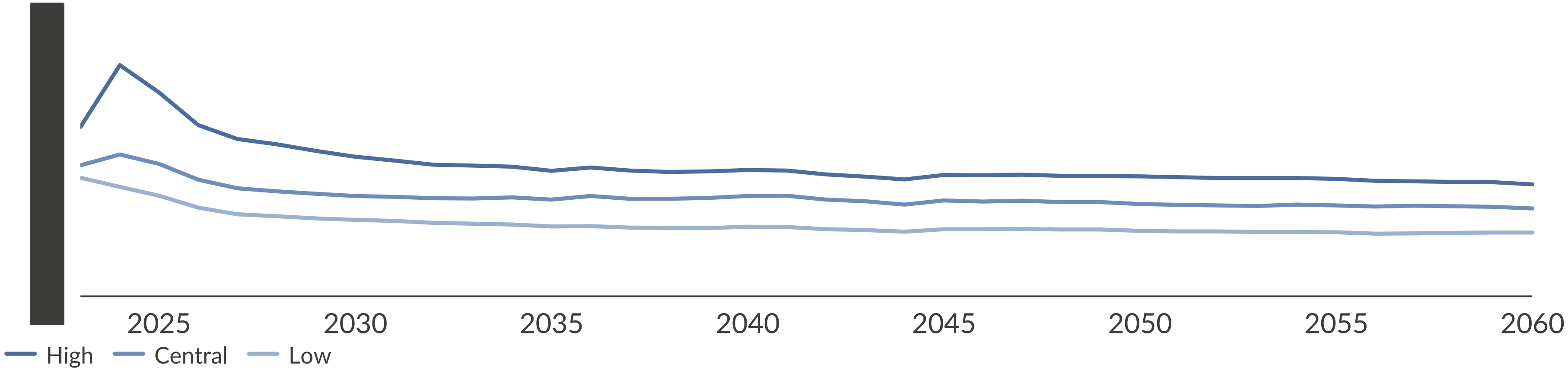
Solar capture prices[1]
€/MWh (real 2022)



Onshore wind capture prices[1]
€/MWh (real 2022)



1) Uncurtailed generation-weighted capture prices.

Source: Aurora Energy Research

Solar

- In the Low case, post-2030 capture prices exhibit an average price of [redacted] €/MWh, [redacted]% below Central, with prices declining only moderately after the mid-2040s when nuclear is phased out and prices are set more often by imports.
- In High, capture prices decline gradually with an average price of [redacted] €/MWh post-2030, as merchant solar buildout increasingly exerts downward price pressure.

Onshore wind

- In the Low case, capture prices are on average [redacted] % below Central after 2030 with an average price of [redacted] €/MWh.
- In High, capture prices decline rapidly post-2024 after a gas price-induced price spike, before continuing to decline more gradually post-2030, at an average price of [redacted] €/MWh.

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While we consider a nuclear exit by 2045 as most likely, concerns around security of supply could lead to a delayed exit by 2065

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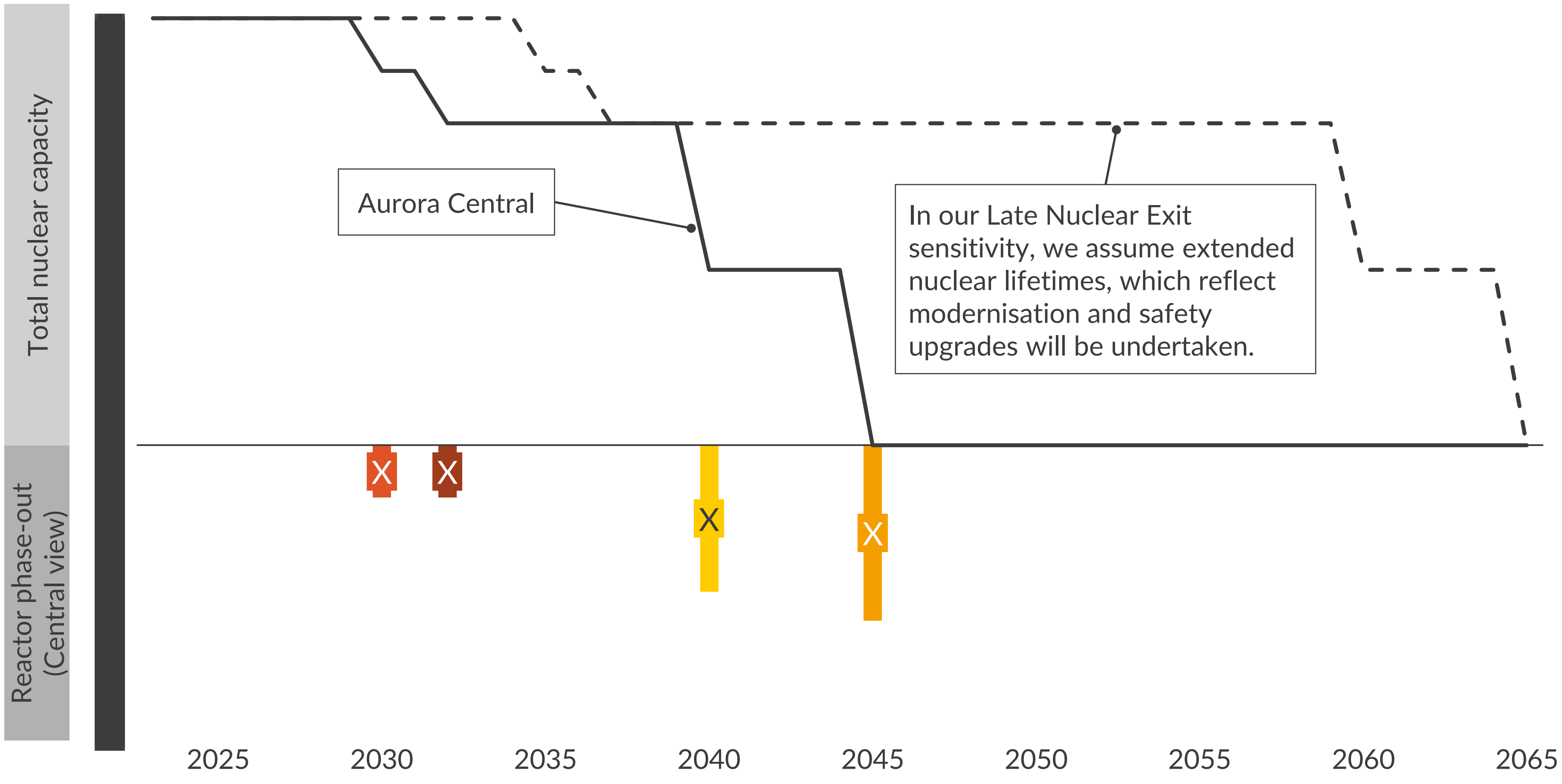
Nuclear capacity shutdown timeline (total end of year)
GW



1) Assuming 60-year lifetime for all four existing nuclear plants.

Sources: Aurora Energy Research, ETH Zurich

Aurora's Central outlook

- With the acceptance of the Energy Strategy 2050, Switzerland opted for a gradual exit of nuclear power:
  - The construction of new nuclear plants is prohibited.
  - Existing nuclear power plants may be operated as long as they are deemed safe by the Federal Nuclear Safety Inspectorate (ENSI).
- Assuming a 60-year lifetime, we expect nuclear energy to be fully phased out by 2045 in Central.

Uncertainties

- Prolonged nuclear lifetime is heavily debated as it could partially alleviate supply tightness in winter months, yet might require expensive investments in plant modernisation and safety upgrades to comply with ENSI requirements.

Delaying the nuclear exit by 20 years would lead to [redacted] €/MWh ([redacted] %) lower baseload power prices on average between 2045 and 2060

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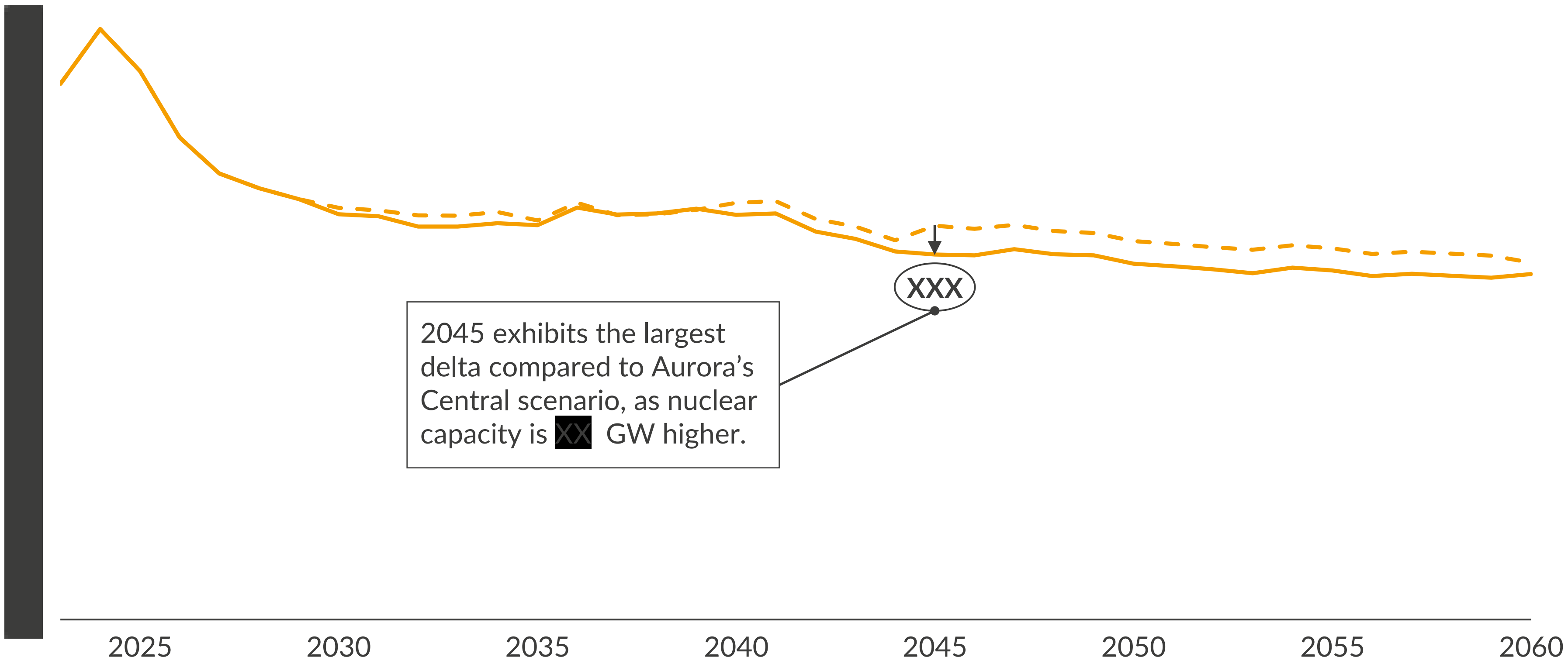
Baseload wholesale electricity price
€/MWh (real 2022)



Average yearly baseload price delta between Late Nuclear Exit sensitivity and Central scenario
€/MWh (real 2022)

Late Nuclear Exit sensitivity — Central[1] — Delta

1) Assuming 60-year lifetime for all four existing nuclear plants.

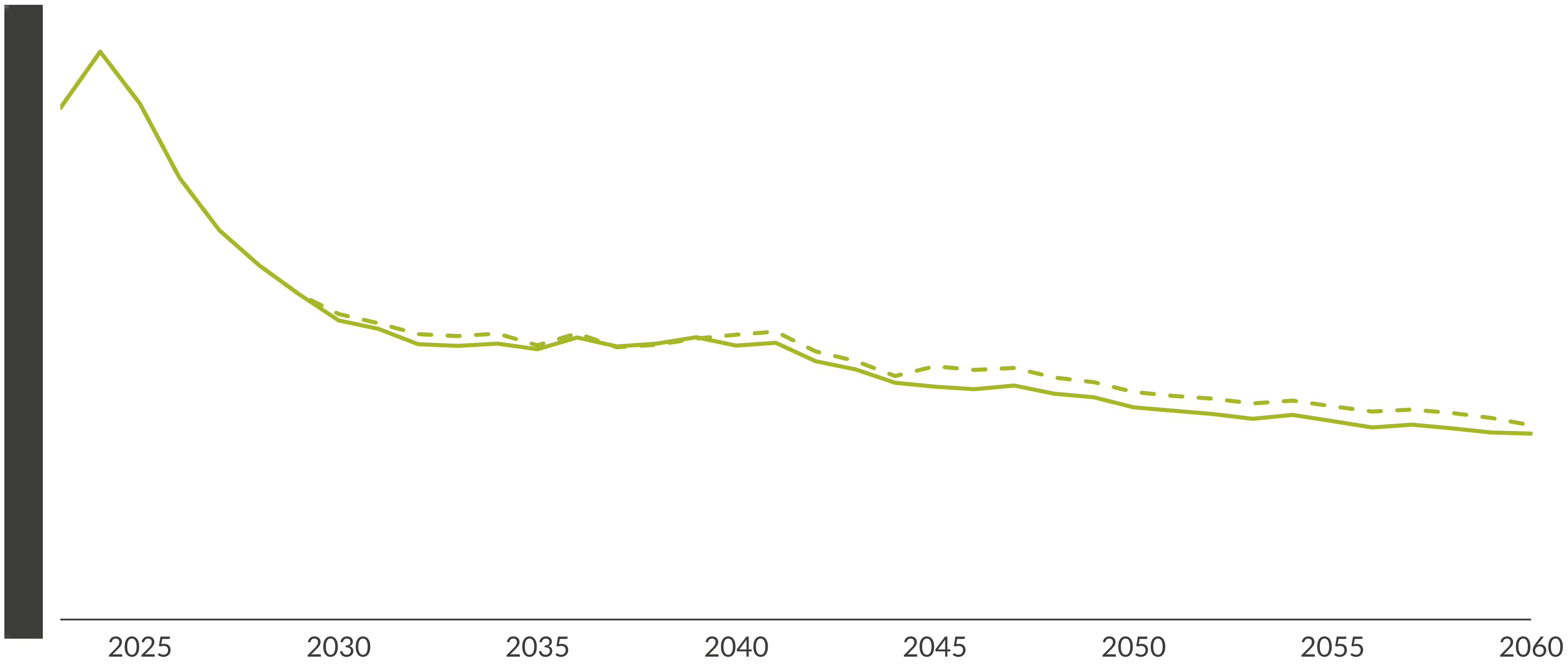
Source: Aurora Energy Research

Impact of a later nuclear exit

- Nuclear power provides a stable baseload supply, which reduces reliance on more expensive imports during winter periods.
- With the nuclear exit being brought back by 20 years, power prices decrease by [redacted] €/MWh ([redacted]%) compared to Central between 2030 and 2044, with prices averaging [redacted] €/MWh in this period.
- Beyond 2044, baseload prices fall to an average of [redacted] €/MWh in the Late Nuclear Exit sensitivity, settling around [redacted] €/MWh ([redacted]%) below the Central scenario due to the high delta in nuclear capacity. By 2060, the price gap starts narrowing to [redacted] €/MWh.

Post 2030, solar capture prices are on average [redacted] €/MWh ([redacted] %) below Central in case of a delayed nuclear exit

Solar capture prices[1]
€/MWh (real 2022)



Average yearly capture price delta between Late Nuclear Exit sensitivity and Central scenario
€/MWh (real 2022)

Late Nuclear Exit sensitivity — Central[2]

1) Uncurtailed generation-weighted capture prices. 2) Assuming 60-year lifetime for all four existing nuclear plants.

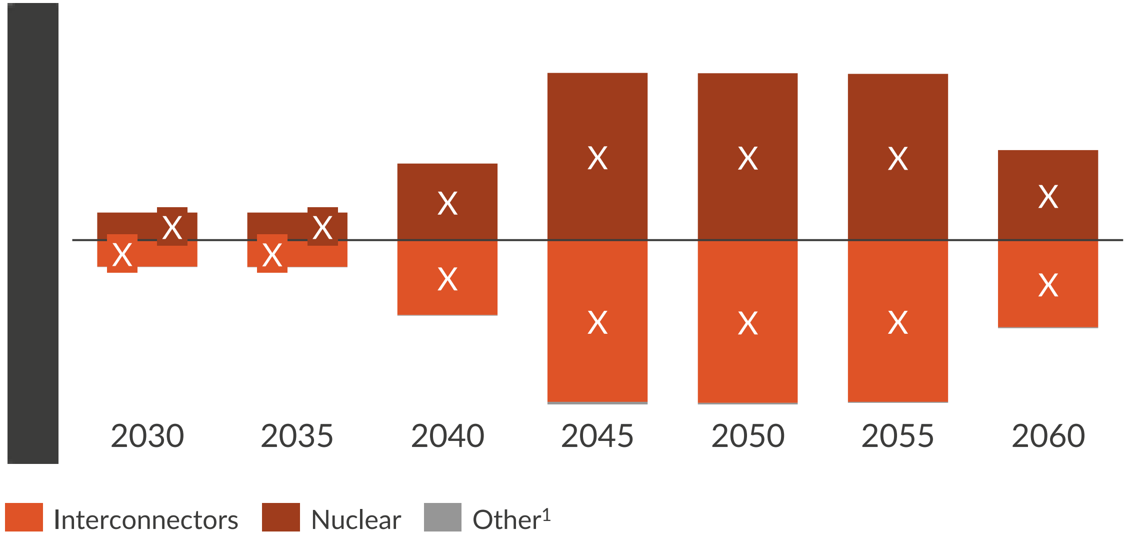
Source: Aurora Energy Research

Impact of a later nuclear exit

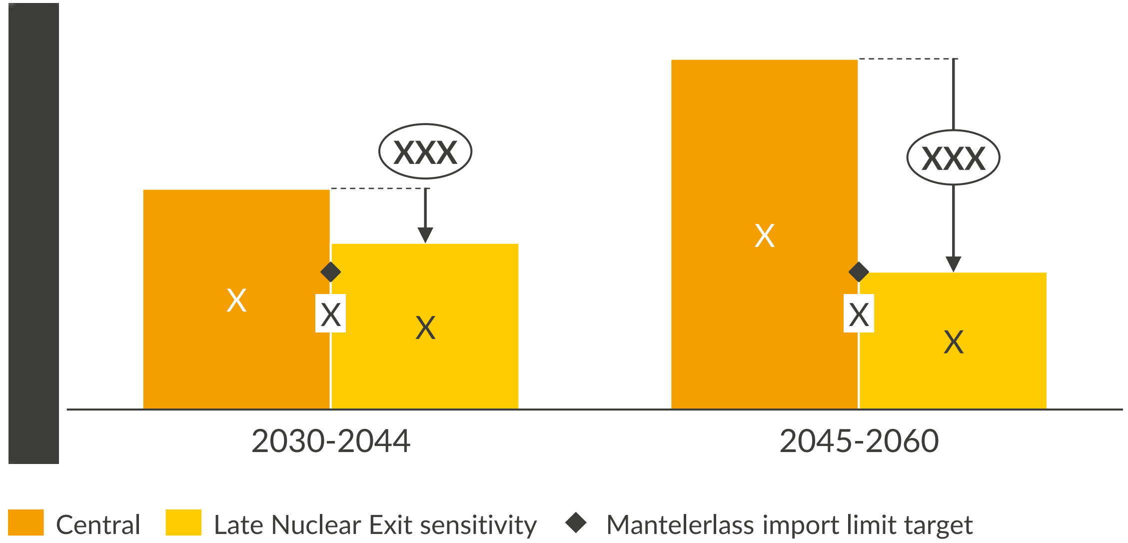
- With nuclear exit being brought back by 20 years, solar capture prices decrease by [redacted] €/MWh ([redacted]%) compared to Central between 2030 and 2060, with prices falling from [redacted] €/MWh to [redacted] €/MWh in this period. Thus, a delayed nuclear exit further diminishes the economic attractiveness of merchant renewables.
- Average yearly capture price deltas for solar are consistently smaller than baseload price deltas, as downward price pressure of prolonged nuclear activity is relatively lower in the summer period due to scheduled reactor maintenance, thus partially mitigating downward pressure on solar capture prices.

Compared to Central, later nuclear exit decreases net imports in the winter half-year by [redacted]% on average between 2045 and 2060

Yearly delta of power generation and net imports between the Late Nuclear Exit sensitivity and Central TWh



Average net power imports in winter half-year[2]
TWh



- Compared to Central, nuclear generation replaces up to [redacted] TWh of annual power imports in the Late Nuclear Exit sensitivity between 2045 and 2055, decreasing Switzerland’s reliance on neighbouring countries.
- While we expect interconnector availability to remain at a minimum of [redacted] %, discussions with the EU regarding an electricity agreement are still ongoing. If these are unsuccessful, it could potentially jeopardise imports as a flexibility measure, with a later nuclear phase-out bringing potential alleviation to the strain on security of supply.

- A late nuclear exit leads to significantly lower imports in the winter half-year, decreasing by [redacted]% on average between 2030 and 2044, and by [redacted]% post-2044 compared to our Central view.
- In case of a delayed nuclear exit, the Mantelerlass target of limiting imports to 5 TWh in winter is almost reached with winter net imports averaging at [redacted] TWh from 2023 to 2060.

1) Other includes other thermal, biomass, other RES, pumped storage, and battery storage. 2) Winter half-years are considered from 1 October to 31 March.

Source: Aurora Energy Research

Agenda

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