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ENERGY RESEARCH

Chilean Power Market Forecast – Aurora's Central Scenario

17th October 2024

Public version

Introducing the Aurora team

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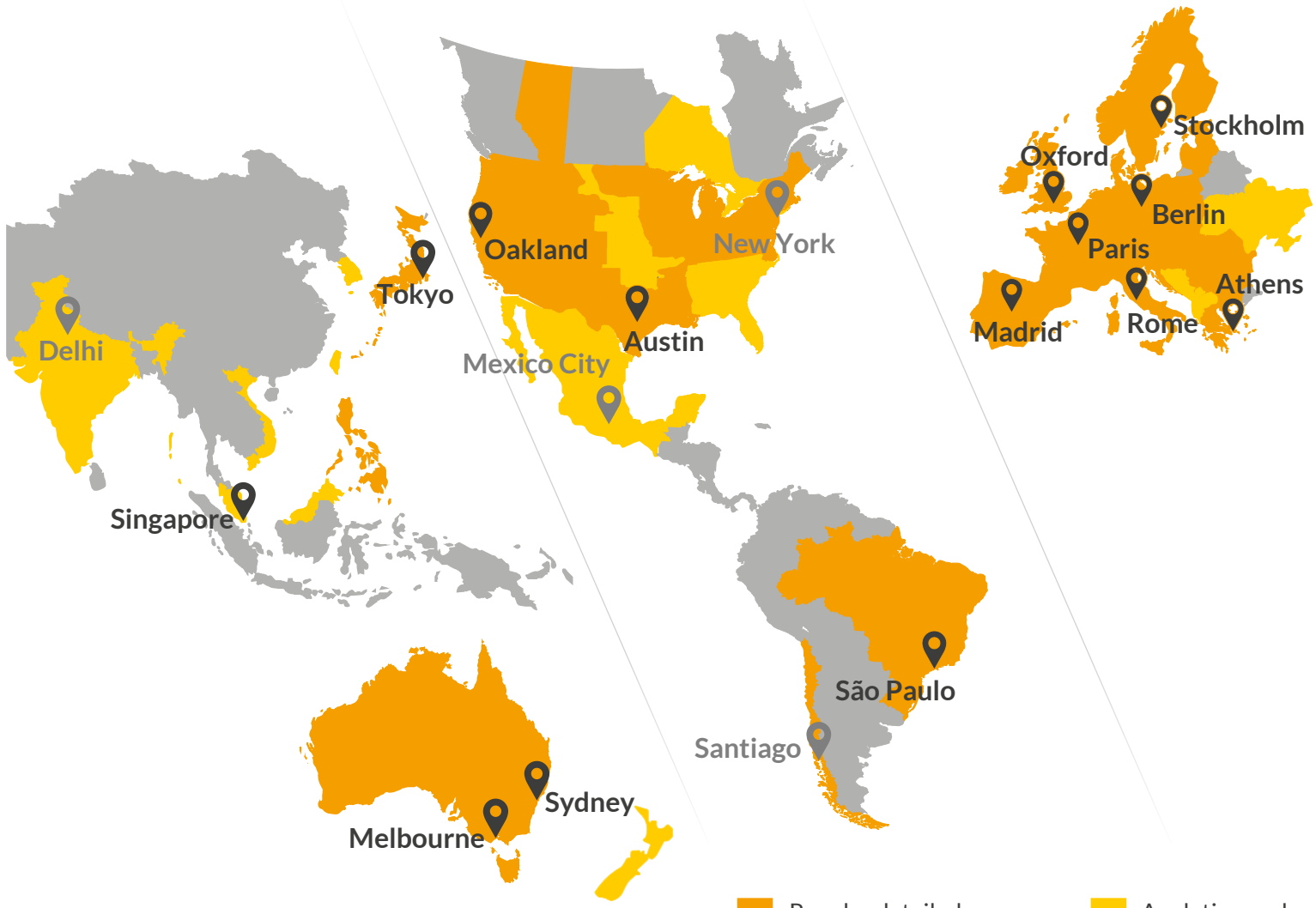

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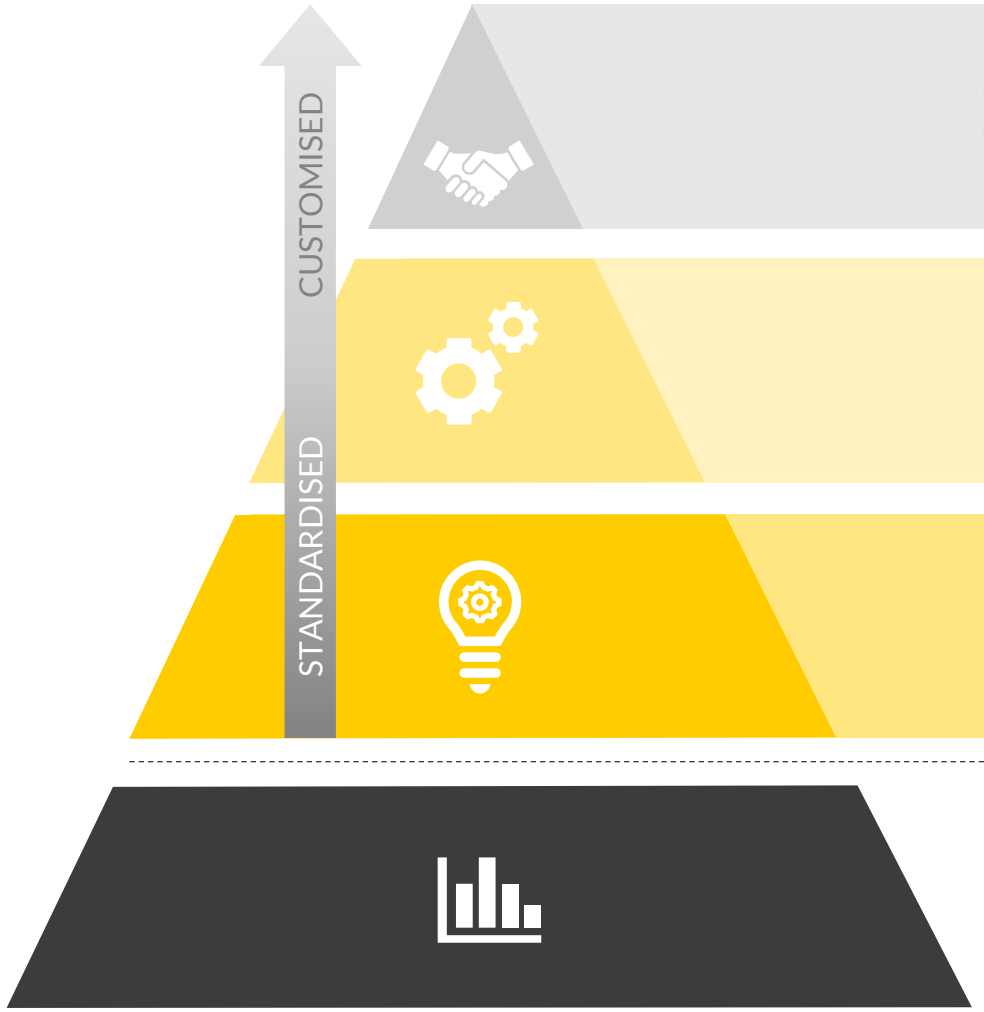

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Developed over 10 years, 70+ dedicated modellers

Source: Aurora Energy Research

Agenda

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I. Aurora's modelling approach to Chile

II. Aurora Central Outlook & Drivers

- I. Key Inputs
  - I. Demand
  - II. Renewables load factors
  - III. Renewables and storage cost assumptions
  - IV. Transmission
  - V. Commodities and thermal capacity

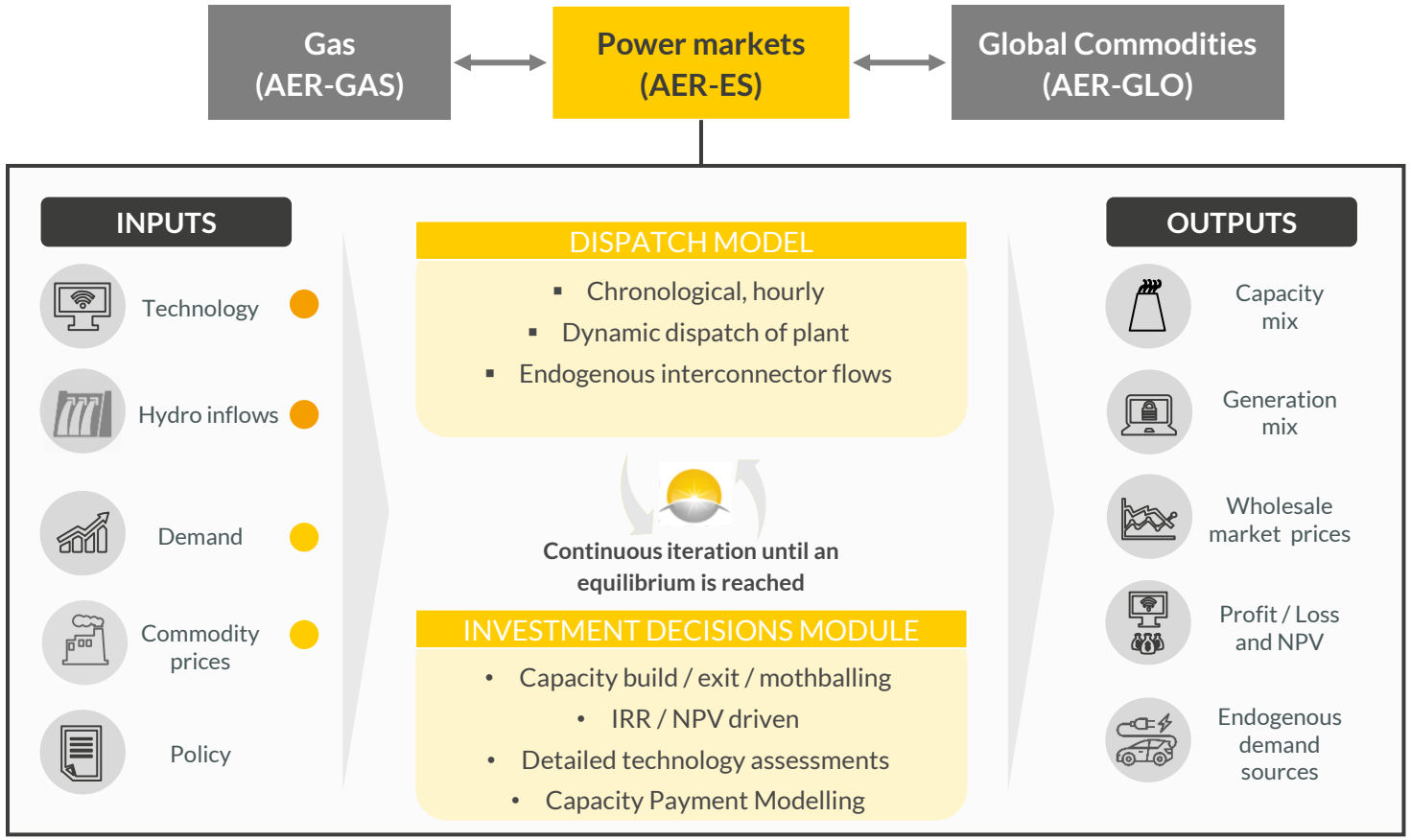
III. Aurora Central Market Outlook

- I. Baseload Prices
- II. Capacity and Generation
- III. Capacity Payments
- IV. Capture Prices
- V. Battery Dynamics
- VI. Coal Phase Out Sensitivity
- VII. Transmission Sensitivity

IV. Key Takeaways

Covered in today's session

Our analysis of the Chilean power market uses our proprietary, in-house modeling capabilities with data from official sources



Official assumptions[1] Modeled in-house

Up to 70	c. 55k	10k	70+
specifications modeled for each plant	investment hours on modeling capabilities	model runs per week	strength of modeling team globally

1) Assumptions from CEN and Ministerio de Energía.

Source: Aurora Energy Research

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Advantages of Aurora's Approach

- Flexible and nimble because we own the code
- Transparent results
- State-of-the-art infrastructure
- Zero dependence on black-box third-party software
- Constantly up to date through subscription research
- Ability to model complex policy changes very quickly
- Ability to model new technologies (e.g. storage) and demand sources (e.g. green hydrogen and EVs)

Chile sees an unequal distribution of demand and generation; solar generation is concentrated in the north, hydro in the central regions

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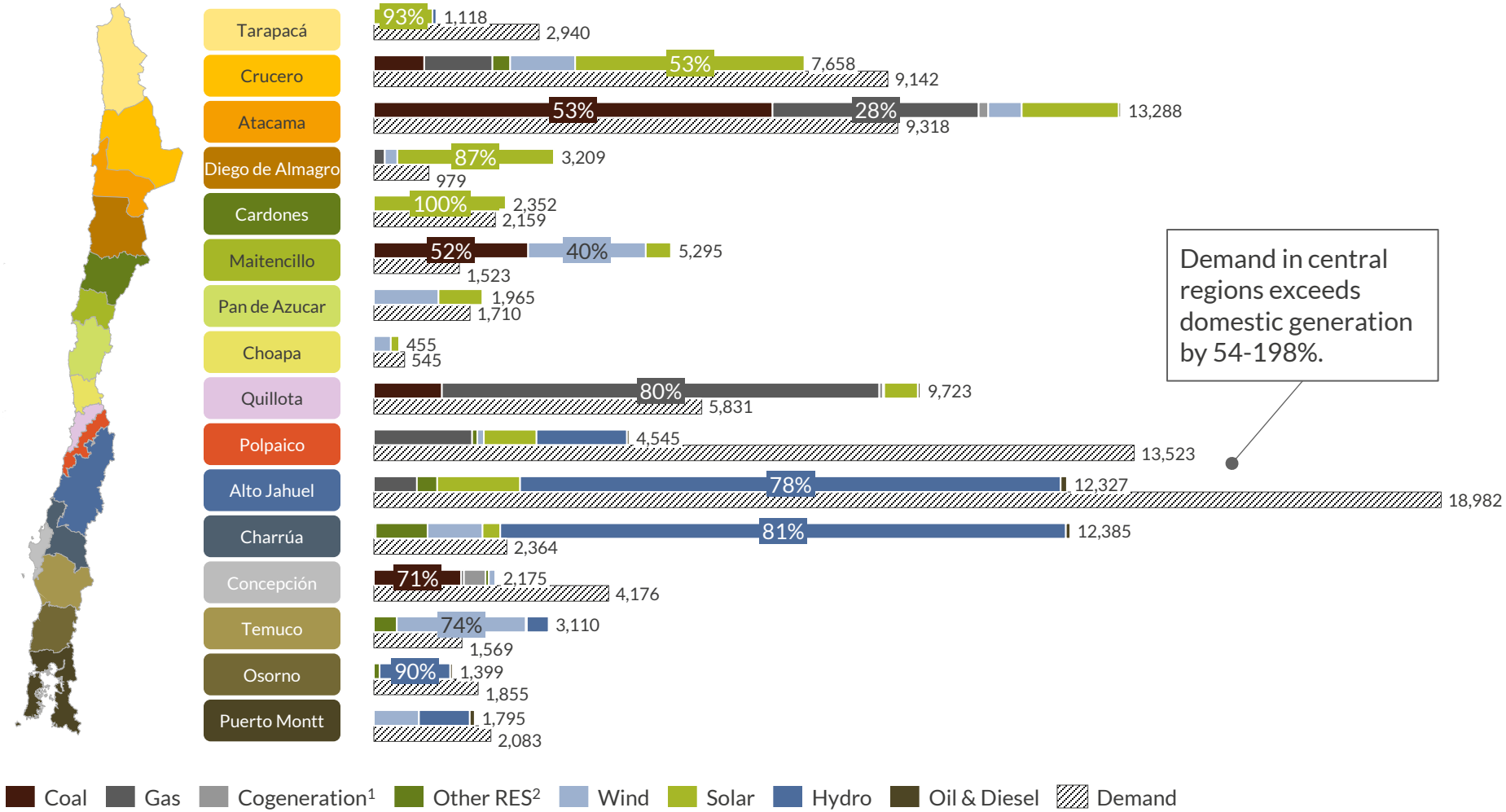
Generation vs demand in 2023 per Aurora nodal hub

GWh



1) Cogeneration includes petcoke. 2) Other renewables include biogas, biomass and geothermal.

Source: CEN

- In 2023, 72% of solar generation came from the northern regions between Tarapacá and Cardones, which benefit from high irradiance levels.
- Coal and gas are most relevant in Atacama and Quillota. Both regions generate over 80% of their hubs total generation using thermal sources.
- Wind generation is spread across the country with the largest hubs in Maintencillo and in the South of SEN (Temuco and Puerto Montt).
- 82% of SEN's total hydro generation in 2023 is in the center (Alto Jahuel and Charrúa), making up around 80% of the domestic hubs' generation. Osorno and Puerto Montt are also dominated by hydro.

Intraday wholesale market prices across Chile are significantly influenced by regional generation mix and interconnection limits

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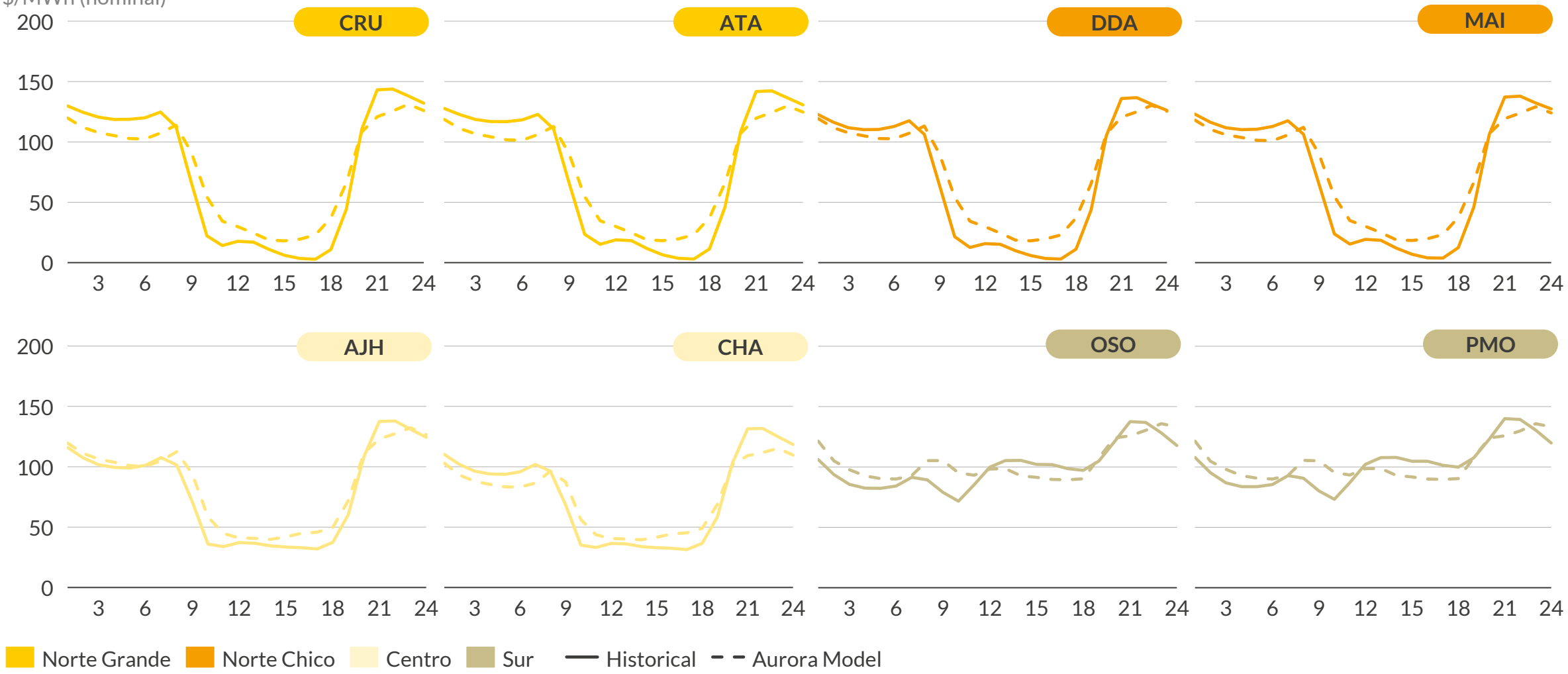
Intraday wholesale market prices
$/MWh (nominal)



Sources: Aurora Energy Research, CEN

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In our forecast each nodal hub has a unique load factor: solar in the desert can reach 31% average yearly load factors, and wind in the south up to 37%

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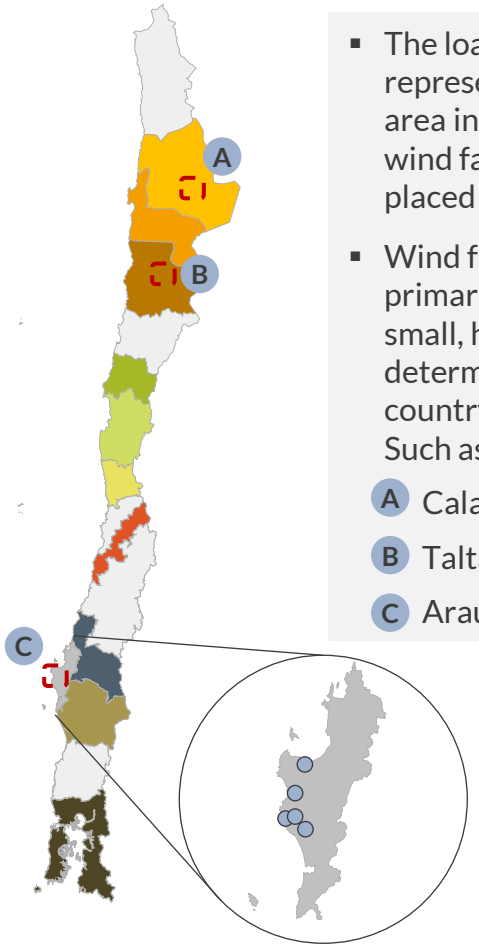
1 While most favorable conditions for wind generation are found along mountain ranges…

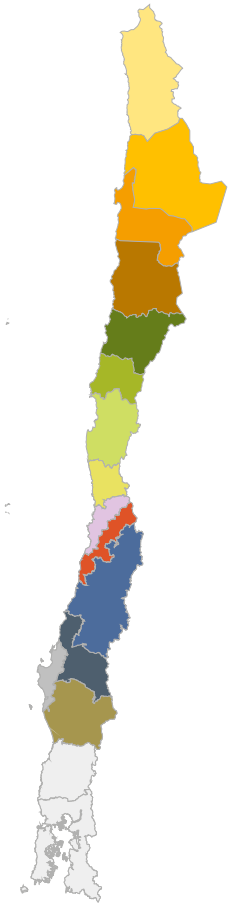
TRP	-
CRU	32%
ATA	21 %
DDA	31 %
CAR	-
MAI	22%
PAN	26 %
CHO	22 %
QUI	-
PLP	19 %
AJH	-
CHA	29 %
CON	37 %
TMC	29 %
OSO	26 %
PMO	24 %



- The load factors represent the windy area in the hub where wind farms have been placed historically.
- Wind farms in Chile are primarily located in small, high-wind areas determined by the country's topography. Such as
  - A Calama region
  - B Taltal region
  - C Arauco bay

2 … solar load factors[1, 2] can go up to 31% in the Northern desert regions of Chile.

TRP	28 %
CRU	31 %
ATA	27 %
DDA	29 %
CAR	26 %
MAI	24%
PAN	24 %
CHO	18 %
QUI	23 %
PLP	21 %
AJH	20 %
CHA	23 %
CON	20 %
TMC	20 %
OSO	-
PMO	-



- Due to geographical diversity, we create a solar profile for each hub.
- We assume no significant load factor difference between utility-scale and small-scale distributed plants.

1) Average across the year. 2)The hubs without a load factor did not have known operational capacity as of May 2024.

Sources: The Wind Power's database, CEN

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III. Key takeaways

In Aurora central, prices in northern renewable hubs stay lower than in demand hubs even with increased interconnections

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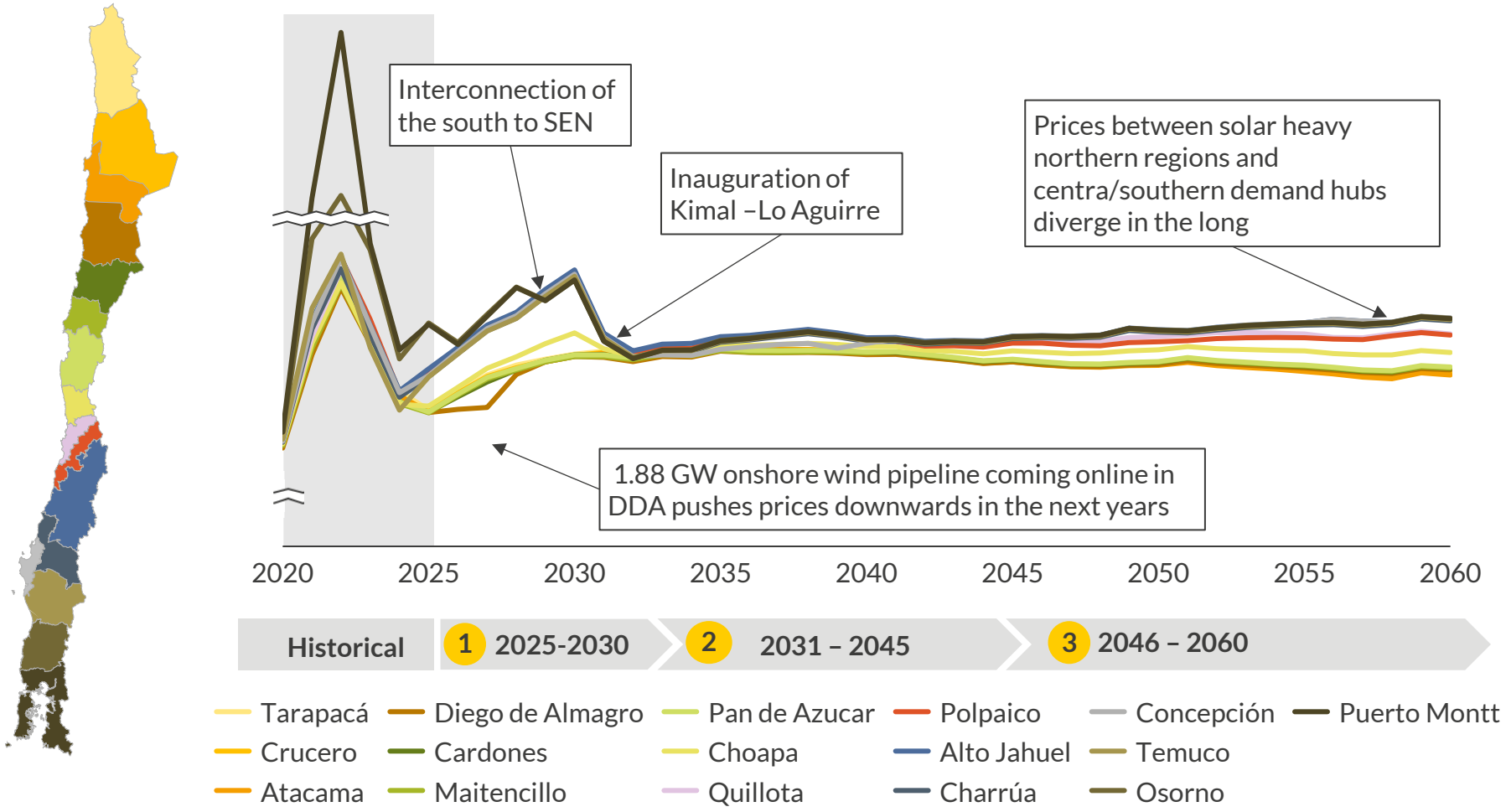
Baseload price per nodal hub in Chile
$/MWh (real 2023)



1) Equivalent of ~57% of current coal capacity

Source: Aurora Energy Research

Outlook for baseload prices

1. In the short-term, baseload prices rise across the system. This is partly driven by demand growth from copper along with 1.8 GW[1] of coal phasing out by 2029. Coal's generation in peak hours is replaced by more costly generation sources like gas and diesel.
2. In the medium term, the 2031 inauguration of Kimal-Lo Aguirre brings baseload prices from central and southern regions to a similar level as observed in the driven by the ability to transmit cheap solar power to central demand centers.
3. In the long-term, prices between the north and other hubs widens, driven by uneven demand growth across hubs, and a slow down of interconnection development.

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Solar and batteries drive Chilean capacity expansion, leading to over 90% of carbon-free generation by 2060

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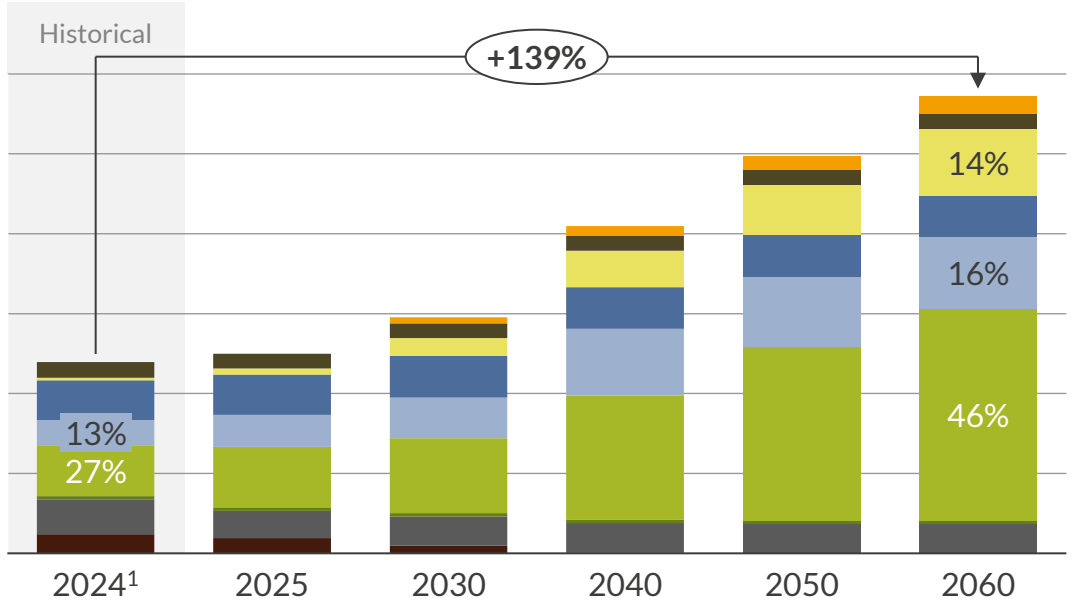
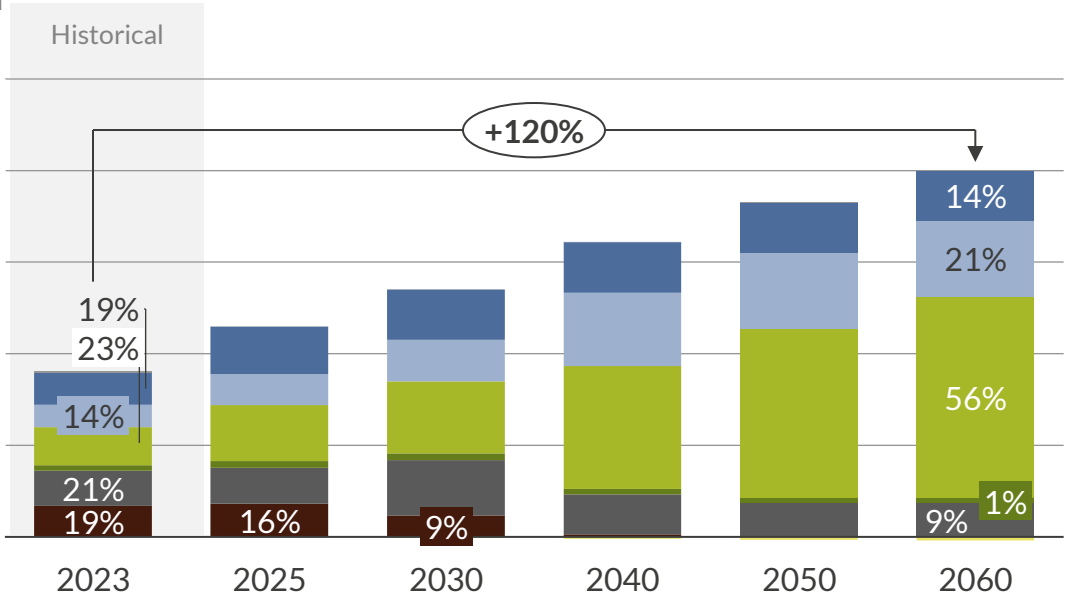
Installed capacity in Chile

GW



Generation mix in Chile

TWh



- Installed capacity increases 139% within the forecast horizon, mostly driven by solar, batteries, and wind.
- Solar power increases its capacity by a factor of 4 leading to a total share of 46% in 2060, while wind capacity almost triples compared to today's capacity.
- Battery capacity grows to 14% of the system by 2060, facilitating shifting of intermittent solar generation in a solar-heavy system and ensuring security of supply.

- Total electricity production increases by 87% from 2023, driven by growing demand (1.7% p.a. increase) over this period.
- Renewables will constitute more than 90% of total generation by 2060, with more than half of Chile's generation coming from solar PV.
- The share of thermal generation will decrease from 40% in 2023 to 9% by 2060, mainly driven by the coal phaseout by 2040.

DSR | Oil | Battery Storage | Hydro | Onshore wind | Solar PV | Other RES | Gas[2] | Coal

1) 2024 updated until July of 2024. 2) Gas includes OCG and CCG.

Source: Aurora Energy Research

Crucero, 100% renewables and storage by 2060, is ranked as top generation and demand hub

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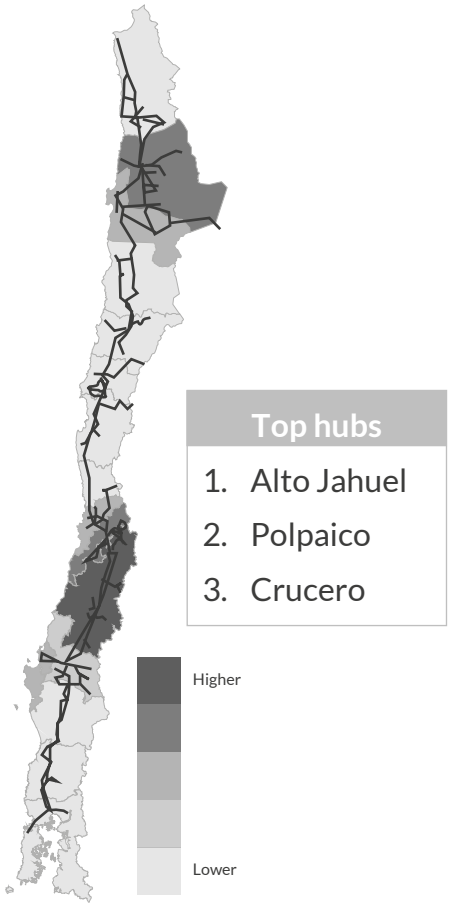
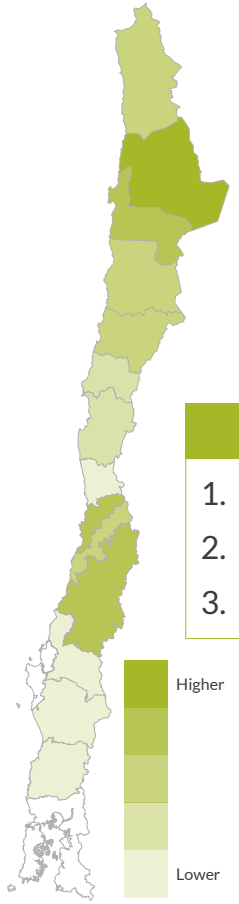
Demand
TWh



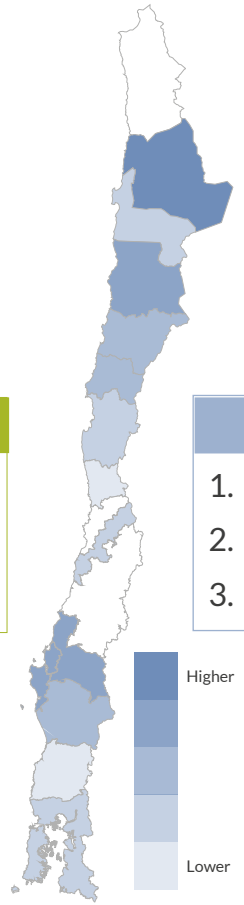
Top hubs
1. Alto Jahuel
2. Polpaico
3. Crucero

Solar Capacity
GW



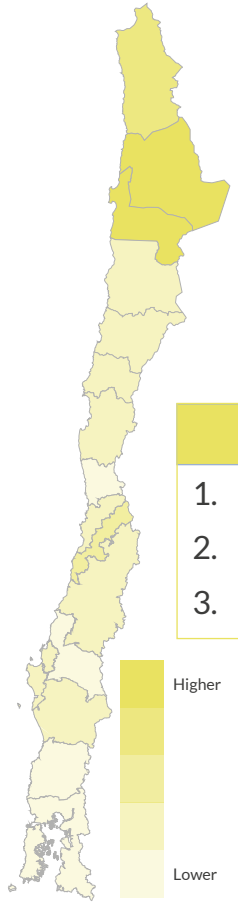
Top hubs
1. Crucero
2. Atacama
3. Alto Jahuel

Wind Capacity
GW



Top hubs
1. Crucero
2. Charrúa
3. Concepción

Batteries Capacity
GW



Top hubs
1. Crucero
2. Atacama
3. Tarapacá

- **Demand** is projected to grow by 84% from 2025 to 2060. Centre hubs concentrate residential and industrial demand, while the North is driven by industrial and mining activities.
- Crucero stands out for its strong RES and BESS buildout due to its optimal natural resources while benefitting from strategic interconnections with the rest of the country, including a 3.3GW HDVC line.
- Despite a higher concentration in the north, **solar** capacity is spread nationwide[1], while **wind** is focused in specific areas in Crucero, Charrúa and Concepción.
- Norte Grande leads in **battery** share due to its intermittency needs; regions like Tarapacá, Maitencillo, and Quillota show the fastest battery growth (12-18% CAGR).

1) Except in Concepción and Puerto Montt, which see no solar buildout.

Source: Aurora Energy Research

Diversity characterizes the hubs, with solar-exporting northern regions supplying the demand-heavy center and natural resource-limited south

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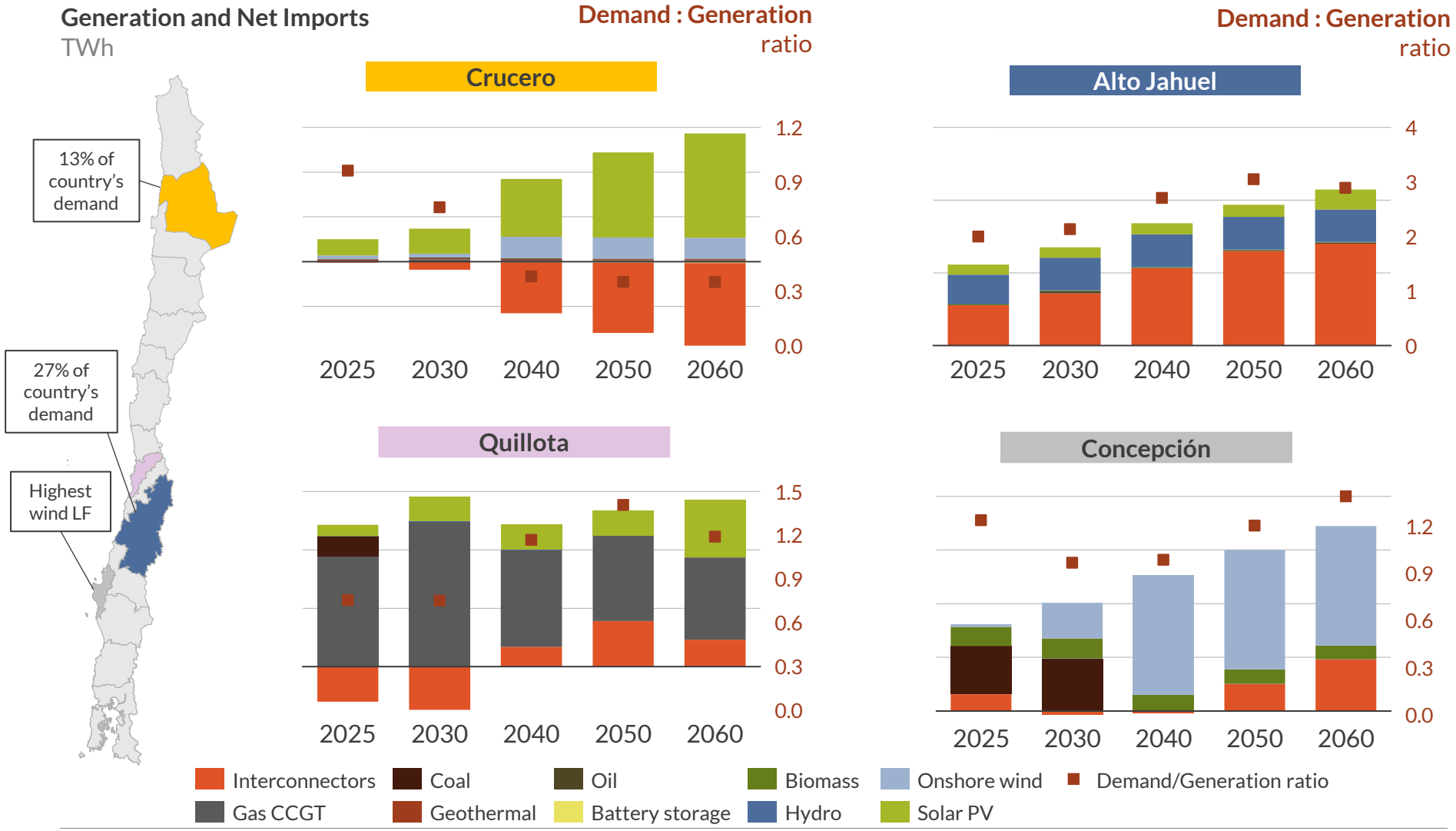

Interconnections

- By 2060, 63% of the total generation is in the north of the country, with center and south hubs being importers.
- Despite being a demand hub, the solar-rich hub of Crucero is also a key exporter, meeting its local mining demand and supplying much of the central region's demand.
- Alto Jahuel, the main industrial and residential demand center meets 67% of its demand by 2060 with imports.

Thermal

- Quillota and Concepción are two hubs impacted by the coal phase out.
- In Quillota, gas replaces coal generation while in Concepción, wind deployment and imports from other regions, eventually compensate coal generation.

Source: Aurora Energy Research

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Based on an adequacy system, Chile's capacity market ensures security of supply, with payments differing across regions and technologies

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Key fundamentals for capacity payments calculation

Capacity

Initial capacity
Potencia inicial
- Calculation differs by technology
- Assessment based on external factors[1]

→ **Preliminary firm capacity**
Potencia de suficiencia preliminar
- Assessment based on internal plant factors[1]

→ **Definitive capacity**
Potencia de suficiencia final
- Adjusted to peak demand hours

Demand

Peak demand – *Demanda punta*
- Average demand over 52 highest hours over the past year calculated on two subsystems (Center-North and South).

MRT[2]

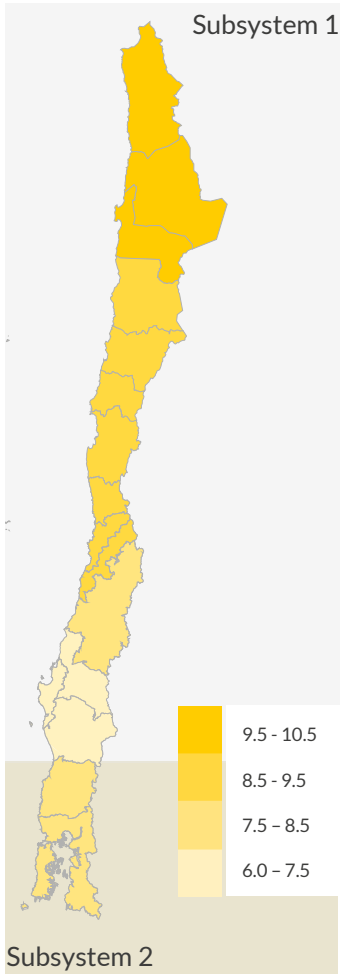
Theoretical reserve margin – *Margen de reserva teórico*
- The MRT reflects the reserve capacity that the power system needs to maintain above the expected peak demand.
- Relevant to determining the basic peak power price.

Price

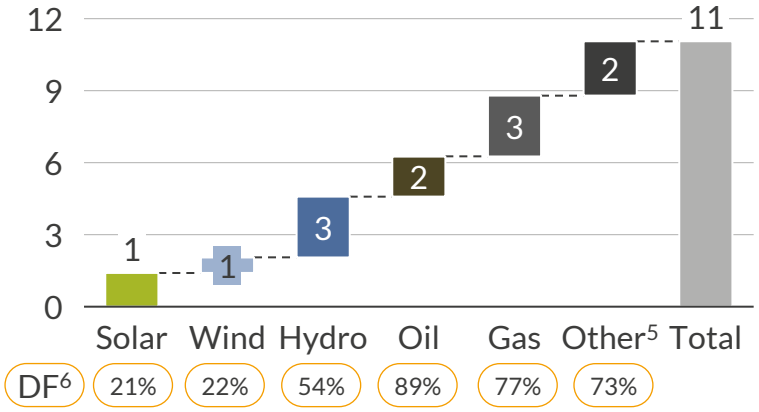
Short-term node peak price - *Precio nudo de potencia a corto plazo*
- Based on the most cost-effective technology: 70MW diesel turbine and considers financial and investment costs.
- Accounts for theoretical reserve margin by subsystem.
- Nodal price is adjusted with a "penalty factor" that reflects the probability of loss of power in transmission.

Annual Payment[3] ($) = Definitive Capacity[4] (MW) x Peak Price ($/MW) x Penalty factor

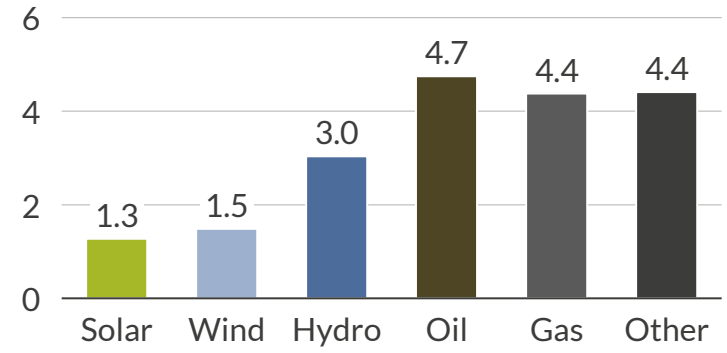
Capacity market price
$/MW/month, real 2023



Total definitive capacity in 2023
GW



Average capacity payment in 2023
$/kW/month (real 2023)



1) External factors refer to resource conditions such as load factors and fuel availability. Internal factors refer to operational status or activity interruptions of the plant. 2) In Spanish, *Margen de reserva teórico*. 3) Capacity market payments are made monthly. 4) Calculation at plant level. To estimate forecast average payment per type of technology, Aurora calculates average de-rating factors of preliminary firm capacity and adjusts payments based on those. 5) Includes coal, biomass and geothermal. 6) Average de-rating factor over preliminary firm capacity in 2023. In Spanish, *porcentaje de reconocimiento*. Sources: Aurora Energy Research, CEN, CNE.

Aurora's analysis shows that a continuation of the current capacity payment approach would lead to oversupply; our forecast assumes adjustments

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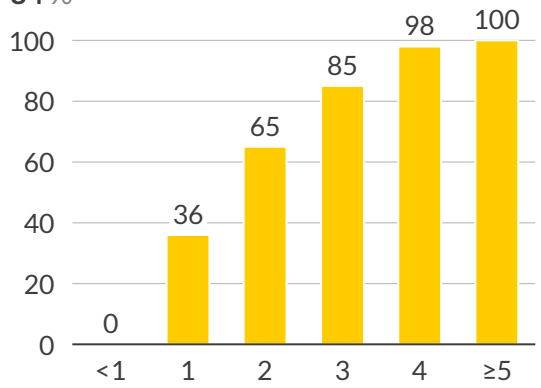
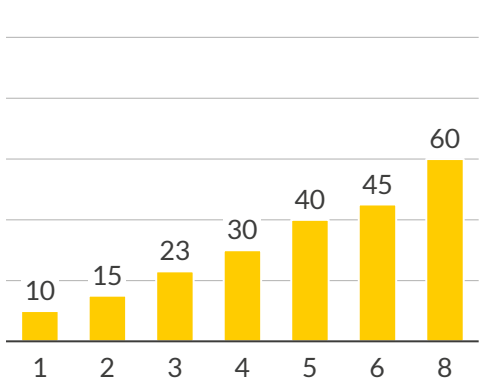
1 Battery storage receives high de-rating factors as outlined in the transitional regime of DS 70/2023, effective until 2034. We expect these de-ratings to be reassessed once the regime concludes.

De-rating factors by hour profiles, '24-'34 %



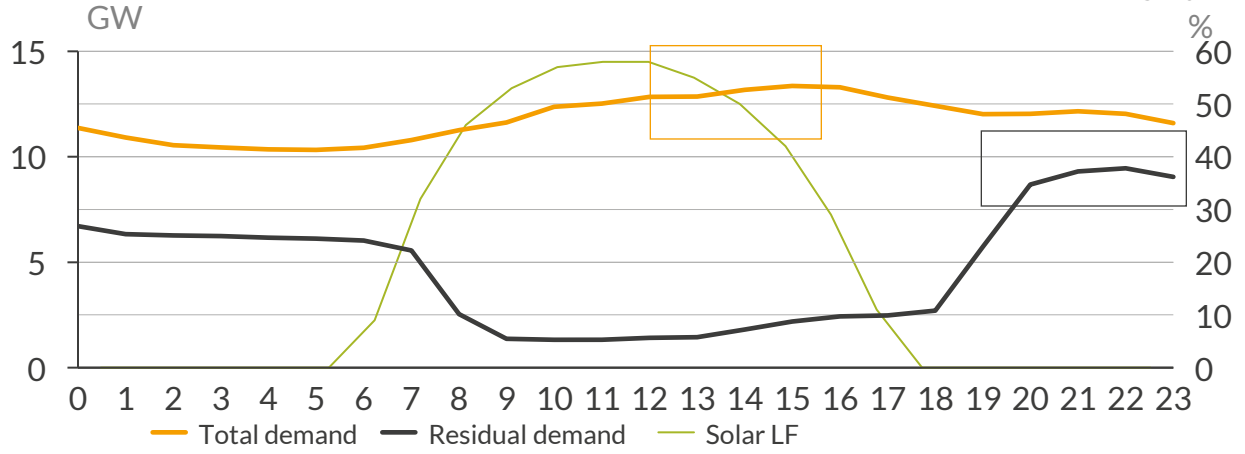
De-rating factors by hour profiles after transitional period[1], %



2 Solar units benefit from the current capacity payment methodology. As the system evolves, we expect peak demand to be re-assessed based on residual demand. This would reduce solar's contribution to security of supply, lowering capacity payments for the technology.

Illustrative daily demand, total demand vs. residual demand

Load factors Solar



3 Aurora expects capacity prices, hence payments, to converge as the system becomes increasingly interconnected.

- Planned expansion of 2x220 kV Cautín-Ciruelos transmission line is being re-tendered and will connect Southern regions to Center hubs.
- While transmission investments minimize power losses during energy transport, penalty factors[2] will gradually reduce price differences between hubs.

1) We have assumed derating factors by duration in line with international benchmarks, like the GB market. 2) Penalty factors adjust capacity prices based on the probability of power loss during transmission. 3) Average monthly payment based on plant payments. 4) Geothermal plant not represented in graph.

Sources: Aurora Energy Research, CEN, CNE

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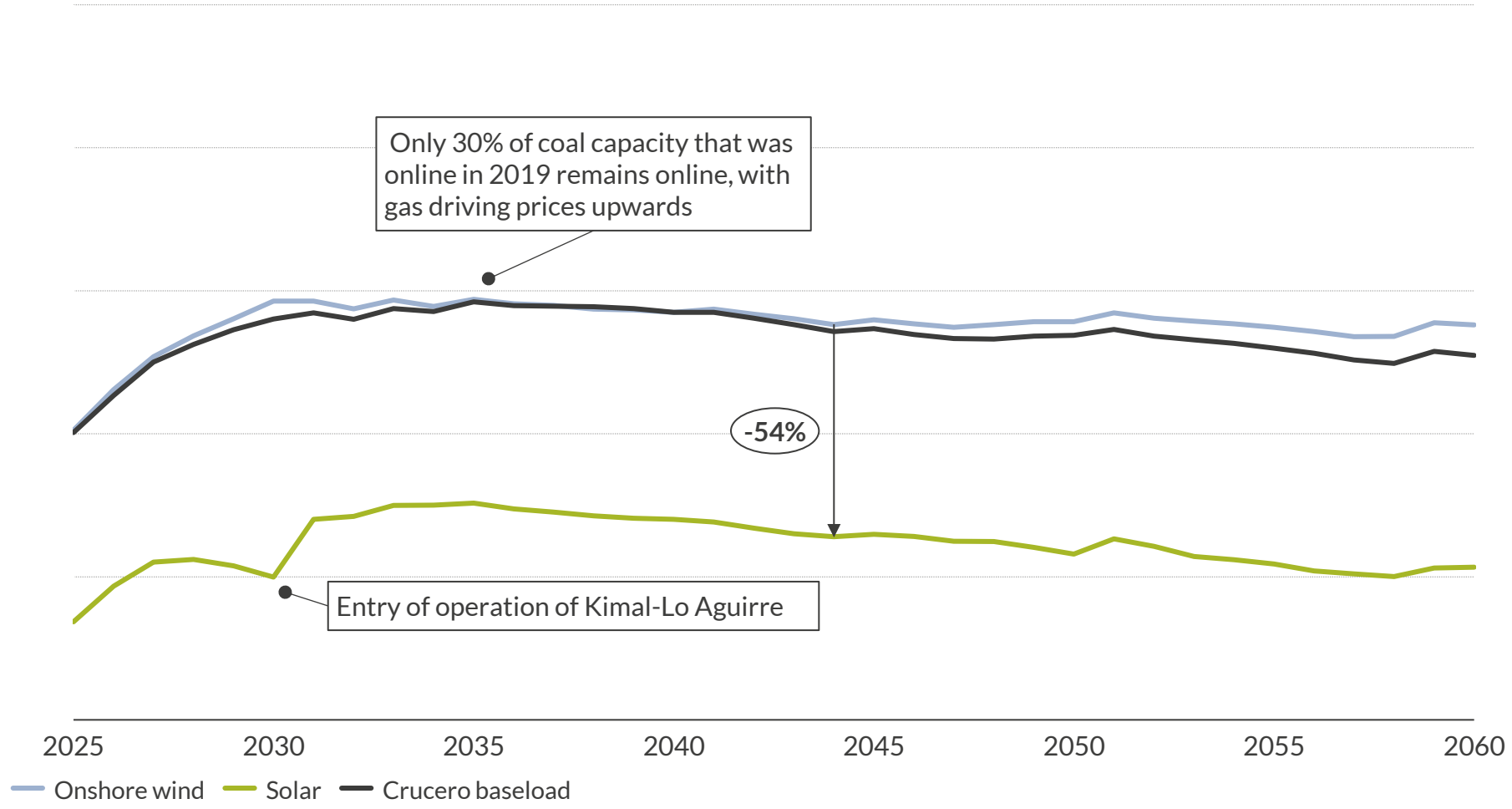
In Crucero, wind capture prices shine brighter than solar PV, with a premium to baseload, due to its complementary profile

Baseload and renewables capture prices[1]
$/MWh (real 2023)

Crucero



Sources: Aurora Energy Research, CEN

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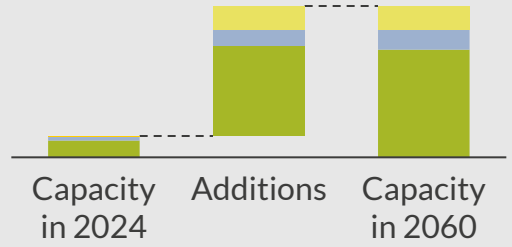
Capacity added in Crucero
GW



- The phase-out of coal, replaced by gas, leads to an increase in capture prices.
- Between 2027 and 2030, solar capture rates do not mirror the rise in baseload prices, as the expansion of the solar fleet leads to cannibalization.

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Chile is committed to ambitious decarbonization targets, including a complete coal phase out by 2040, with most plants offline by the early 2030s…

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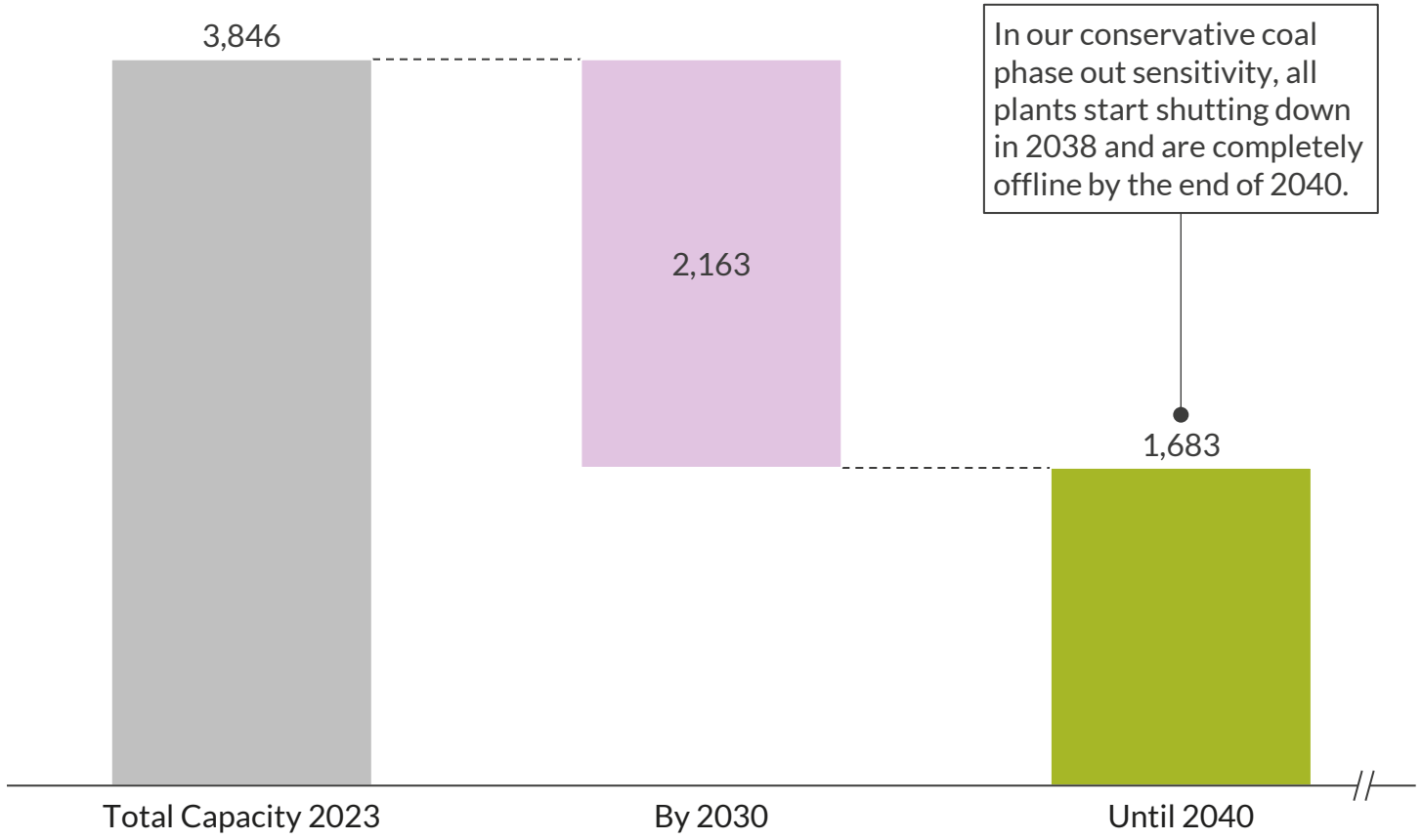
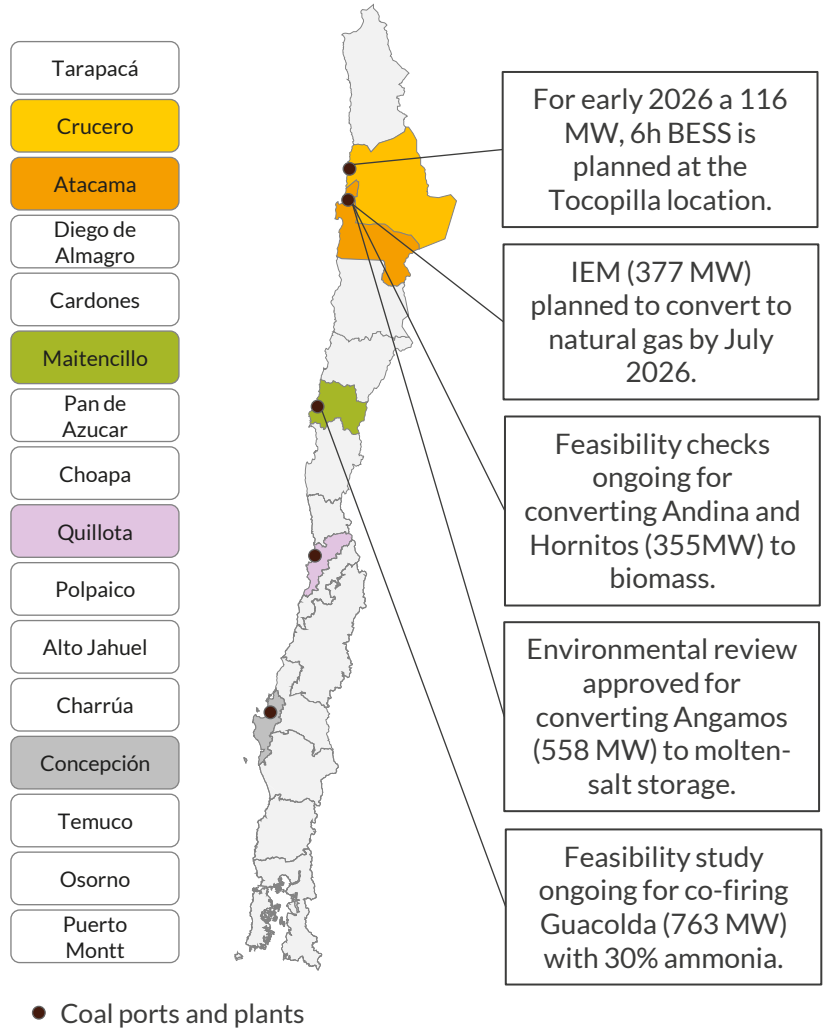
Coal Capacity phase-out by year
Gross Capacity (MW)





Sources: CEN, Ministerio de Energía, Chile sustentable, AES, Engie, Enel and Colbún press releases.

… raising prices by an average of 30% between 2025 and 2040 compared to a scenario where coal plants remain operational until the 2040s

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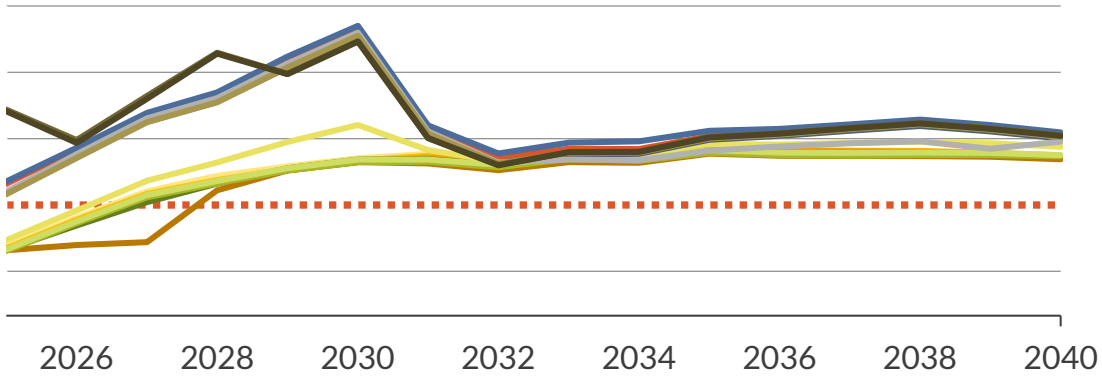
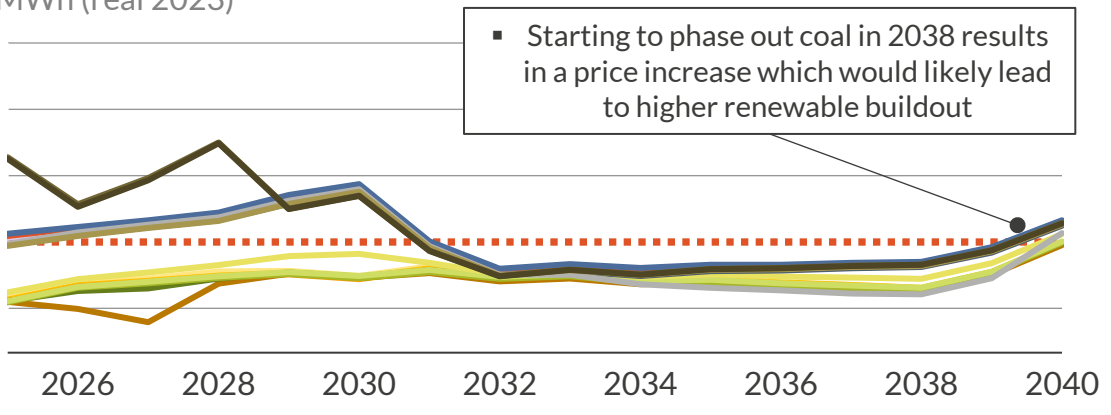
Baseload prices per nodal hub in Chile –*Aurora coal phase out*
$/MWh (real 2023)

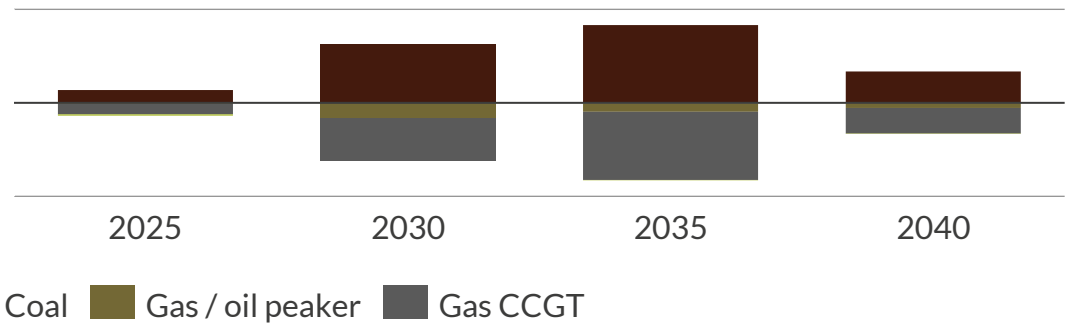


Baseload price per nodal hub in Chile – *Conservative coal phase out*
$/MWh (real 2023)



Tarapacá, Atacama, Cardones, Pan de Azucar, Quillota, Alto Jahuel, Concepción, Osorno
Crucero, Diego de Almagro, Maitencillo, Choapa, Polpaico, Charrúa, Temuco, Puerto Montt

Delta in Generation: Central coal phase out x Conservative coal phase out
TWh



- According to current plans, phasing out coal will lead to 2.1 GW of capacity going offline by 2030, which will be replaced by more expensive fossil fuel generation from gas and diesel.
- In this 15-year period, the shift from coal is expected to raise prices by 30%. As coal generation is replaced by gas-powered CCGTs this is estimated to reduce direct CO_2 emissions by about 69 million tonnes.

Source: Aurora Energy Research

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By 2060, Chile's system will be dominated by solar and batteries, with transmission growth driven by the expansion of renewables away from demand centers

AURORA

1. Chile's installed capacity is set to increase by 139% by 2060, driven predominantly by solar, battery storage, and onshore wind. Solar energy will represent 46% of the total installed capacity by 2060.

2. Over 90% of Chile's electricity generation will come from renewable sources by 2060, with solar playing a dominant role. Battery storage will support the integration of these renewable sources as thermal generation falls to just 9%, largely due to the phase-out of coal by 2040.

3. Battery storage will see substantial growth, with a focus on long-duration (8 hours) batteries. These batteries will play a crucial role in balancing supply and demand, particularly in solar-heavy regions like the north.

4. Solar capture prices face downward pressure due to cannibalization effects. Wind buildout is likely to be limited by geographical constraints despite high returns in certain areas of the country.

5. Key interconnection projects such as the Kimal-Lo Aguirre HVDC line, expected to be completed by 2032, will enhance regional power transmission, leading to converging prices across the country. Transmission growth will continue as renewables expand away from demand centers.

6. Despite lowering system emissions, the gradual phase-out of coal by 2040 will lead to increased baseload prices, with an average rise of 30% from 2025 to 2040 as gas and diesel plants take over peak generation.

7. A continuation of the current capacity payment approach would lead to oversupply. We expect capacity payments to evolve and consider lower "derating factors" for solar as the focus shifts to ensuring security of supply during the highest residual peak demand hours (or something closer to a LOLE/LOLP approach). Capacity payments for batteries are also likely to decline over time as the marginal impact of storage on security of supply in the system decreases with more battery buildout.

Details and disclaimer

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