RystadEnergy

Whitepaper

Energy Storage Outlook

Energy Macro Report

Global energy storage growth set to surge by nine times through 2040

Energy Macro Analytics

Transition in power mix puts energy storage on spotlight

The global power mix has reached a critical point, and Rystad Energy expects a peak in fossil fuels in the power sector to be imminent, with a structural shift ahead of the industry. While power demand is expected to continue to see strong growth in 2025 and beyond, the growth rate of low-carbon energy sources is now close to covering the entire demand increase.

The pace of the energy transition is, however, far from evenly distributed across the world, with South America and Europe currently leading in the share of non-fossil energy sources. China, meanwhile, has been the global growth driver for power demand in recent decades and is also by far the largest renewable energy market globally.

In Rystad Energy's current base case forecast, solar energy is projected to grow more than all other energy sources combined between 2025 and 2050, expanding tenfold over the period. Energy storage will play a critical role in integrating an ever-increasing share of intermittent renewable energy in the global power mix, as well as providing the needed flexibility for the secure operation of the power system.

Global installed energy storage is on a steep upward trajectory. From just under 0.5 terawatts (TW) in 2024, total capacity is expected to rise ninefold to over 4 TW by 2040, driven by battery energy storage systems (BESS).

Last year saw a record-breaking 200 gigawatt-hours (GWh) of new BESS projects coming online, a growth rate of 80%. China maintained its leading position in new battery storage additions, with more than 100 GWh of added capacity. This is followed by the US with 35 GWh of new BESS capacity, marking another year of growth. Germany, Australia and the UK round out the top five leading countries in BESS additions. The increased capacity in 2024 brought total global operational battery storage to 375 GWh.

The transition happening in the power mix is opening markets for battery energy storage systems. The increased share of intermittent renewables, together with low flexibility in supply and load, creates price volatility in the liberalized power markets. These price spreads can make energy trading (arbitrage) a good source of revenue for BESS.

Additionally, the declining cost of battery storage systems in recent years, combined with technological advancements, has significantly reduced the cost of storing electricity. With the global average cost of BESS projects falling below $300 per kilowatt-hour (kWh), the storage cost of electricity can be as low as $60 per megawatt-hour (MWh). This lower storage cost allows BESS operators to retain a larger portion of the price spread as profit.

The growing occurrence of negative electricity prices highlights the increasing need for flexibility on both the demand and supply sides of the grid—a challenge that energy storage is well-positioned to address. Notably, the successful integration of battery storage systems with solar farms in California serves as a valuable model for other markets. These examples demonstrate how co-located BESS and solar installations can deliver clean, sustainable energy throughout the day.

As the power sector transitions to more renewable generation sources, such developments pave the way for energy storage technologies to play a central role in the evolving power mix.

Peak fossil fuels in power impending, estimated structural shift in 2026

The global power mix has entered a pivotal phase. Fossil fuel-based generation is beginning to decline in absolute terms, even as electricity demand continues to grow. This shift is approaching quickly, with Rystad Energy's base case forecast pointing to a negative fossil growth this year. A rapid decline is, however, not expected, and the peak may be delayed to 2026 or even 2027 in the case of exceptional demand growth globally or an underperformance in renewables. Regardless, a structural decline is expected to take hold in the short term.

Fossil generation is expected to decline by 97 terawatt-hours (TWh) this year, while non-fossil sources – driven overwhelmingly by renewables – are projected to expand by a record 1,270 TWh, fully covering global demand growth and pushing fossil fuels into retreat.

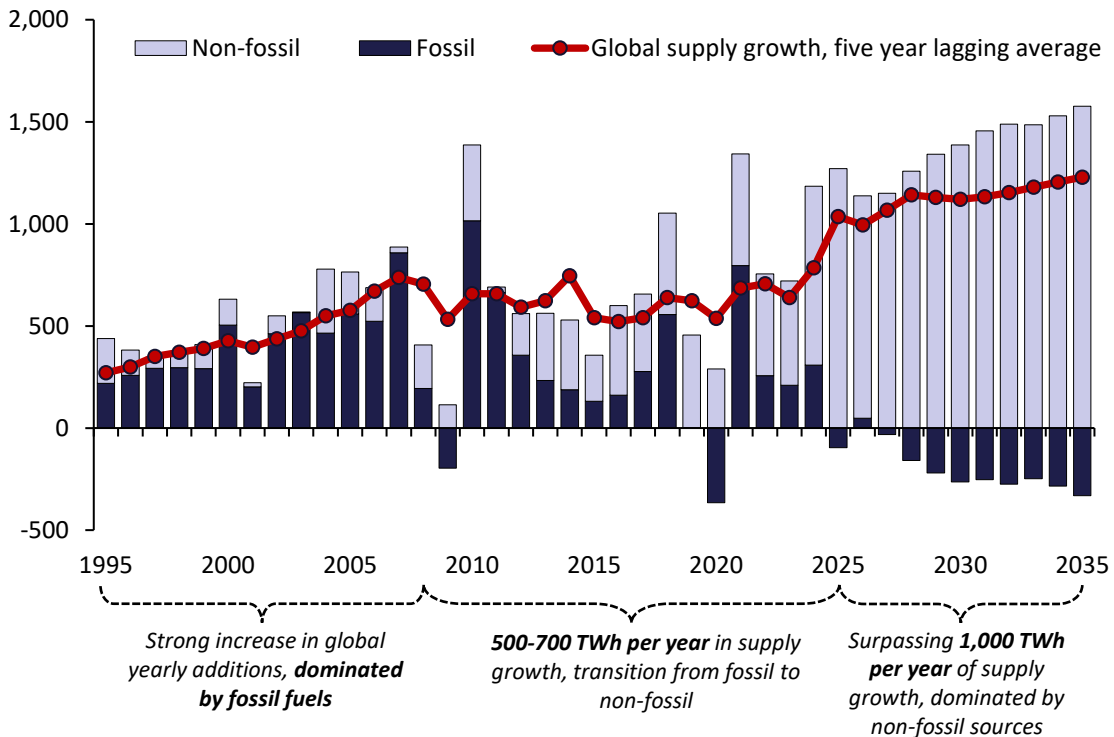
This follows a landmark year in 2024, when non-fossil additions reached 876 TWh, nearly three times the growth from fossil sources (308 TWh).

The two-year period marks a decisive break from past patterns of power expansion. This inflection reverses decades of fossil dominance, where fossil fuels contributed around 65-70% of net power additions from 1995 to 2007. Between 2007 and 2015, the share of fossil additions fell to around 55%. Meanwhile, from 2015 to 2025, fossil fuels provided just 20–25% of global net additions, while non-fossil sources – largely solar and wind – are the primary growth engine.

Looking ahead, this dynamic is expected to intensify. In the near term, non-fossil generation is set to rise by over 1,000 TWh in 2025 to exceed 1,500 TWh per annum by 2035. Fossil generation, meanwhile, is expected to decline, contracting by roughly 250 TWh yearly by 2030, and nearly 350 TWh by 2035.

Based on this, 2025 is set to be a signal year for a new phase in the global power system, where demand growth is chiefly met by renewable energy, and fossil generation is headed into a structural decline.

Global y-o-y change in power generation, fossil vs non-fossil
Terawatt-hours (Twh)



Source: Rystad Energy Power Solution

Regional energy transition trajectories: A world of contrasts

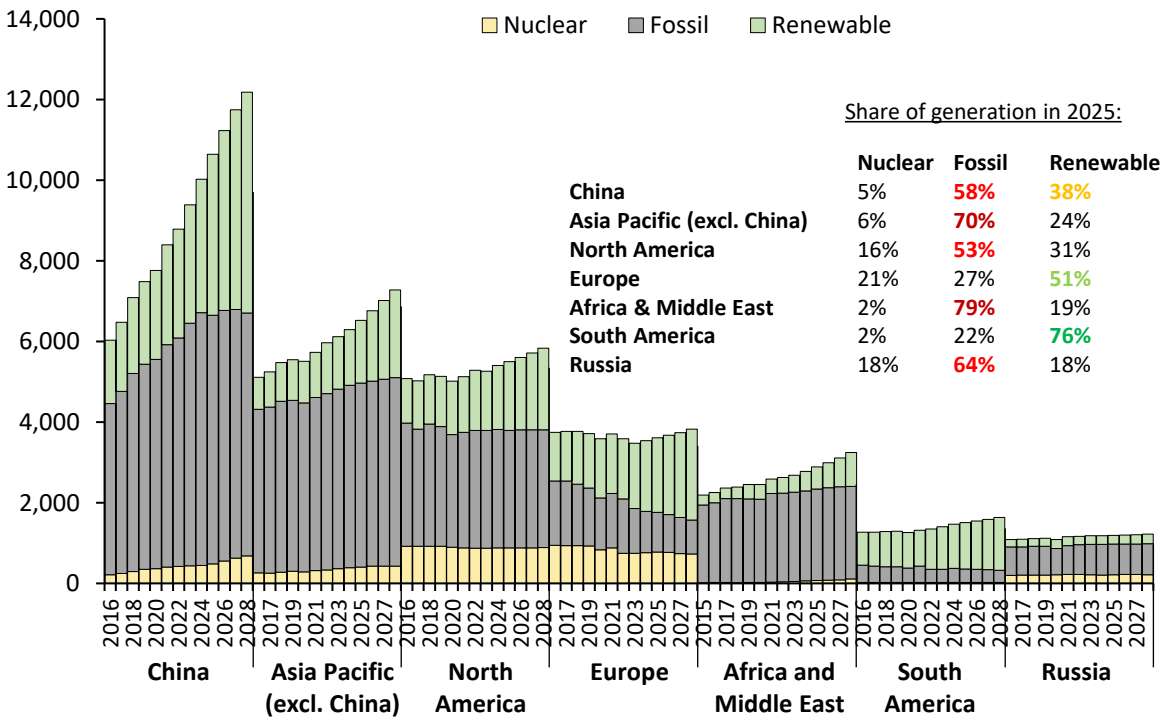
Although we believe a structural decline in global fossil fuel demand from the power sector is on the cards, the different regions across the world have vastly different energy transition trajectories.

As illustrated below, China has been the global growth leader in absolute terms over the last decade. Although the country has also been the leader in renewable energy deployment, fossil fuels constitute the majority of this growth. While China's power demand is expected to see a spike in the coming years, fossil fuel generation is expected to plateau as renewable capacity rapidly expands.

The same cannot be said about the "Rest of Asia Pacific" segment, where fossil fuels are not peaking before 2031 in our current base case forecast. As of 2025, this region has the second-highest share of fossil fuels globally, behind Africa and the Middle East. Although the "Rest of Asia-Pacific" segment comprises a diverse set of countries, one common factor for most is a rapidly growing power sector, and either a limited renewables potential or a relatively low deployment up until now.

North America and Europe also have relatively different trajectories. While both regions have seen weak power demand growth over the last decade, they saw solid growth last year and are expected to see the same growth this year. A key difference is that North America has a substantially higher share of fossil fuels, in which natural gas dominates. Natural gas demand is also expected to grow in the coming years in North America, while the total share of fossil fuel in the power sector peaked long ago in Europe.

Global power generation by type and region, 2016-2028
Terawatt-hours per year



Share of generation in 2025:

	Nuclear	Fossil	Renewable
China	5%	58%	38%
Asia Pacific (excl. China)	6%	70%	24%
North America	16%	53%	31%
Europe	21%	27%	51%
Africa & Middle East	2%	79%	19%
South America	2%	22%	76%
Russia	18%	64%	18%

Source: Rystad Energy Power Solution

Solar and wind to see the highest growth, with flexibility critical

Looking at the longer-term generation forecast, it is clear from the figure below that we expect solar and wind to represent the majority of global growth through 2050.

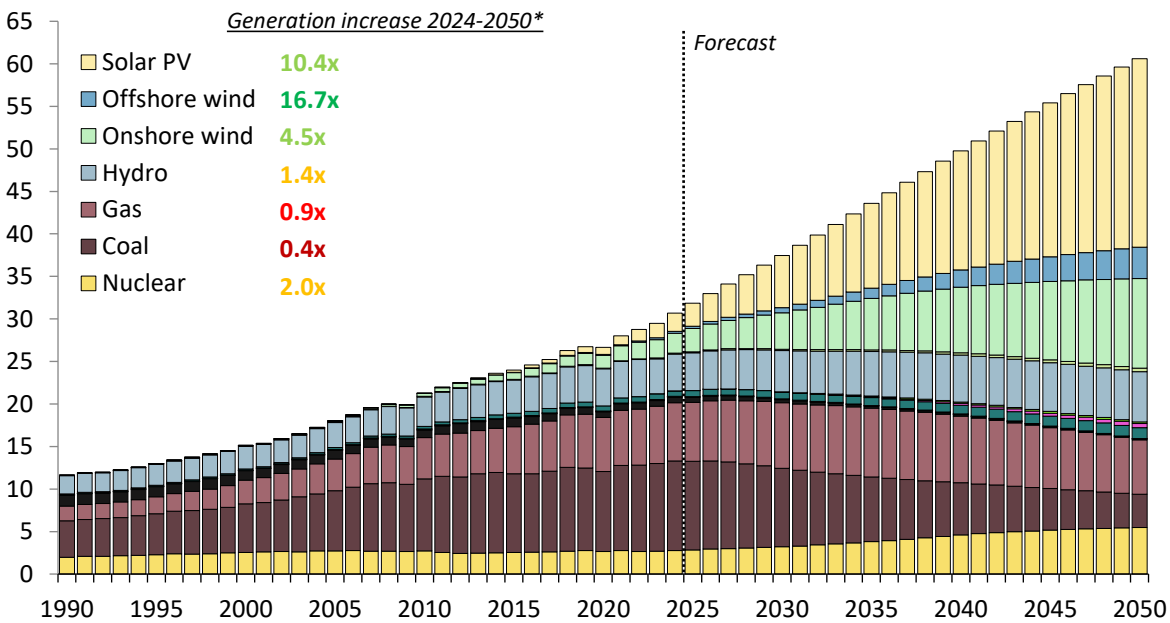
Among the large conventional energy sources, we expect nuclear energy to see the most significant increase, both in volume and percentage-wise growth, between 2024 and 2050. We are seeing the start of the nuclear renaissance, with many countries refocusing attention on large-scale nuclear reactors, as well as the expected rollout of small modular reactors. In the current base case forecast, nuclear energy doubles between 2024 and 2050, surpassing coal in the mid-2040s and becoming the fifth largest source of supply by 2050.

Currently representing the largest source of supply globally, coal power generation is set for a significant decline between now and 2050, as most countries aim for complete phaseouts or large reductions over the next 25 years. Coal will also not be competitive on cost across many regions, and multiple countries are also implementing large coal-to-gas switching programs, which is a major reason for a very resilient gas-for-power forecast in the Rystad Energy base case.

As the share of intermittent renewables increases across most regions, flexibility requirements will also rise, and for now, these is mainly met cost-effectively with gas power. BESS will also play its part here, and the role of storage will be the primary focus for the rest of this report. Hydropower is expected to see limited growth, as most regions already have exhausted their potential. Most of the growth is expected across Asia and Africa.

In the current base case forecast, solar PV is projected to add more new generation capacity than all other energy sources combined between 2024 and 2050, expanding tenfold over the period. As solar and wind are intermittent in nature, flexibility will be critical going forward, and we expect energy storage to play a critical role in the continued integration of massive amounts of solar and wind.

Global gross power generation by energy source, Rystad Energy base case forecast
Petawatt-hours per year



*The number indicates the generation multiple between 2024 and 2050
Source: Rystad Energy Power Solution

Global energy storage growth set to surge by nine times through 2040

Global installed energy storage is on a steep upward trajectory. From just under 0.5 TW in 2024, total capacity is expected to exceed 4 TW by 2040, marking more than a nine-fold increase. This acceleration reflects a rapid scale-up in manufacturing and deployment across key markets, with China set to dominate growth in absolute terms.

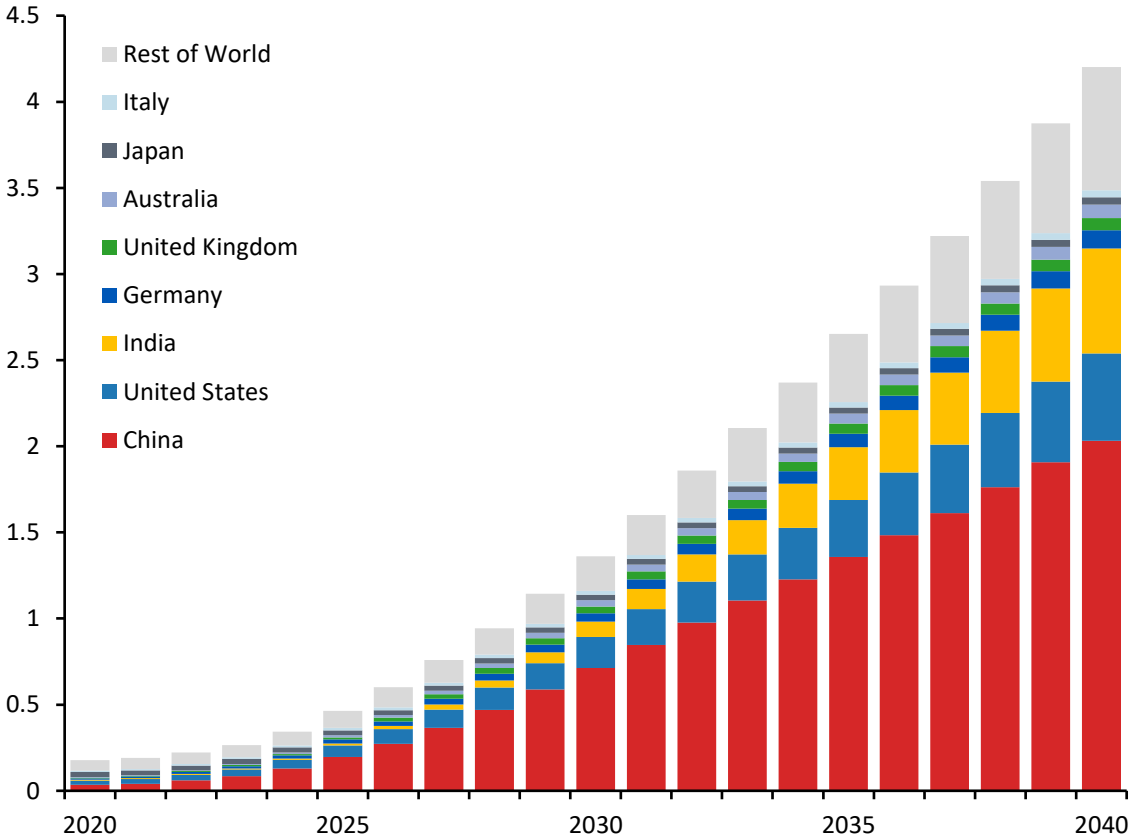
As solar and wind energy drive the growth of power generation, the demand for energy storage is rising, with storage technologies playing a crucial role in enabling reliable renewable power delivery.

China is projected to add over 1.9 TW by 2040, accounting for half of total global additions. The US, India, Germany, and Australia also show strong growth momentum, supported by market incentives, policy tailwinds, and expanding use cases for grid flexibility and renewable integration. Emerging and advanced economies are ramping up efforts to address storage bottlenecks in power systems, which are increasingly reliant on variable energy sources.

The annual global growth rate from 2024 through 2040 averages nearly 24%, with more than 3.6 TW of new capacity expected over this period. This makes storage one of the fastest-growing infrastructure segments globally. The growing role of the rest of the world outside major economies signals a broadening shift, as cost reductions and technology diffusion drive adoption beyond the early leaders.

Global installed energy storage by country

Terawatt



Source: Rystad Energy Energy Storage Solution

Global battery storage market accelerates toward new records

Another record-breaking year in the BESS industry was witnessed in 2024, with nearly 200 GWh of new projects coming online. This marked an 80% year-on-year growth and brought total global operational BESS capacity to 375 GWh.

As variable renewable energy sources continue to account for a growing share of the global power mix, battery energy storage is increasingly recognized as a key solution for enhancing the reliability and flexibility of power systems across markets.

China remains the largest BESS market and is projected to maintain its lead in 2025 with over 150 GWh of annual additions.

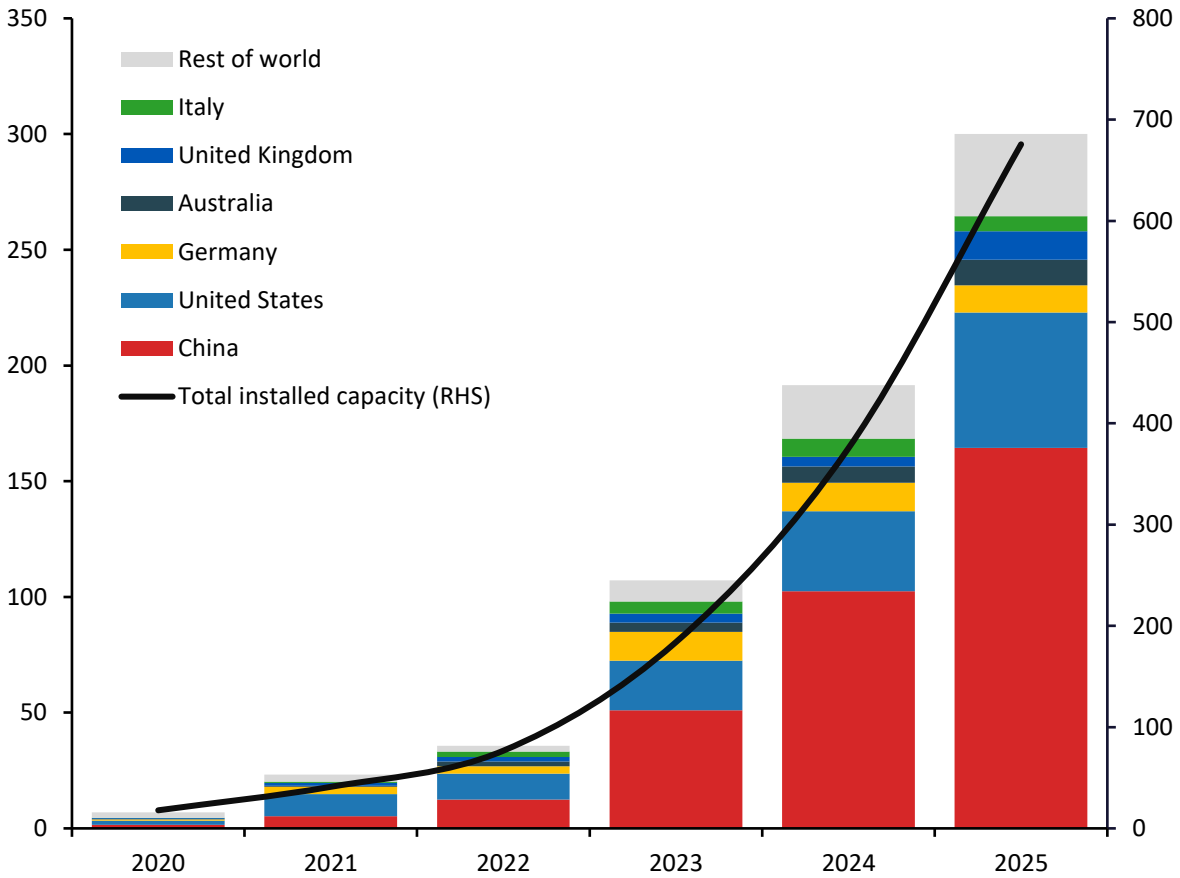
The US follows as the second-largest market, adding approximately 35 GWh in 2024, and is expected to continue positive year-on-year growth in the coming years.

Growth in Australia and the UK, which are also considered mature markets for utility-scale BESS, is expected to be driven primarily by large-scale applications this year. In contrast, Germany experienced flat growth in 2024, mainly due to its reliance on residential segments. However, utility-scale deployment is anticipated to accelerate in the country this year as permitting and application processes are streamlined.

Global battery energy storage system (BESS) additions by year

Yearly additions, Gigawatt-hours

Total operational capacity, Gigawatt-hours



Source: Rystad Energy Energy Storage Solution

Negative prices surging in markets with high share of renewables

An ongoing shift in the pricing dynamics in the power market accelerated last year, with heightened volatility and a notable rise in negative pricing instances in the day-ahead market as electricity supply outstripped demand, forcing producers to pay to offload their excess power onto the grid.

This is largely the result of an increase in intermittent renewable energy sources such as wind and solar power, which, unlike traditional fossil fuel-based power generation, cannot be ramped up or down to meet demand. Instead, renewable energy output is closely tied to weather conditions such as sunlight and wind availability, which are not always in sync with consumption patterns.

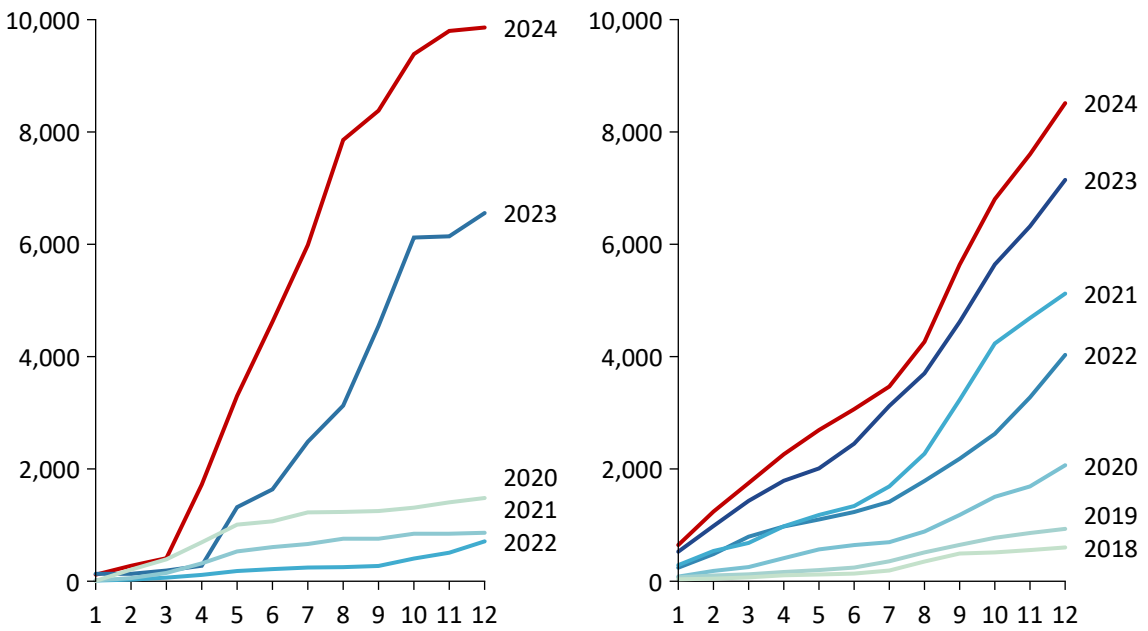
The occurrence of negative prices has already been a core element of the Australian market for several years, as the country has one of the largest shares of solar PV in the power mix in the world.

But this is not limited to Australia. In 2024, a surge of negative pricing in the European summer highlighted the challenges that come with renewable energy integration. Solar energy production peaks in the summer due to longer daylight hours, contributing to an oversupply of electricity during certain periods.

This oversupply was a significant factor behind the negative pricing phenomenon in Europe, which typically has peak demand in the wintertime due to heating needs. However, it is important to note this is not just a function of intermittent supply, but also an indicator of how flexible the remaining baseload is in addition to the flexibility of demand. Nevertheless, increased numbers of negative hours also indicated the need for storage systems. Energy storage systems increase flexibility from the demand side by charging from the grid and the supply side by discharging.

Number of hours with negative prices in Europe (left) and Australia (right)*

Number of hours



*Across all power markets in Europe and Australia, respectively. Since the number of power markets across the two regions are different, the two charts are not directly comparable

Source: Rystad Energy Renewables & Power Solution

Rising volatility sustaining the BESS arbitrage opportunity

Another direct result of a high share of intermittent renewable energy in the power mix is an increase in the one-hour intraday spread, defined as the difference between the highest-priced and lowest-priced hours in one day. This is connected to the occurrence of negative prices discussed earlier, as the daily lows fall, but it does not fully explain some of the price fluctuations that have been observed.

The price volatility makes energy trading (arbitrage) a viable revenue stream for BESS players. However, arbitrage opportunity varies in each power market.

Three main factors can explain the very large intraday spread:

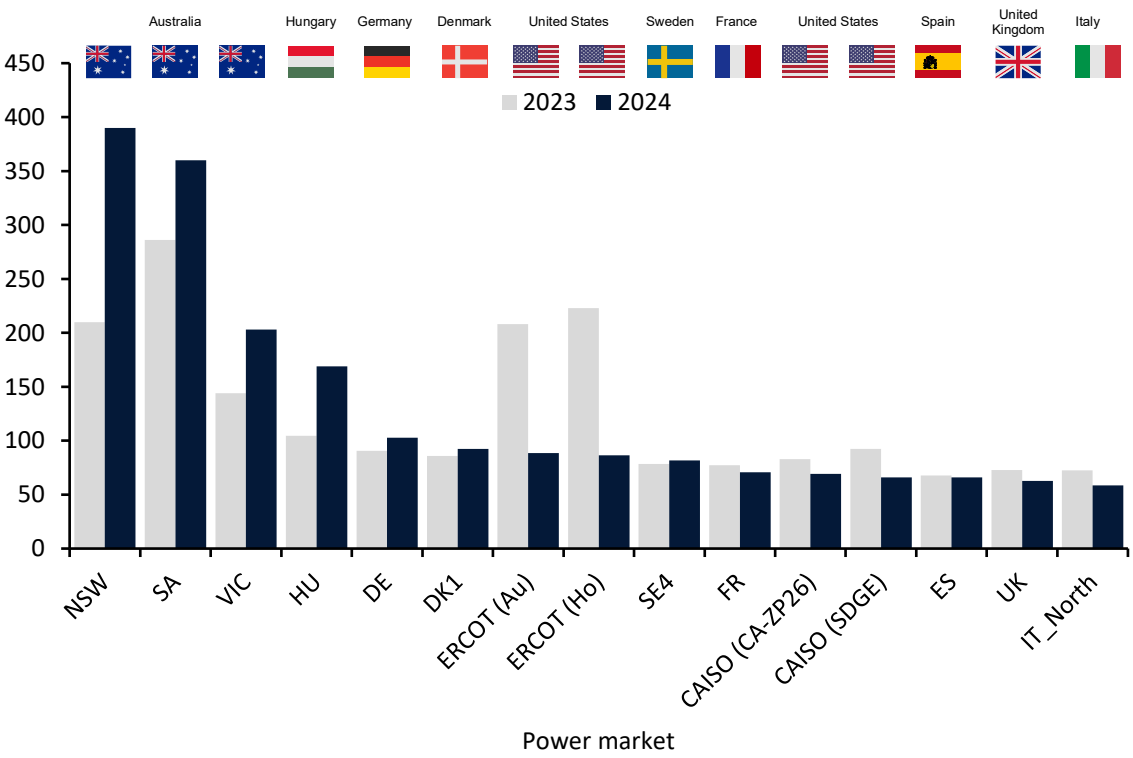
- Weak interconnection between the neighbouring states, and in some cases, within each state.
- Effect of unplanned outages of fossil capacity. When this happens, there is typically a massive spike in prices.
- Fossil versus renewables. The combination of high solar penetration and (often inflexible) fossil generation leads to large differences between solar generation on and off peaks.

In 2024, electricity markets in eastern Australia were highly volatile due to weak regional interconnections, unexpected supply outages, low daytime prices from solar, and high evening prices driven by expensive gas.

Texas, an energy-only market, is weakly connected to neighboring states. It relies mostly on natural gas, with increasing contributions from solar and wind, and represents the perfect scenario for price volatility. Nevertheless, the extremely hot summer in 2023 increased the peak prices in Texas and marked a record-high volatile year as well.

Average one-hour intraday spread across global power markets

USD per megawatt-hour



Source: Rystad Energy Energy Storage Solution

BESS capex drops another 20%, making it more affordable than ever

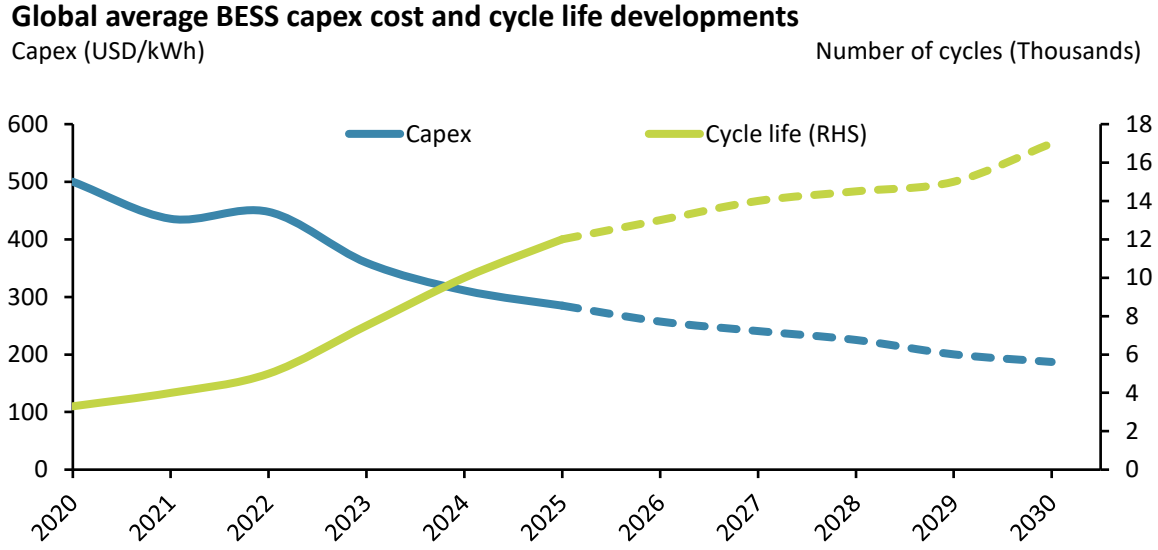
The global average cost of BESS fell below $300 per kWh in 2024, adding to the significant price declines of the past three years. Additionally, advances in battery technology research and development have extended system lifespans.

Manufacturers currently guarantee battery storage systems for over 10,000 cycles and more than 80% battery health during that lifespan. A combination of lower system costs and improved cyclability has made electricity storage more affordable.

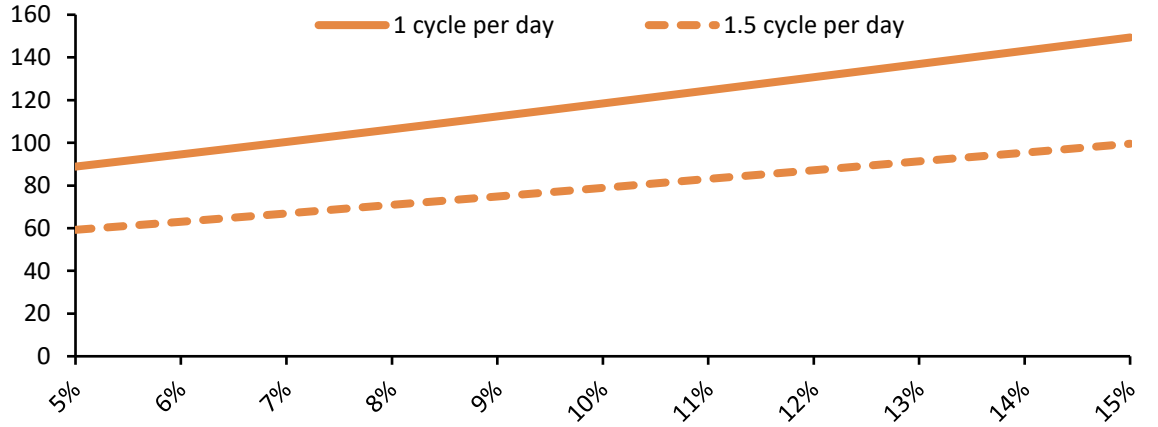
Up to 1.5 full cycles per day during 20 years of operation will still be within the guaranteed range of a battery storage system.

Assuming a system cost of $250 per kWh, the cost of storing 1 MWh of electricity can be as low as $60 per MWh, with an included discount rate of 5%, making BESS competitive in many power markets around the world.

Global average BESS capex cost and cycle life developments



Levelized cost of storage* on different discount rates with capex of $250/kWh



*Lifespan of 20 years. 95% round-trip efficiency, 90% depth of discharge, and 1% annual degradation are included in the calculation. 1% of the capital expenditure cost is considered as annual fixed operational expenditure cost.
Source: Rystad Energy Energy Storage Solution

BESS helps California harness more solar power for evening demand

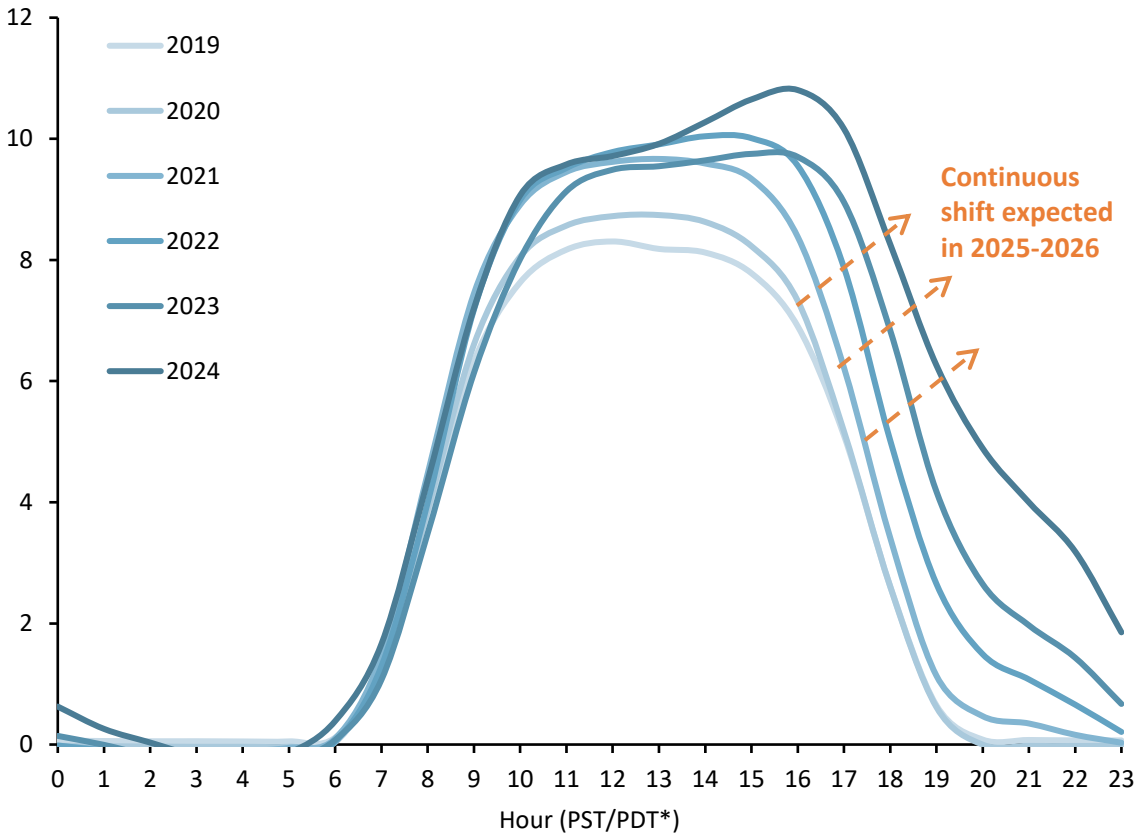
Battery storage systems are increasingly shifting solar-generated power into the evening in California. Since 2021, the combined output from solar generation and net battery storage discharge has remained relatively steady at around 10 GW per hour during the day. However, as battery storage capacity grows, this combination is extending its coverage across more hours of the day.

Just four years ago, batteries accounted for less than 1% of power demand during discharge periods. That share rose to approximately 3% in 2022, 4-5% in 2023, and averaged around 8% last year.

Over the first quarter of 2025, it has surged to about 11%. Instances where batteries supply more than 15% of the California Independent System Operator's (CAISO's) power needs during evening and nighttime hours are becoming increasingly frequent.

CAISO is a world leader in battery storage integration, with 12 GW of operational utility-scale BESS. This successful integration serves as a model for other markets with significant solar capacity, offering a roadmap for effectively incorporating battery storage into the broader energy mix.

Average CAISO generation from solar and BESS combined throughout the day
Gigawatt-hours



*PST/PDT – Pacific Standard / Daylight Time
Source: Rystad Energy Power Solution

Would you like to learn more?

This whitepaper is a condensed version of our latest Energy Macro Report. As part of our Energy Macro Analytics product, we publish comprehensive reports monthly, covering the latest updates and market trends. This report was created in collaboration with our Renewables & Power research team.

If you want to know more about our Renewables & Power Solution, including our energy storage research, or to request a brief demonstration session, please use the QR code below.

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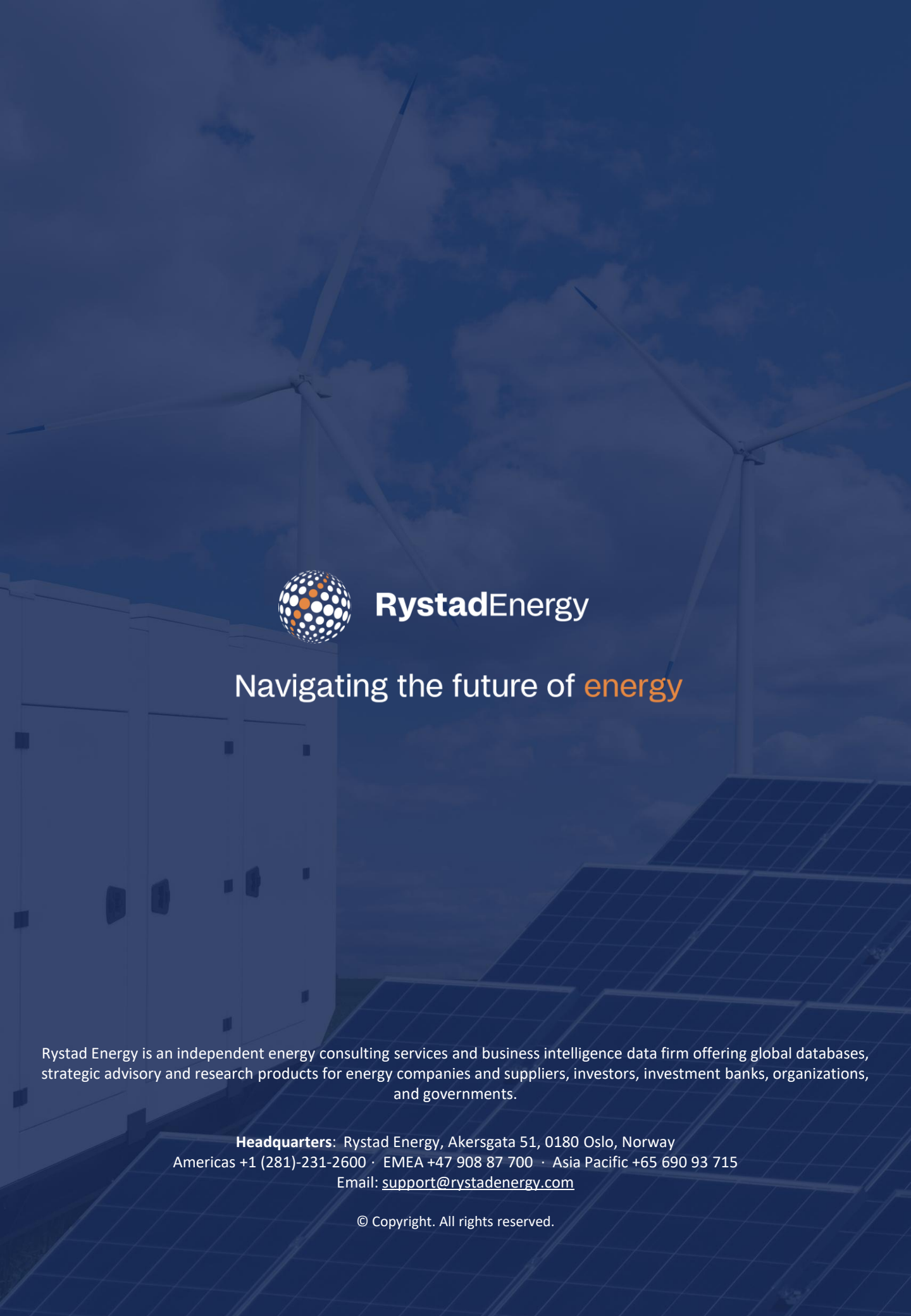

RystadEnergy

Navigating the future of energy

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