Top Ten Cleantech Trends in 2024

Clean Energy Technology Team:
Gas, Power & Climate Solutions Team

Melissa Manning, Executive Editor

S&P Global
Commodity Insights

Clean energy technology investments in 2024 will rise by 10%-20% compared with 2023, S&P Global Commodity Insights forecasts. This report identifies the top trends to watch in the sector – from competition among solar and storage manufacturers to record offshore wind capacity auctions and growing interest in low-carbon hydrogen as a feedstock.

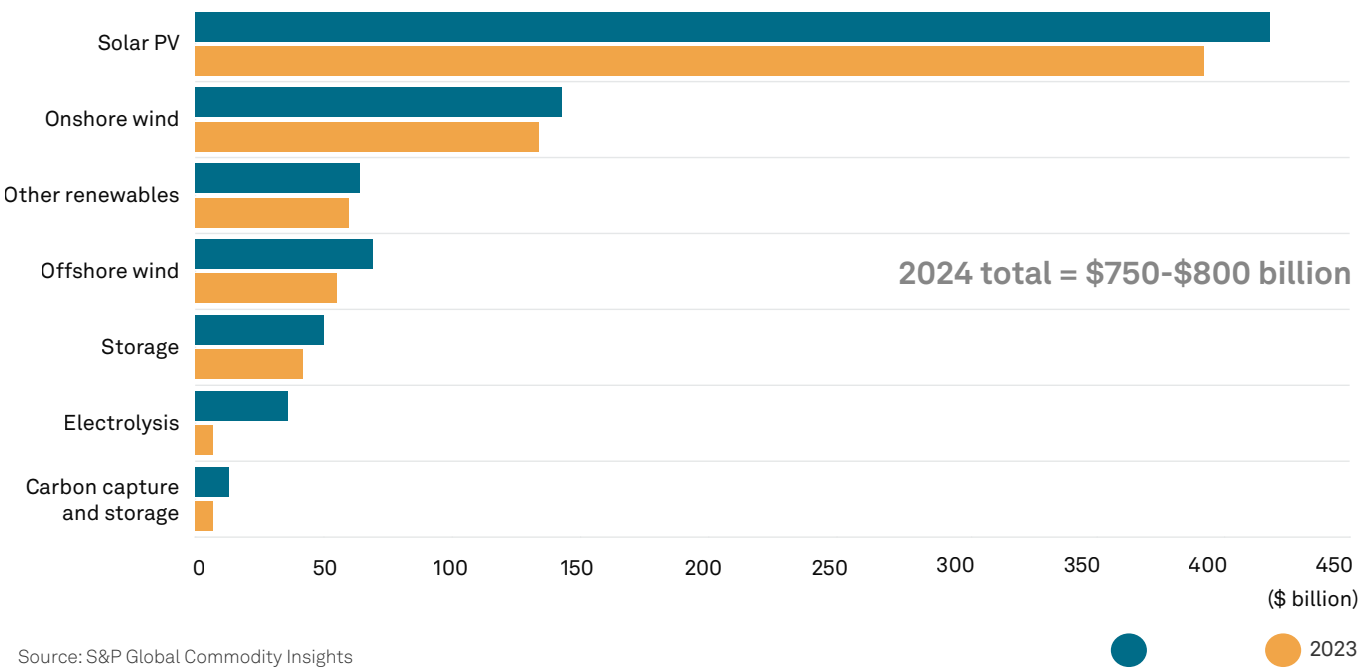
1. Clean energy technology investment[1] will reach nearly $800 billion in 2024 and $1 trillion by 2030

The S&P Global Commodity Insights forecast of nearly $800 billion in clean energy technology investments for 2024 is 10%-20% higher than 2023 spending levels. Solar will enjoy the largest share of the additional spend and account for some 55% of total investment. Onshore wind is the second-largest segment in terms of absolute investment but grows more slowly; the fastest-growing areas for new investments are battery energy storage and electrolysis.

S&P Global Commodity Insights tracks over 6,500 individual solar and energy storage projects expected to be commissioned in 2024, in addition to millions of distributed projects, making the investment opportunity very diffuse. Some 150 green hydrogen projects and 65 carbon capture, utilization and storage (CCUS) projects, including capture, transportation, and storage, will be commissioned in 2024.

Policy will continue to drive investments across clean energy technology, particularly for new technologies. CCUS policy and regulations will continue to evolve, driving a big increase in the pipeline of projects. The first-ever mandate to store CO2 in Europe reduces uncertainties around the infrastructure needed for CO2 transport and storage and provides a positive signal to the global CCUS market, as does the enhanced 45Q tax credit contained in the US Inflation Reduction Act. A similar picture is emerging for hydrogen, with consumption mandates approved in Europe and auctions for support underway in Australia, India, the European Union and its member states, and the UK. The publication in December 2023 of the highly contentious US Treasury guidance for the 45V hydrogen production tax credit will define the investment framework in the US.

Global offshore wind industry set for busy 2024



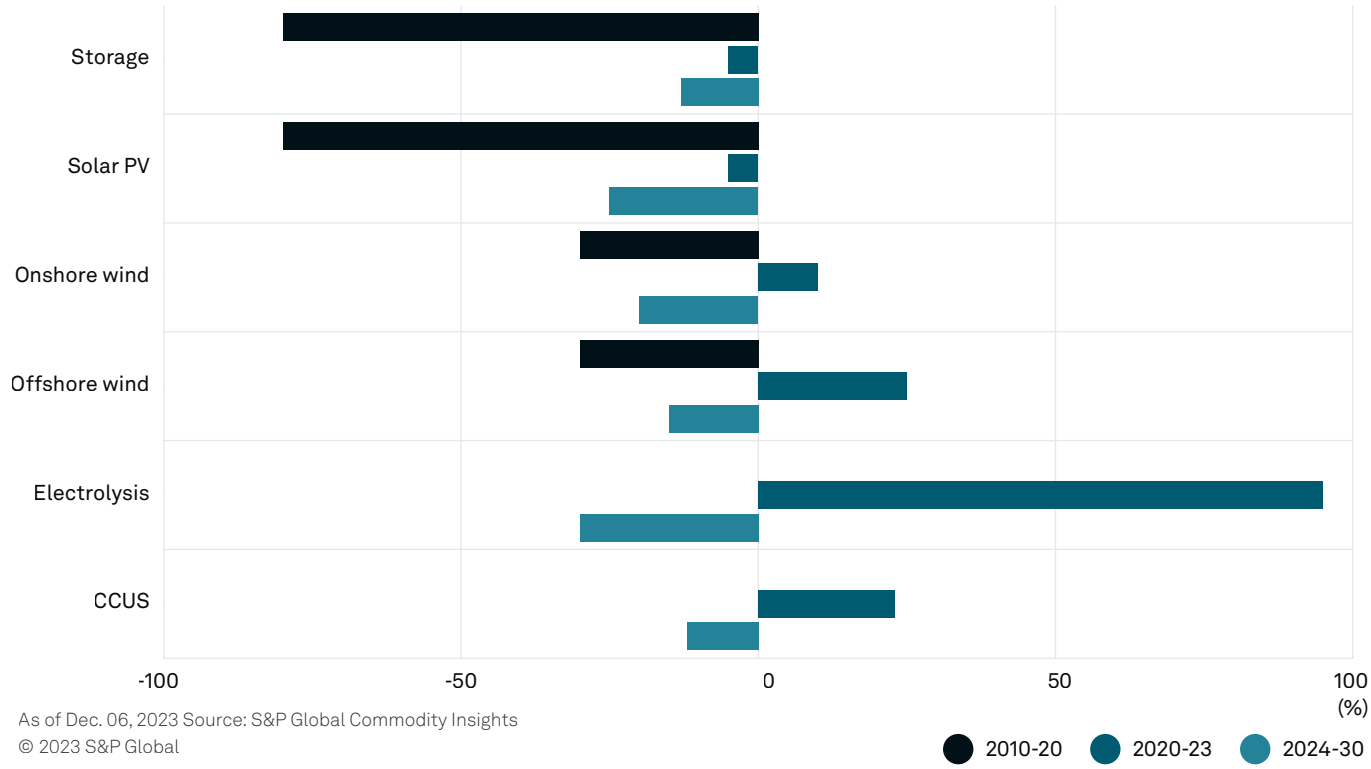
Source: S&P Global Commodity Insights

2. Average capex of clean energy technologies will decline by another 15%-20% by 2030

Despite rising costs of offshore wind and hydrogen, oversupply and falling raw material prices will ensure that the average cost of clean energy technologies continues to decline in 2024. The combination of oversupply and falling raw material prices is rapidly driving down the costs for solar and batteries from their 2022 highs. Costs came down significantly in 2023 and will drop well below 2020 levels in 2024. Going forward, continuous improvements to technology will ensure equipment costs will continue to fall, overcompensating for upward pressure on development costs (permitting, grid connection, etc.) and labor. As these technologies account for the vast majority of capacity additions, the average cost of adding clean energy technologies to the grid will continue to fall **by another 15%-20% by 2030**.

While this trend holds for mass-produced, commoditized technologies like solar and batteries, the return of cost declines will take more time to materialize for wind. Offshore wind (outside of China) has been particularly vulnerable as investment is concentrated in a few large projects with long lead times. Escalating capital costs have led to numerous power purchase agreement (PPA) cancellations in the US, low appetite in the Gulf of Mexico leasing round, and failure of a contract for difference (CfD) auction round in the UK.

Evolution of capex of clean energy technologies



As of Dec. 06, 2023 Source: S&P Global Commodity Insights

Emerging technologies like green hydrogen and CCUS have seen the largest cost increases over the past two years, but they represent a very small share in total clean energy technology investment. Electrolysis costs are almost 95% higher than 2020 levels due to increases in balance of plant, operation and maintenance of all subsystems, and equipment. First-of-their-kind projects are costing much more than expected and benefits of scale have not yet materialized. Although the cost increases for electrolysis make project economics more challenging, the ongoing decline in costs for commoditized, mass-produced products like PV panels, driven by massive production capacity additions and technological improvements, will bring down the cost of hydrogen from electrolysis. Lessons learned from this first generation of projects are expected to reduce capital costs of future projects as real-world performance data allows project design to be optimized. Compliance buying requirements in Europe and Japan will ensure a customer for these early-stage, high-cost projects.

3. Clean energy technology manufacturers are making decarbonization core to both products and strategies

The renewables industry has been scrutinized in the past for selling components to generate low-carbon electricity while not focusing enough on lowering the carbon footprint of the most energy-intensive parts of the value chain. However, things have changed. Renewables manufacturers are developing strategies to lower emissions at the core of their products and have very ambitious plans to decarbonize their products and operations before 2030 to further set themselves apart from higher GHG emissions from the natural gas, oil, and coal sectors. This is also part of a bigger movement to increase the transparency and traceability of renewable supply chains and materials.

> "Europe has the lowest average carbon intensity of the power system across global regions."

Two key opportunities exist to decarbonize: 1) In manufacturing processes, particularly energy-intensive ones, by using low-carbon electricity resources such as renewables and hydroelectric power, and less coal or natural gas. In the case of solar, where about 90% of all CO2 emissions in the PV supply chain come from electricity consumption, this is doable. 2) In technology and materials, by changing processes. In the case of solar PV, for example, a progressive reduction in materials consumption, such as of polysilicon or silver; the exploration of less-intensive new manufacturing technologies such as direct wafer and perovskites; and use of lower carbon footprint materials. For batteries, a push for higher energy densities; a shift to technologies that require less mining-intensive metals, such as lithium-iron-phosphate (LFP) batteries instead of nickel-manganese-cobalt (NMC) or developing alternative technologies to lithium-ion batteries which use more abundant, lower-carbon materials such as sodium-ion, flow batteries, or gravity storage.

Primary drivers of this change are policy and customer demand. In Europe, companies are anticipating the implementation of the Carbon Border Adjustment Mechanism (CBAM) and a new regulation on batteries, which will trigger reporting their lifetime carbon footprint and prioritize decarbonization of the operations and products ahead of policy mandates extended to other regions. This goes beyond the clean energy technology

industry, reaching mining and other hard-to-abate sectors like steel and cement, that are focused on decarbonizing operations through hydrogen and CCUS projects.

Increasingly, customers are interested in low-carbon products. For instance, low-carbon solar PV modules are already a key qualification criterion for large developers, investors, and offtakers, but more work is needed around standardization and policy support for low-carbon solutions across clean energy transition technologies. Thus, appropriate certification will be critical to ensuring that carbon reduction promises are realized and that a level playing field exists between players. The CBAM and Renewable Fuel of Non-biological Origin mandates will ensure that the European Union plays a key role in defining global standards and methodologies.

4. Oversupply is driving solar and storage manufacturers into a price war – compressing margins and jeopardizing localization efforts

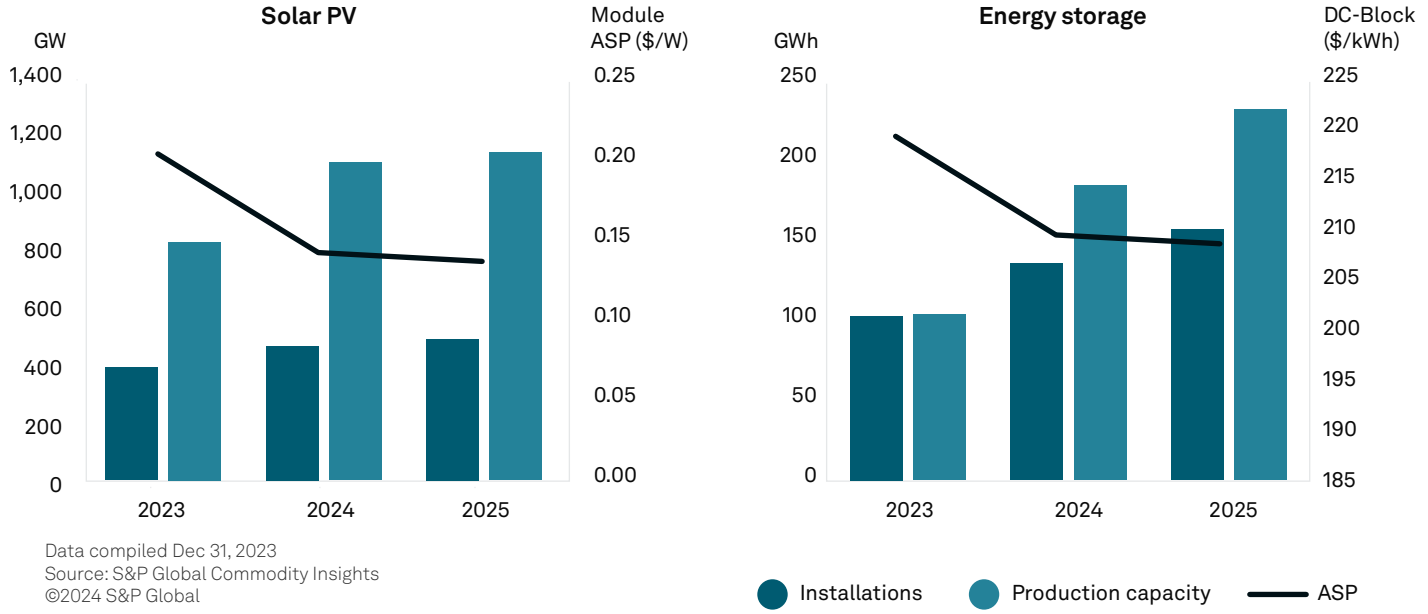
Solar and battery manufacturers had solid margins for two years but are facing lower margins through 2024. In the case of solar, downstream players (distributors and installers) are also impacted by high inventory levels that need to be written off due to declining market prices, putting some of these companies at high financial risk. Oversupply and price drops in raw materials led to a downstream price war in the second half of 2023 for solar modules and batteries and will lead to market consolidation in 2024. Smaller Tier 2 and Tier 3 manufacturers are likely facing negative gross margins while leading Tier 1 companies need to differentiate themselves with innovative products or exceptional price over quality.

Battery energy storage system manufacturing is becoming more crowded, with new entrants attracted to the promise of global installations more than doubling in the next two years as energy storage is increasingly recognized as a critical asset to enable highly decarbonized power systems. Joining the incumbent supplier base of traditional system integrators, battery cell manufacturers are increasingly expanding downstream to offer systems, and other companies such as solar panel manufacturers and large industrials have also entered battery energy storage system manufacturing. Growth has been particularly pronounced in China, up nearly sixfold in 2022 and accounting for 30% of global installations, helping a group of new Chinese system manufacturers to scale and seek internationalization.

S&P Global Commodity Insights anticipates that the current landscape of costs and competitive prices for both solar PV and batteries will make it increasingly challenging and expensive to build manufacturing capabilities in the US and Europe, which could jeopardize ongoing localization efforts. Both technologies were prominently included in the US Inflation Reduction Act (IRA), aimed at increasing US self-sufficiency and resilience, but with uneven results to date. Announcements of new US solar capacity are mostly at the module level, and the overall expectation of "self-sufficiency" of the solar PV industry has not yet changed dramatically.

> "In the next two years, manufacturers will add 309 GW of solar module and 129 GWh of energy storage system production capacity – in both cases this is more than global demand in 2022"

Production capacity, installations and ASPs by technology, 2023-25



Data compiled Dec 31, 2023
Source: S&P Global Commodity Insights

In the case of Europe, announcements have been either delayed or canceled. RepowerEU set major renewables and manufacturing targets but without clear supportive packages for local industry or mandates to incentivize local content procurement. This is critical to developing local manufacturing in these regions. Any manufacturer, before making investment decisions, must be certain of the existence of market demand for locally manufactured products, since higher manufacturing costs in the US and Europe prevent them from being exported due to global competition.

5. Expect record high offshore wind capacity auctions in 2024 despite rising capital costs

Despite the recent rise in costs of offshore wind due to supply chain bottlenecks and soaring interest rates that have driven up financing costs, the upcoming year is poised to witness an unprecedented milestone. Over 60 GW of new capacity is set to be auctioned in at least 17 different markets — an all-time record in the realm of offshore wind energy. This surge in auctioned capacity serves as a resounding testament to the unwavering dedication of both established and emerging markets toward advancing and embracing this pivotal technology.

The road map spans mature markets around the North and Baltic Seas, such as the UK, Germany, the Netherlands and Denmark, as well as relative newcomers Norway, Ireland, Lithuania, Estonia and Finland, which are in the early stages of tapping into their offshore wind resources. Along with auctions for new fixed capacity, France will announce the winners of the world's first three large-scale floating offshore wind tenders (250 MW each), taking the technology to a new stage of its development.

> "Over 60 GW of new offshore wind capacity is slated for auctions in 2024 globally – enough to cover Poland's total power demand."

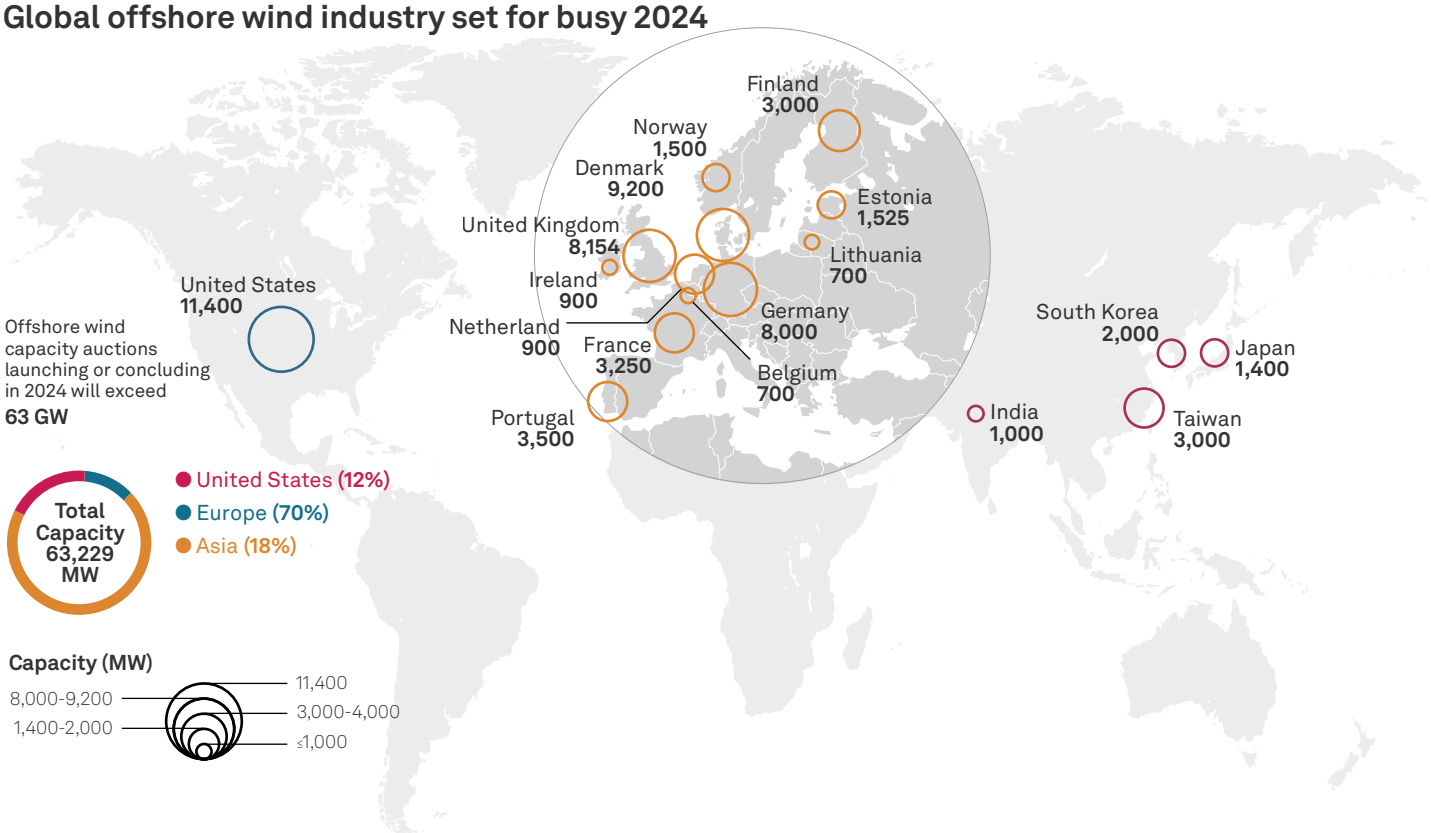
Four states along the US East Coast, among them New York and New Jersey, are hastening solicitation rounds, partly in reaction to recent turmoil with PPA offtake agreements. Despite the recent substantial cost surge of nearly 50%, state authorities are emphasizing the significance of offshore wind for the country's future generation mix, offering a total capacity of up to 11.4 GW in 2024.

India is on the verge of launching its inaugural offshore wind offtake and lease tenders, mirroring the momentum seen in Taiwan, Japan and South Korea. Across the Asia-Pacific region, these markets are fervently advancing their project pipelines and ushering in new capacity during the current year. Mainland China is also expected to auction new projects, although the exact volume on offer is yet to be announced.

The auctions aim to bring new capacity online in the late 2020s or early 2030s, helping global markets to deliver on their aggressive capacity commitments and expand the offshore wind fleet from the roughly 70 GW installed today.

After a series of significant setbacks in 2023, notably witnessed in the UK Allocation Round 5, strike prices are poised to climb across various global markets. Developers blamed a bid ceiling that was too low in an environment of rising project costs, leading to the auction failing to allocate any capacity. The result prompted the UK government to increase the price cap for the 2024 auction by 66%, from £44/MWh to £73/MWh in 2012 prices. This adjustment reflects a proactive measure to adapt to evolving market dynamics and is necessary in other markets as well.

Global offshore wind industry set for busy 2024



This chart does not include lease auctions that will take place in Colombia, India, the UK and the US.
UK capacity includes potential eligible offshore wind projects for Allocation Round 6. Actual outcome depends on awarded strike price and size of auction budget. US will solicitate up to 11.4 GW across four states: NW (4.2 GW); NJ (2 GW); CT (2 GW); RI (1.2 GW)

Data compiled Jan. 9, 2024
Source: S&P Global Commodity Insights 2011859

6. Western wind turbine giants will continue to face higher competition from the East

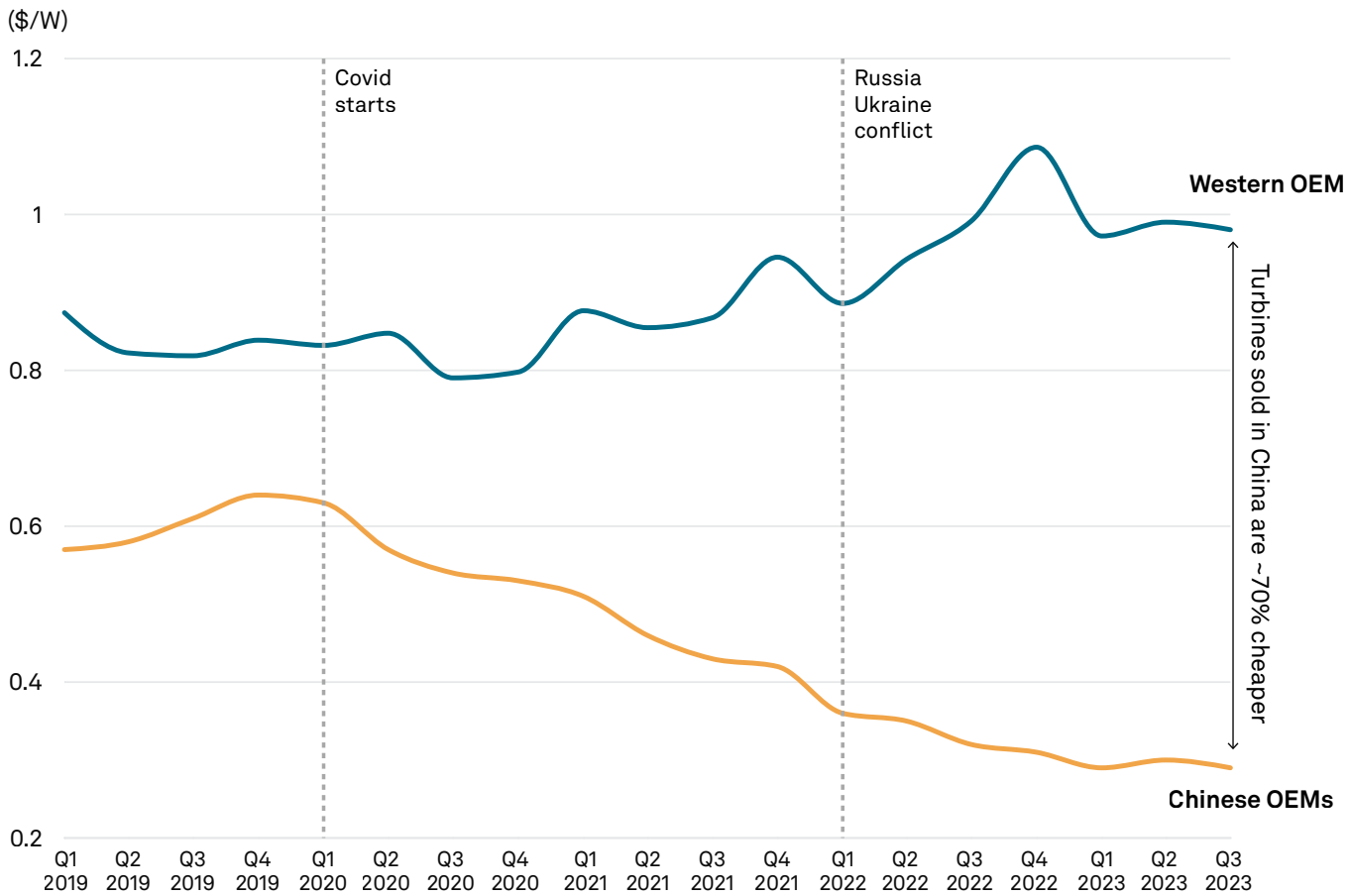
The global wind turbine supply market has been historically divided into two groups: around 15 Chinese manufacturers supply their domestic market, while four regionally diversified Western firms cater to the rest of the world. In the recent past, Western and Chinese manufacturers have been operating under markedly different business conditions.

Balance sheets of Western turbine makers have weakened, a result of high input costs, supply chain disruptions, mounting overheads, and onerous contracts. In contrast, Chinese turbine makers are increasingly competing in international markets through lower prices, technological innovation, and new supply chain investments.

Recently announced turbines by the Chinese surpass Western counterparts by at least 30% in rated capacity, while the price gap has grown to nearly 70%. The intense competition for orders in China's zero-subsidy era has resulted in a technology race and pricing pressures, a trend set to continue.

> "One blade of the largest announced 18-MW offshore turbine is the size of two Boeing 747 aircraft parked nose to tail."

Average selling price of onshore wind turbines, Q1-2019 to Q3-2023 (US$ per watt)



Source: S&P Global Commodity Insights

Note: Average domestic bid prices for Chinese turbine makers have been used as a proxy for ASP.

In this situation, Western turbine makers must increasingly contend with the dual challenge of regaining profitability while safeguarding market share. They have responded with a multi-pronged strategy: refocusing on core European and US markets, maintaining pricing discipline, strategically enhancing supply chains, and embracing alternative routes to innovation by industrializing globally relevant turbine platforms. Their efforts are supported by protective policies aimed at bolstering local supply chains in their core markets, such as the US Inflation Reduction Act and Europe's Wind Power Package.

At the same time, China is experiencing reduced appetite for new wind projects, declining margins on turbine sales, and significant manufacturing overcapacity. This is pushing Chinese vendors to offer attractive pricing and lenient contract terms in order to entice international customers, resulting in a record surge in order intake from India, Africa, the Middle East, and Central Asia. Going forward, the Chinese will increasingly look to instill confidence in their technology and build a global track record, while leveraging attractive pricing as a market entry tool.

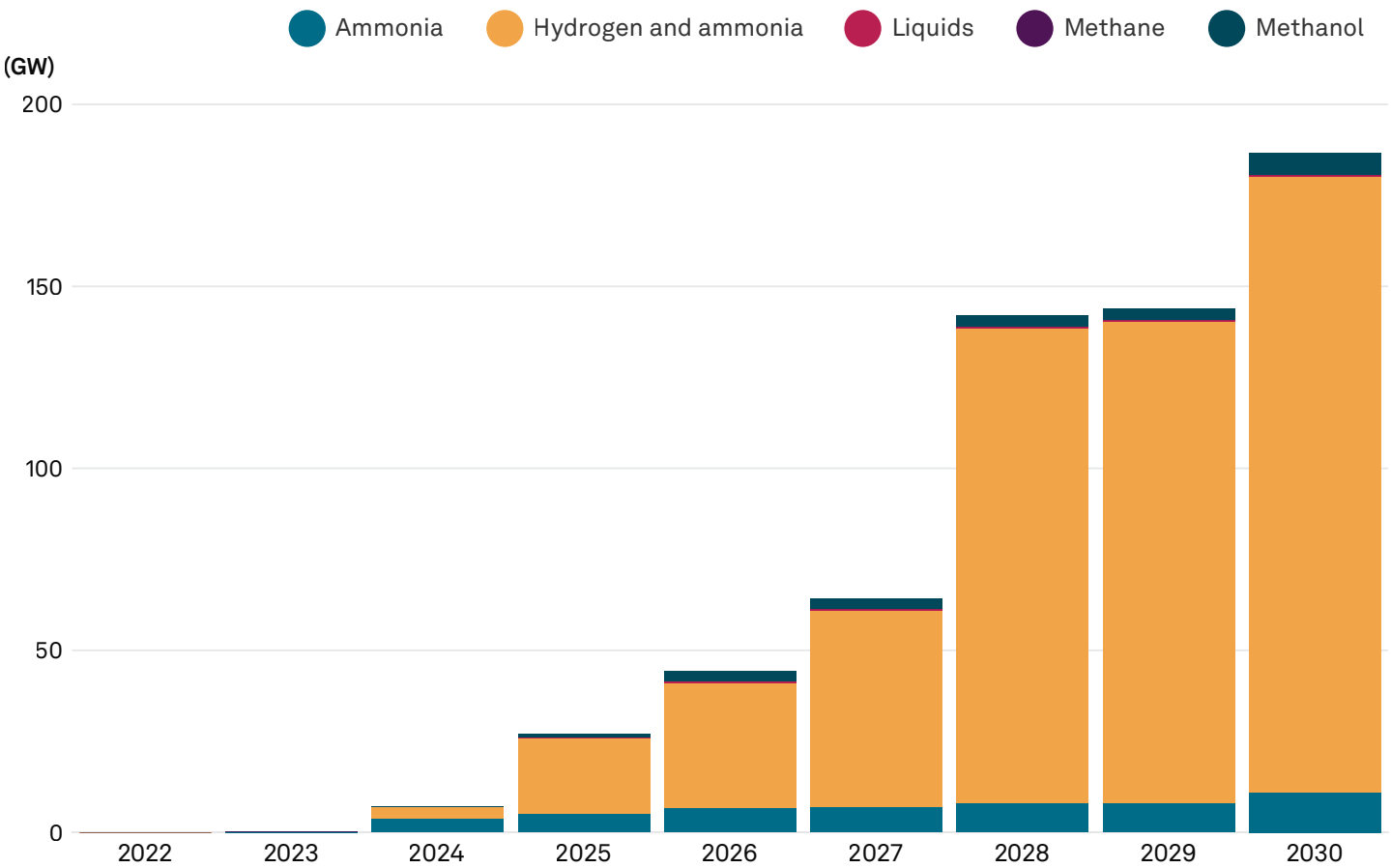
7. Expect higher global interest for low-carbon hydrogen as feedstock for ammonia, synthetic methane and synthetic liquids

Aided by subsidies and driven by mandates, investment into hydrogen as a feedstock has begun flowing. In Denmark, support for green hydrogen production was auctioned to green e-fuels and e-methanol facilities. The Danish results hint at the possible outcome of a broader EU auction through the European Hydrogen Bank that will provide €800 million of support to renewable hydrogen producers.

In the Middle East, blue hydrogen and green hydrogen facilities aim to meet demand from Europe or Japan. The NEOM hydrogen megaproject is under construction in Saudi Arabia, looking to convert 2 GW of electrolyzed hydrogen to ammonia. For blue ammonia, the Abu Dhabi National Oil Company (ADNOC) and Mitsubishi are partnering to establish a low-carbon supply chain connecting the United Arab Emirates to Japan.

In the US, the Inflation Reduction Act's hydrogen production and carbon sequestration provisions have galvanized blue hydrogen production. Chemical companies BASF, Yara International and CF Industries are joining Air Products in establishing world-class facilities across the Gulf Coast. Synthetic methane is also of interest, with Tree Energy Solutions looking to convert green hydrogen and captured carbon to low-carbon methane. These companies seek to capitalize on the country's low energy prices and favorable policy.

Electrolysis projects producing liquid hydrogen carriers



Source: S&P Global Commodity Insights

8. 2024 will be a milestone year for technology-based carbon dioxide removal

Rapid development of methodologies to verify carbon crediting and certify CDR, along with significant funding for technology-based removal, are driving the project pipeline to unprecedented levels (88 million metric tons per annum CO2 capture capacity under the current pipeline). CDR has been identified as a critical tool for achieving climate targets, and buyers are willing to pay a premium for technology-based methods that are durable and easy to track.

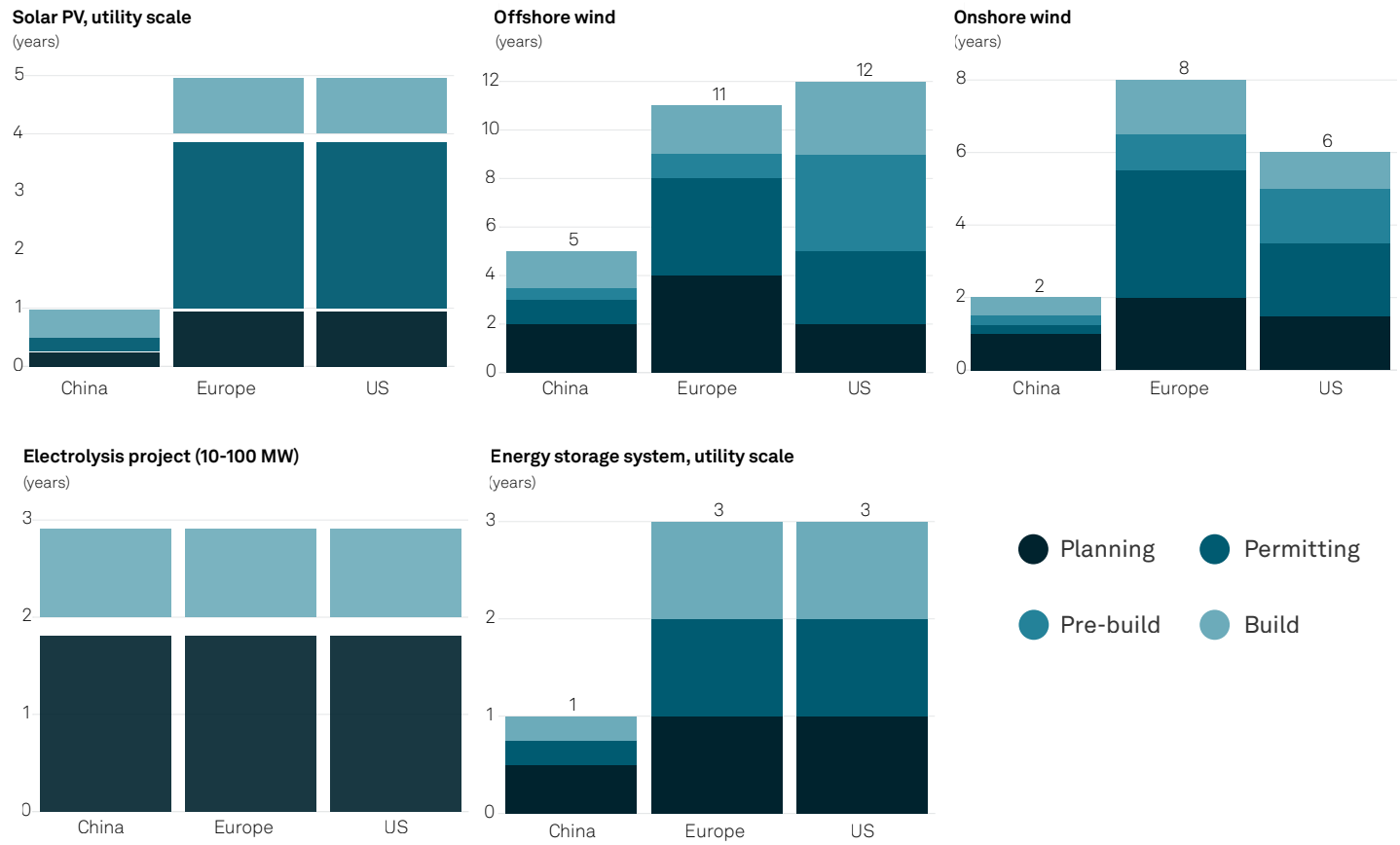
The market is responding — seven methodologies to verify carbon crediting from technology-based CDR have been announced recently. Two are private, while five are part of independent standards endorsed by the International Carbon Reduction and Offset Alliance (ICROA). Although most of these methodologies are still undergoing validation and verification, once published they will provide a more rigorous carbon crediting estimation. The EU is also expected to adopt a carbon removal certification framework in 2024.

The crediting guidance, coupled with growing demand for technology-based CDR, are expected to lead to a significant increase in projects in 2024 by reducing uncertainty for potential buyers. Government support and funding for CDR in Europe and the US are likely to accelerate the trend. Projects that aim to capture biogenic or atmospheric CO2 are especially attractive due to restrictions on the CO2 sources that can be used for synthetic fuels.

9. Efforts to alleviate grid congestion and permitting constraints will continue to streamline renewable power development

One of the two major commitments out of COP28 was tripling global renewables capacity by 2030 to 11 TW. S&P Global Commodity Insights' renewables outlook is aligned with this goal (using 2022 as baseline), and no major limitations or shortages are foreseen from a material or supply chain perspective. However, most of the renewable capacity additions are expected to be solar, which is the fastest clean technology to install. Adding a majority of solar will only increase grid congestion and curtailment, given its intermittency and lack of sufficient storage capacity.

Indicative time to market for renewables and electrolysis projects, by development phase (in years)



Source: S&P Global Commodity Insights

Grid-connection delays and grid congestion are becoming major bottlenecks for renewable deployment around the world, including delaying the build-out of energy storage that could help to address the problem. Globally, markets will focus on two key means of reducing these bottlenecks and accelerating renewable build-out:

- Higher investment in transmission and distribution (T&D) and storage. The biggest factor behind grid-connection bottlenecks is that T&D investment lags generation capacity investment. This is a global phenomenon that is exacerbated in markets with higher renewable integration. In China, the largest renewable and battery energy storage system (BESS) market, T&D grid investment grew by 7.9% year over year between 2019 and 2023 while complete investment in the power sector grew by 54% year over year, triggering grid-connection bottlenecks and curtailment and affecting project internal rates of return.
- Facilitation of development of other renewable technologies (e.g. offshore wind, geothermal) that are now suffering from cost increases and big interconnection and permitting challenges. The goal: creating a more balanced approach to renewables portfolios and making it easier to integrate renewables into the energy mix.

10. Transmission system operators will be required to assess their flexibility needs from 2025, driving additional large-scale energy storage procurement

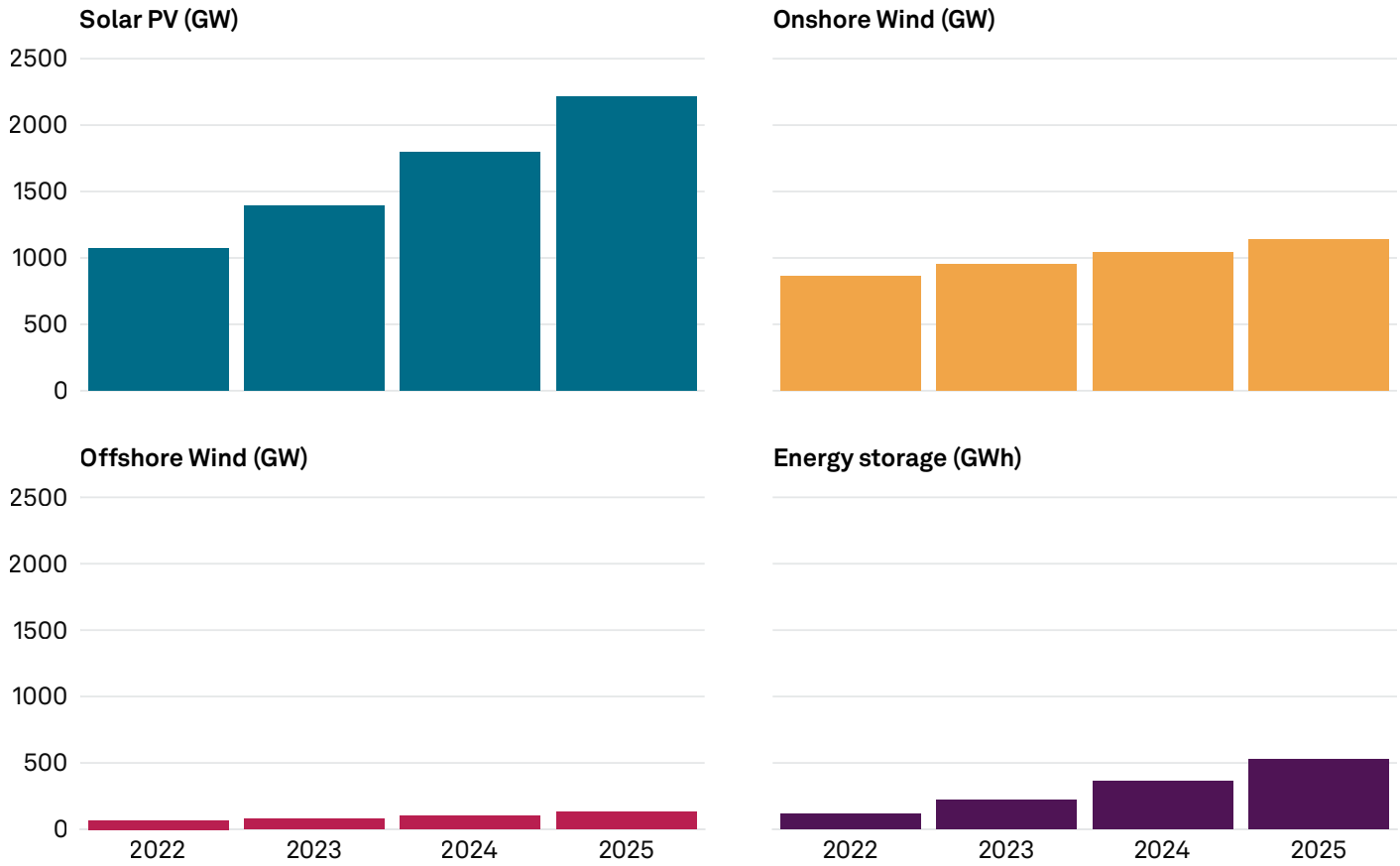
A power system that is highly dependent on intermittent renewable generation (such as wind and solar PV) will require increased flexibility to ensure that the supply of electricity is balanced with demand. Transmission system operators (TSOs) are taking action to ensure that flexibility assets such as storage and demand response will be available when they are needed.

Italy's recent announcement of a significant GW-scale energy storage tender by local TSO Terna, for eight-hour durations, is an example of this top-down strategy to energy storage procurement, likely to be seen in other countries in the coming years.

According to March 2023 electricity market design proposals, countries in Europe must evaluate their electricity systems' flexibility requirements biennially, starting in January 2025. These assessments will include the capacity for non-fossil fuel-based flexibility such as demand response and storage. Based on these evaluations, each member state is expected to establish objectives for demand response and storage.

> "By 2025, solar and wind will provide nearly 50% of capacity and 30% of electricity generation in Europe."

Global solar PV, wind and energy storage installed capacity



CONTACTS

Americas: +1 800 597 1344
Asia Pacific: +60 4 296 1125
Europe, Middle East, Africa: +44 (0) 203 367 0681

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