10 Cleantech Trends in 2023

Technologies to reduce emissions and confront climate change

S&P Global
Commodity Insights

S&P Global Commodity Insights 10 Cleantech Trends in 2023

1. Component prices decline but do not immediately translate into lower renewable system capex.
2. The rapid build-out of local manufacturing for solar and batteries is expected in the United States and Europe, driven by strong demand and energy security concerns.
3. Distributed generation expands to new segments while business models evolve.
4. Big energy statements in 2022 driven by acute energy needs must now "go from words to actions" to ease current blocks for renewables.
5. Turnaround strategies of western turbine manufacturers will underpin the future competitiveness of wind energy.
6. New announcements increase the gap between offshore wind targets and industry realities.
7. The United States takes center stage in hydrogen and carbon capture, utilization, and storage (CCUS) development through the Inflation Reduction Act (IRA).
8. CCUS continues to build momentum with the move from planning to action starting to shape up through strategic partnerships and collaboration.
9. The energy crisis gives life extension to nuclear.
10. Large opportunities arise for a broader range of clean, non-power energy technology options, particularly heat pumps.

1. Component prices decline but do not immediately translate into lower renewable system capex

After two years of tight supply chain dynamics, raw material and shipping costs decline in 2023, which has a direct impact on solar, wind, and energy storage component prices. Global shipping costs are even back at pre-pandemic levels. These lower prices will, however, not translate immediately into overall lower capex for renewable power systems.

Land access and grid connections now prove to be the biggest bottleneck for the industry. This has the unintended consequence of driving up development costs as investors look to deploy capital quickly into markets where supply of available grid connections is insufficient and as investors are willing to pay for expediency in the form of large premiums for construction-ready projects. Equally, another major challenge for renewable power capex is the rising costs of construction labor. A shortage of skilled workers risks pushing these cost increases above inflation levels in the most active markets. Additionally, any improvements in capex risk being counterbalanced by the rising costs of capital. On top of these overall cost influencing factors, each technology has its own dynamics that will impact capex throughout the year.

> In 2023, the investments in solar, batteries, and wind come within reach of global upstream oil and gas investments.

Solar photovoltaics (PV)

In 2023, PV module prices return to the downward curve they were following prior to the pandemic, at a faster pace than anticipated. In the first weeks of 2023, polysilicon supply has already eased, and prices dropped sharply. This will trickle through to module prices, even if some of the drop will be offset by manufacturers seeking to recover margins.

Further down in the value chain, installers and distributors will also raise their margins where possible. Rooftop solar systems are therefore unlikely to become much cheaper for the end user, given the high demand. The utility-scale segment will reap the main benefit of lower module prices, and we project the demand for large PV systems to intensify globally, even more so in cost sensitive emerging markets.

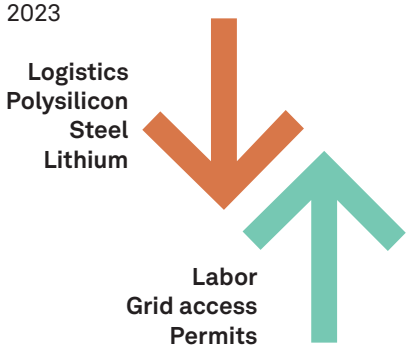
Wind

Average selling prices of ordered turbines have risen continuously since the second half of 2021 as Western original equipment manufacturers (OEMs) gradually started passing supply chain cost inflation to customers to recover margins. With the installation of turbines typically lagging the order date by up to two years, capital costs of projects in western markets could start increasing from 2022 onward, through 2024.

Capital costs are expected to flatten and start decreasing thereafter, driven by an expected correction in turbine prices from 2023 onward. Factors, including a sharp reduction in freight and key raw material costs like steel and a growing threat from lower-cost Chinese OEMs, will contribute to this.

Figure 1

Solar, wind, and storage capex dynamics in 2023



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Energy storage

In 2023, energy storage prices decline modestly as lithium becomes more available. Already in the second half of 2022, prices for energy storage stabilized, following the 20–30% increase that had taken place over the previous 12 months. High demand keeps capex from falling significantly.

Fundamental drivers like rising energy costs and aggressive policy drivers make 2023 a record year for energy storage installations. To meet the demand expansions, competition heats up to secure supply of batteries across the energy storage supply chain. Companies across the space are increasingly able to enter long-term agreements, at larger scale than ever before. But these don't come without compromise. In many cases, supply has been agreed from factories that are yet to be built, and to out-compete automotive offtakers, prices are elevated.

2. The rapid build-out of local manufacturing for solar and batteries is expected in the United States and Europe, driven by strong demand and energy security concerns

Over the past two years, the global cleantech supply chains have been challenged to meet strong demand on schedule. Lockdowns, geopolitical events, and of course, Russia's invasion of Ukraine have wreaked havoc on critical supply chains for the energy industry. This has elevated efforts to protect energy supplies around the world and made "energy security" a priority. Governments and large energy consumers have responded in a profound way, by trying to reduce dependence on imported gas as prices have soared and supplies curtailed. Once renewables are installed, they benefit from not relying on a supply of fuel, and as a result, countries around the world are turning to them to become the center of their energy supply.

In 2023, the industry will continue to respond to various policy mechanisms that have been put in place, by building close to 500 GW of wind, solar, and battery energy storage globally—over 20% more than the amount installed in 2022. However, concerns persist over Chinese dominance of the manufacturing of the equipment—particularly for solar and batteries—and the various risks involved in being over-dependent on a single region to supply the required goods.

This has been the trigger for renewed ambitions to increase local manufacturing—particularly in Europe and North America. The single biggest such policy intervention was a host of manufacturing incentives introduced by the Inflation Reduction Act (IRA) in the United States, which offered generous incentives for local manufacturing for a variety of clean energy technologies in a bid to become more self-sufficient and stimulate the economy. Equally, Europe has big ambitions to increase renewables installations following the announcement of REPowerEU and wants to increase its ability to manufacture locally. Self-sufficiency, human rights concerns, local

> Between 2021 and 2030, Europe and North America will install 2,000 square miles of solar panels —nearly the area of Los Angeles.

employment, and tax incentives are some of the drivers toward onshoring in these markets. The figures below highlight the huge opportunity to localize domestic manufacturing for solar in the European Union and United States, given the limited capacity available currently.

Figure 2

Demand versus manufacturing capacity for Li-ion batteries by region (GWh)

Data compiled Dec. 1, 2022.
Sources: S&P Global Commodity Insights; S&P Global Mobility.
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In contrast to solar, efforts to localize the manufacturing of battery cells are more progressed. With electric vehicle manufacturers keen to lock in supply of this critical component, a number of large facilities will become operational in Europe and North America in 2023, with many of them joint ventures or partnerships between large Asian battery manufacturers and major established automotive OEMs. As a result, on paper, Europe and North America will have sufficient local cell manufacturing capacity to meet local demand. However, imports continue to make up a large proportion of the market, as many of the facilities are in the early stage of development and are yet to optimize utilization rates and costs. In addition, the vast majority of the processing of critical raw materials required for battery cell manufacturing continues to take place in mainland China.

By 2026, the Netherlands will have installed 1 kW of residential PV for each inhabitant, enough to cover the average personal electricity consumption.

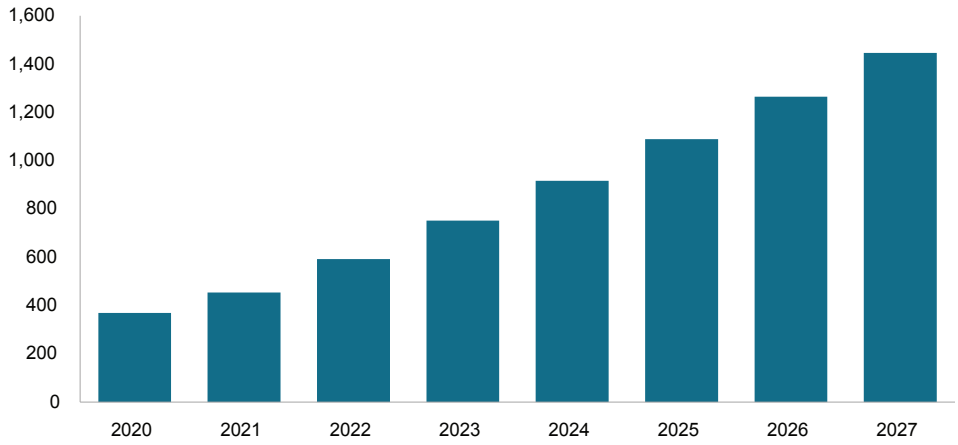
3. Distributed generation expands to new segments while business models evolve

If in 2022, distributed solar consolidated its position as a mainstream electricity supply option across many established markets, then in 2023, the technology will spread to new consumer segments and gain ground in new markets. New types of households and small businesses will gain access as shared solar solutions become available, further expanding the distributed generation footprint. More PV systems will be paired with storage as policy support for collocated solutions increases.

Among households, the most common investment approach continues to be the upfront cash payment, possibly supported by green credits. At the same time, utilities and electricity distributors push for a more diversified landscape, with rental, lease, and power purchase agreement options that will soften the investment required by the consumer. These third-party financing solutions hence spread beyond the United States, where such models have been deployed extensively over the past decade.

Figure 3

Cumulative installed distributed PV capacity (GW)



Data compiled Jan. 10, 2023.
Systems below 5 MWdc.
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Commercial and industrial consumers are set to increasingly deploy third-party financing as liquidity becomes a major concern for many businesses. Companies across many markets are eager to achieve near-term reductions in electricity bills, with on-site solar being a viable option. For the providers of third-party financed PV systems, the challenge is to secure contracts with credit-worthy offtakers, given the economic headwinds expected in 2023.

As energy management and efficiency gain importance among building managers, solar PV becomes a key element of proposed solutions. Different configurations that combine solar PV with, for example, heat pumps or electric vehicles hence spur new usages for distributed solar. The need to manage distributed energy solutions also spur new software development.

Policymakers increasingly support distributed generation despite sending conflicting messages at times. The introduction of electricity subsidies or

price caps to offset consumer bills in developed markets may actually hold back some consumers that were considering investing in solar panels. At the same time, governments are incentivized to push for more distributed solar generation in a move to reduce the overall cost of subsidies. Therefore, the overall policy landscape will favor more distributed generation, either through cash grants, value-added tax reductions, tax rebates, or feed-in tariffs. The combined support for solar and storage will spread, creating further consumer flexibility regarding power production and consumption.

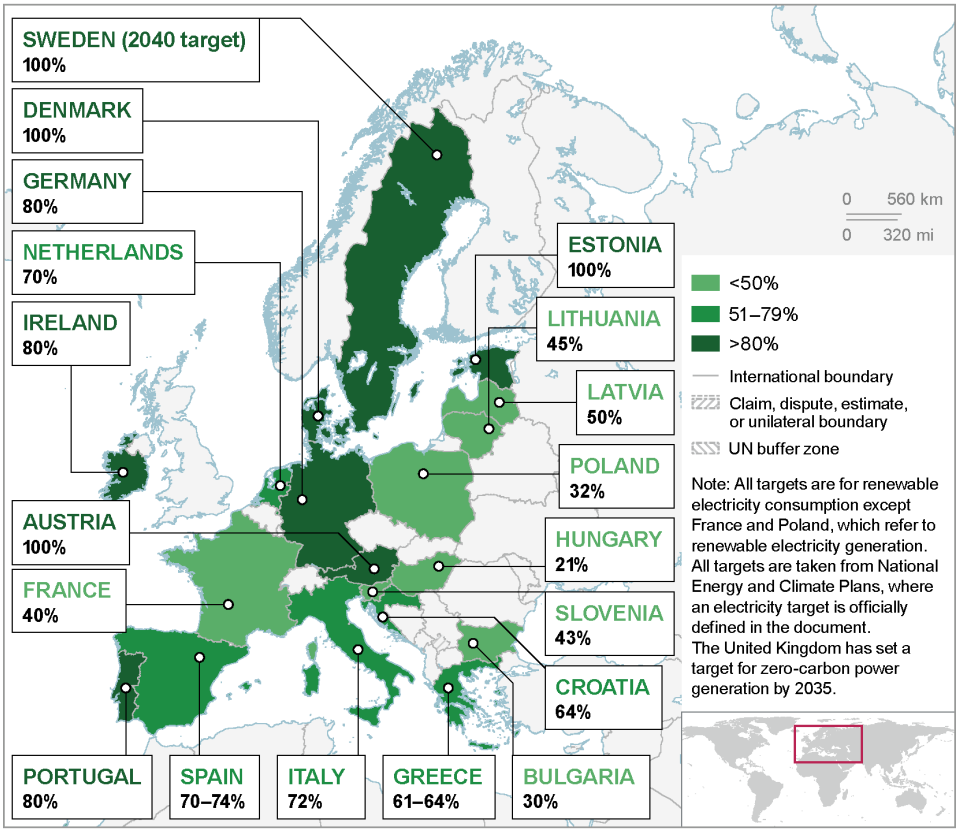
4. Big energy statements in 2022 driven by acute energy needs must now "go from words to actions" to ease current blocks for renewables

International developments in the past year have shifted the focus, highlighting the central role of clean energy technologies (i.e., renewables, energy storage, hydrogen, carbon sequestration) not only as enablers of a low-carbon economy but also as pivotal drivers to increasing energy security, independence, and power systems' resilience. The energy, materials, and logistics crises have raised questions about the current globalized manufacturing approach and established supply chains.

Denmark, Austria, and Estonia are targeting 100% national renewable electricity targets by 2030, while Germany, Portugal, and Ireland aim for 80%.

Figure 4

European renewable electricity targets, 2030



Data compiled Jan. 11, 2023.
Source: S&P Global: 2008371.

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There were several big energy announcements in 2022: the publication of REpowerEU, which sets the groundwork for a dramatic acceleration of renewables within the European Union; the passing of the IRA bill in the United States, a reconciliation bill that unlocks $370 billion in climate and energy investment in the United States; and the publication of mainland China's updated nationally determined contribution, which increases the installed capacity of wind and solar power to more than 1,200 GW by 2030.

Despite this momentum, there are significant operational hurdles that must be overcome in the short term for a successful and speedy renewable integration in the national power systems. A milestone year is needed in 2023 to unblock some of the current hurdles if targets want to be achieved by 2030.

- **Permitting processes.** Permitting processes must be streamlined to process a flood of projects. Several European countries are rolling out new measures in 2023 after the European Union called on all member states to accelerate permitting, but implementation will take longer in some countries and a lack of personnel remains a concern. Long administrative delays are also a major delay factor in the United States.
- **Grid enhancement.** With grid constraints widely touted as a major barrier to renewables, investments in enhancing and reinforcing grid infrastructure to mitigate against "congestion" and make it more capable of handling higher levels of intermittent renewables will be necessary in 2023 and beyond. Energy storage technologies will increasingly play a role in this as an alternative to conventional grid upgrades.
- **New infrastructure and supply chain.** New offshore and onshore transmission grid infrastructure and supply chain need to be planned and developed to install and connect a vast stream of fixed and floating offshore wind projects. The lack of suitable ports for manufacturing, assembly, and staging, as well as wind turbines and foundation installation vessels capable of erecting turbines bigger than 15 MW, may slow down the overall development of offshore wind technologies and therefore require sufficient investment in a timely manner.
- **Labor shortage.** Renewable companies have noted a tight labor market, particularly for some roles such as installers, electricians, and grid specialists, given the rapid increase in renewable installations. Governments and industry will have to increase the supply of such roles to alleviate labor as a bottleneck. Some expected solutions will be to boost apprenticeship programs, especially for electricians, and promote a labor shift from industries in decline to the renewables industry via educational programs to highlight transferrable skills and adaptability.

5. Turnaround strategies of western turbine manufacturers will underpin future competitiveness of wind energy

An investment-intensive technology race for new turbines coupled with a perfect storm of commodity price inflation and supply chain uncertainty resulted in **three major European turbine makers collectively reporting losses exceeding €1 billion in the first nine months of 2022**.

As a short-term response, these **OEMs hiked average turbine selling prices by nearly 25% in 2022; prices should start to stabilize this year.** However, long-term profitability will be underpinned by a multipronged strategy involving product modularization, industrialization of manufacturing, and revenue stream diversification.

In line with this, turbine vendors will continue to trim their product portfolios and drive sales of new and more profitable modular platforms. Although the trend toward larger turbines is expected to continue, the future pace of product development will probably slow down as vendors refocus on industrializing existing models, opt for an evolutionary research and development strategy, and explore technology and manufacturing synergies between onshore and offshore divisions, further developing product modularity.

Despite the growing call for regionally self-sufficient supply chains, **modularized wind turbine architecture inherently favors globalization**. As a result, we expect some consolidation of the supply footprint to continue in favor of the Asia Pacific region, mainly for commoditized and easier-to-transport tier-2 components.

With global annual wind additions set to grow by over 40% by 2030, **OEMs with weakened balance sheets will continue to opt for partnerships** with independent equipment manufacturers, grow the share of outsourcing, and explore new collaborative business models to ramp supply chains.

The threat from lower-cost Chinese turbine makers will intensify in 2023, supported by a widening turbine price gap with Western peers, strong demand growth in their captive domestic market, and a push for international diversification. However, these players will need to further adjust portfolios to be compliant with grid codes, alleviate reliability concerns, reduce mainland China–centered supply chains, and do this while dealing with a growing threat of carbon border taxes and duties on Chinese imports.

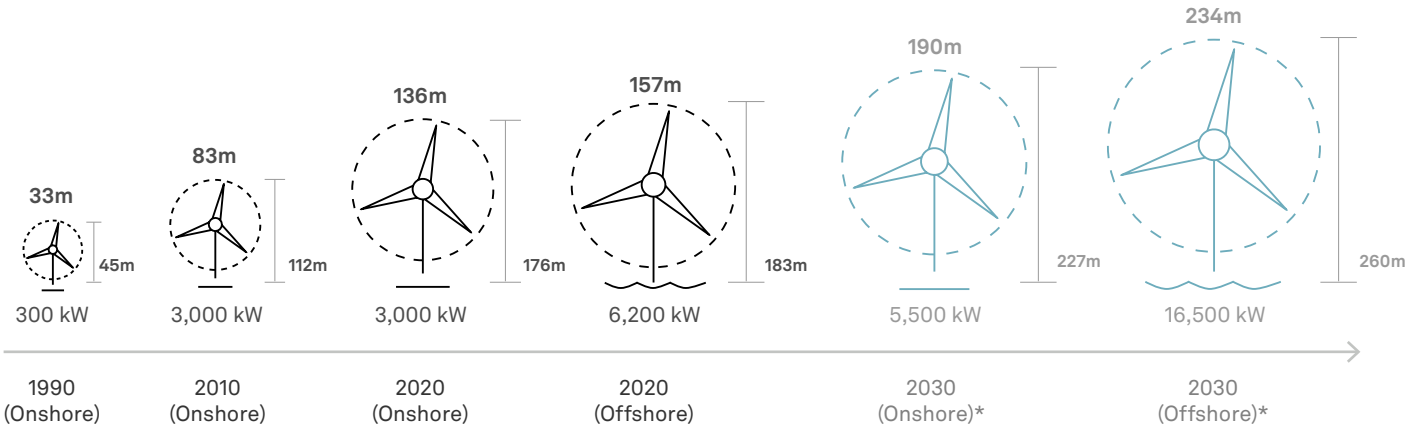
Given the high consumption of steel and other raw materials, there is a growing push to ensure that raw materials are sustainably procured. For Western OEMs, investments in reducing life-cycle emissions and enhancing recyclability will increasingly become a key differentiator, especially in mature markets.

The global wind industry is expected to consume more steel annually than France's economy.

Unit generation capacity of onshore wind turbines is expected to nearly double between now and 2030 and triple for offshore wind.

Figure 5

Evolution of installed wind turbine sizes, 1990–2030



As of Dec. 6, 2022
*Weighted average configurations of wind turbines to be installed in 2030 have been estimated.
Turbine sizes shown in the exhibit denote the global weighted average.
Source: S&P Global Commodity Insights
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6. New announcements increase the gap between offshore wind targets and industry realities

Global installed offshore wind capacity grew by more than 6 GW in 2022 to surpass the 60 GW mark, with new additions in mainland China, the United Kingdom, France, Germany, Vietnam, Japan, and Italy. Offshore wind appears to be on the cusp of a boom as many mature and emerging markets seek to accelerate their growth through dedicated policies and binding national targets. Aggregated national plans, excluding mainland China, would bring the global offshore wind installed capacity to 475 GW by 2050, with half of that (241 GW) in operation by 2030. To meet the ambitious 2030 targets, between now and 2030, the industry will need to deliver 23 GW of new capacity annually, four times more than was set in 2022.

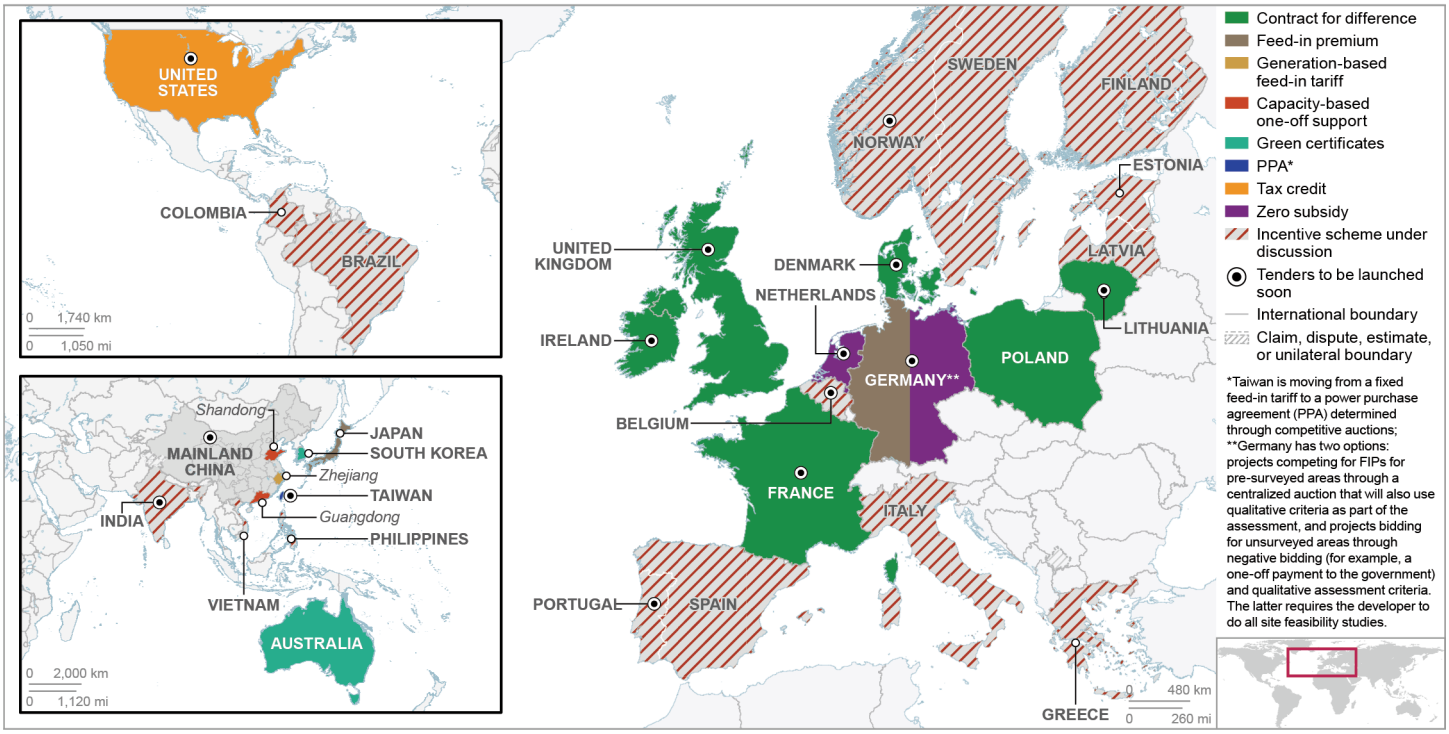
But it is increasingly clear that the offshore wind sector is likely to face supply chain challenges as well as a related "missing money" problem as fierce price competition among offshore wind developers has driven winning auction bid prices down to very low levels and squeezed the supply chain to an extent that the investments needed to meet 2030 targets could be threatened.

In Europe, it is likely that government and industry will take measures sufficient to stimulate the needed long-term investment in the offshore wind supply chain, avoiding major constraints on growth and creating a range of opportunities for profitable investment over time. Auction mechanisms are

> Annual installations must quadruple 2022 installations to reach the cumulative offshore wind industry target of 240 GW by 2030.

Figure 6

Global offshore wind policy scheme overview, January 2023



Data compiled Dec. 29, 2022
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likely to be modified to reward offshore wind more properly for the value it provides to the dual goals of energy transition and energy security—by basing awards more on nonprice criteria. This would gradually ease the race to the bottom and the related missing money problem in the supply chain.

Wind turbine manufacturers are focusing on restoring profitability, which might slow down their investments into next-generation platforms for manufacturing larger turbines that risk making their existing platforms obsolete.

Outside of Europe (and mainland China, which has its own domestic industry), supply chain constraints will delay offshore wind deployment to some extent, particularly in the United States and emerging Asian markets.

7. The US takes center stage in hydrogen and CCUS development through the IRA

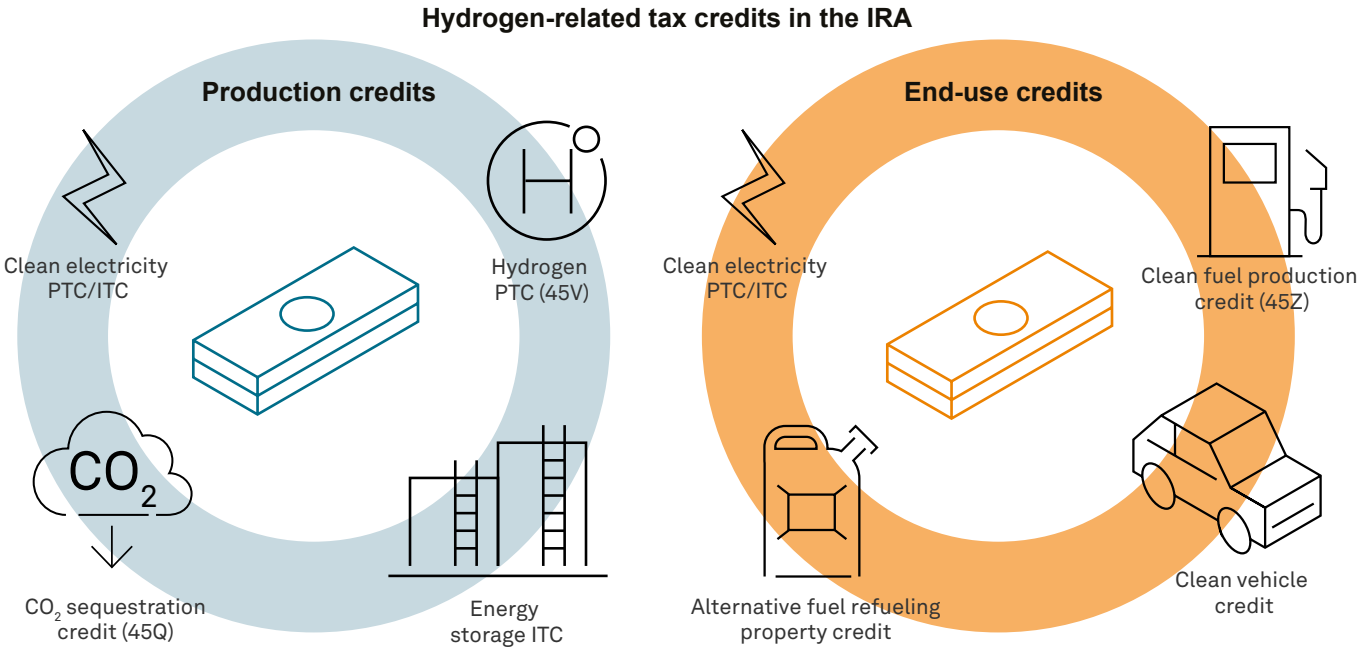
Accommodating federal policy has shifted the United States from laggard to leader in the development of low-carbon hydrogen production. The combination of the IRA's multiple tax credits and the Bipartisan Infrastructure Law's Hydrogen Hubs has set off a race for project development across North America.

Combined, the Congressional Budget Office estimates these bills will provide over $375 billion in stimulus to the energy sector. The IRA provides the lion's share, with an array of tax credits spanning the entire hydrogen value chain. By allowing producers to stack tax credits, the legislation transforms the production landscape, potentially making green hydrogen cheaper than grey.

> IRA subsidies allow green hydrogen to displace natural gas in the United States.

Figure 7

There is a plethora of tax credits hydrogen companies could qualify for
Only some of these credits can be stacked, but companies up and down the value change have a chance to benefit



ITC = investment tax credit; PTC = production tax credit.
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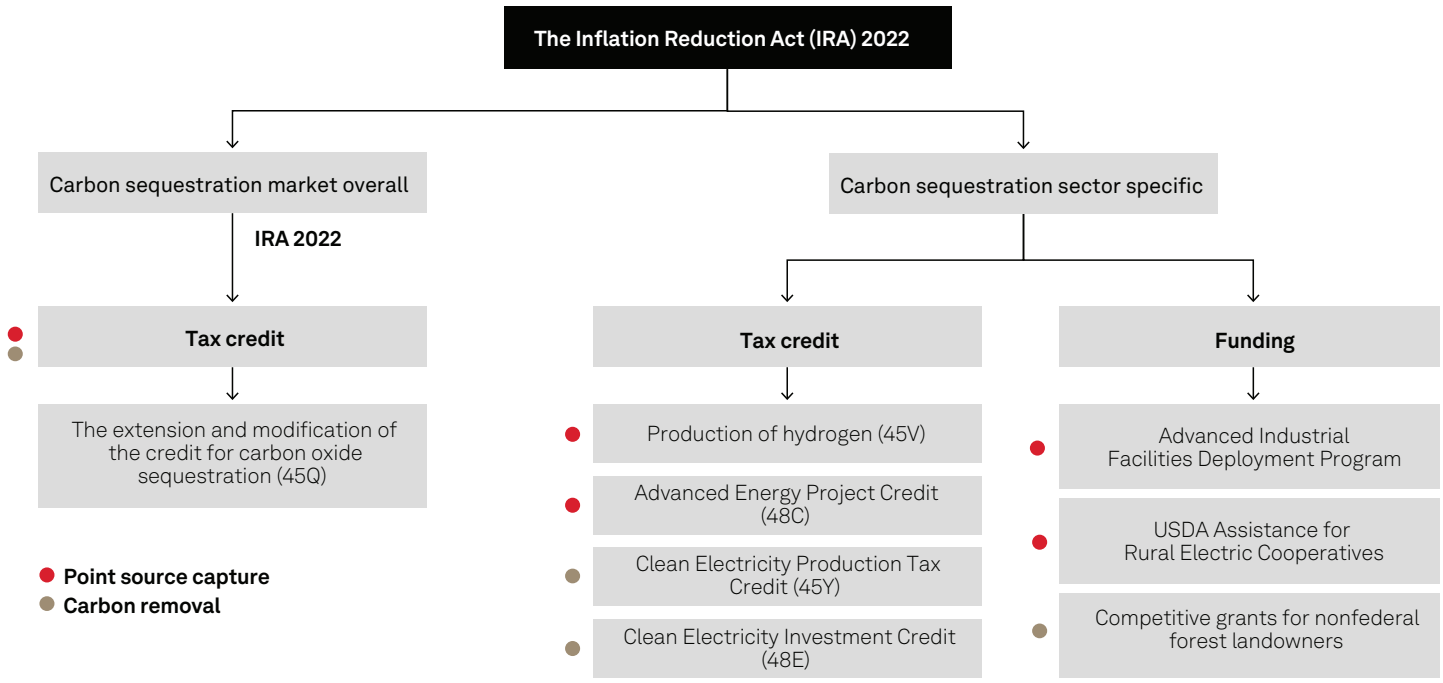
Response to this landmark industrial/environmental policy was immediate. Canadian policymakers plan to enact similar tax credits while Europeans are moderating the stringency of how they account for renewable hydrogen generation. Japanese and South Korean leaders are looking at the new prospect of importing low-cost and low-carbon hydrogen from North America to meet their decarbonization goals.

For the private sector, companies await guidance from the US government to finalize their strategies. Important questions regarding project qualifications and carbon accounting in the IRA are outstanding. And procurement officers grapple with the implications of the "Build America, Buy America" provisions in the Bipartisan infrastructure Law. Once these procedural hurdles are cleared in 2023, the race for US hydrogen development will begin in earnest.

Groundbreaking incentives from combining the IRA bill, the infrastructure bill, and Low Carbon Fuel Standard (LCFS) will dramatically accelerate investments in CCUS projects. States with primacy will see a significant acceleration in CCUS project deployment. However, the permitting backlog risk continues in multiple major states without primacy for Class VI underground injection control (UIC) wells.

Figure 8

Carbon sequestration
Main components of the IRA policy



Sector-specific components of the IRA bill refer to incentives that only apply to specific sectors or projects for carbon sequestration.
USDA = United States Department of Agriculture.
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8. CCUS continues to build momentum with the move from planning to action starting to shape up via strategic partnerships and collaboration

Consensus continues building on the need of CCUS technologies to meet net-zero targets. Despite a significant increase in activity, the CCUS market is still very niche. During second half 2022, more capture capacity was added to the active pipeline compared with the existing projects moving forward beyond planning stage, increasing the ratio of the projects still in early stage of development to around 70%.

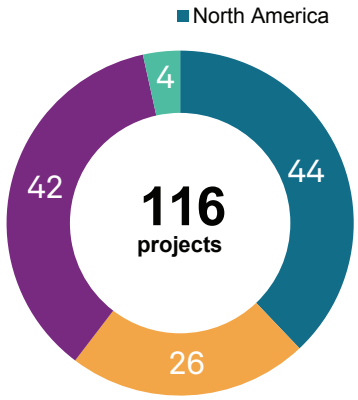
Several simultaneous drivers contribute to keep driving the momentum:

- **CCUS hubs.** Among all the newly announced projects during second half 2022, 11 large-scale projects are connected to the existing CCUS hubs, and 6 projects are associated with new CCUS hubs, accounting for more than 40% of total capacity in the active pipeline. The move from planning to action is starting to be shaped up by strategic partnerships and collaboration that use synergies and scale to reduce overall CCUS project costs and mitigate risks.
- **Hard-to-abate sectors.** CCUS is becoming an essential carbon reduction mitigation technology for hard-to-abate sectors. Cement is leading the way with multiple projects and investments in cutting-edge capture technology. Multiple power plants around the globe have announced their plans to adopt CCUS, significantly boosting the expected volume of carbon dioxide (CO2) capture capacity by 2030.
- **Voluntary carbon markets (VCMs).** Carbon markets and the development of a standardized methodology for CCUS projects in the VCM will become another driver for CCUS growth. Increasing interest in and premium prices for technology-based solutions due its permanence criteria over nature-based solutions (NBS) will trigger additional investments for direct air capture (DAC) and CCUS projects
- **DAC.** DAC is set to proliferate with multiple megaton projects expected before 2030 given unprecedented policy support (i.e., IRA) and investment levels announced for this technology, but the biggest challenge (higher cost than other capture technologies given low CO2 concentration) still needs to be overcome.

More than 70% of global CCUS large-scale projects in the pipeline are in the early stage of development. Only 3% are currently under construction.

Figure 9

Expected operational CCUS projects between 2022 and 2027



Data compiled Dec. 1, 2022.
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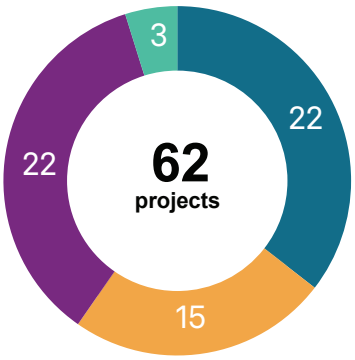
Figure 10

Announced CCUS projects*



Data compiled Dec. 1, 2022.
*Only includes CCUS large-scale projects expect to start operations before 2027.
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9. Energy crisis gives life extension to nuclear

Momentum is building for nuclear power. As the drive to slow climate change intensifies, there is growing recognition that the pathway to net zero will be faster and easier if nuclear energy is part of the solution. What kind of part will depend on regional policy and shifting attitudes toward this technology.

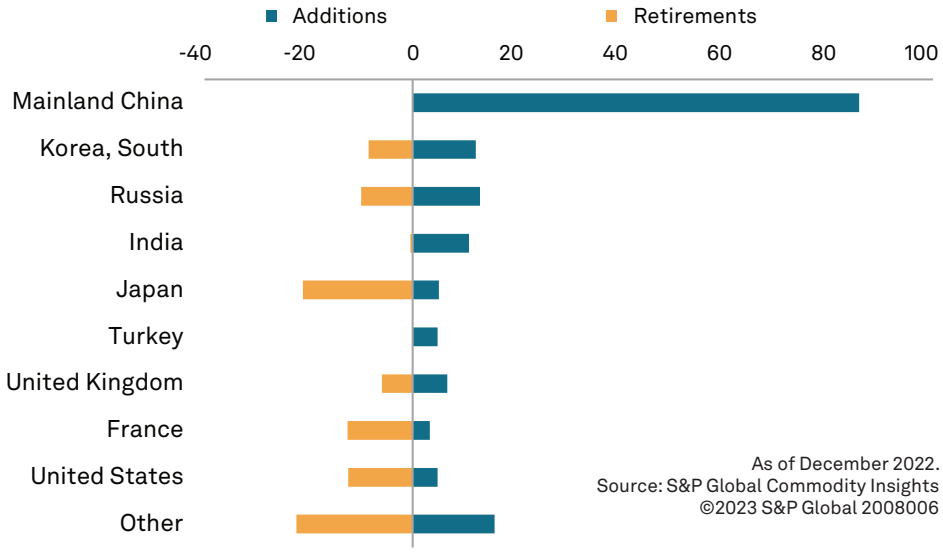
The nuclear center of gravity for newbuild capacity is shifting from North America and Europe to mainland China, which is forecast to account for 53% of new nuclear build capacity between now and 2035. In the United States, the focus is on lifetime extensions, with help from new production tax credits for existing plants introduced with the IRA. In parallel, efforts are under way to build a pipeline of new designs. In Europe, after much debate and negotiation, nuclear was added to the European Union's Taxonomy of Sustainable Activities. Yet, while some Western European countries are reconsidering the speed of their nuclear phaseout programs, lifetime extensions and limited newbuild programs in France, the United Kingdom, and Eastern Europe will not compensate for retirements.

Dozens of small modular reactors (SMRs) and advanced designs (fourth generation) are under various stages of development, supported by public and private funding. Chances are good that demonstration and initial commercial units of some new designs will be built before 2035.

> About 160 GW of new additions forecast by 2035, nearly twice as much as during the past 13 years.

Figure 11

Nuclear capacity additions and retirements, 2022–30 (GW)



As of December 2022.
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Substantial volume from advanced designs, if it happens, would come post 2040 at the earliest. These new designs face first-of-a-kind hurdles, including those concerning licensing and supply chains, and costs may not decline fast enough to spur enough orders.

Broader use of nuclear energy. High-temperature designs hold the potential for direct hydrogen production and to replace fossil fuels in several hard-to-decarbonize industrial sectors. Additional demand for small-sized reactors could come from power systems not suitable for large ones, at industrial sites, and in remote locations.

10. Large opportunities arise for a broader range of clean nonpower energy technology options, particularly heat pumps

Half of total final energy is consumed in the form of heat, versus 20% for power generation and 30% for transport. Yet only about 11% of heat is produced using modern renewables—a much lower share than for power generation.* And while the share of renewables in power generation has almost tripled over the past decade, the share of renewables in heat has barely grown by a third.

Rising gas prices and concern about fossil fuel dependence have brought heat sharply into policy focus. This is creating opportunities for a wider range of technologies that can help accelerate the decarbonization of heat. Heat pumps will play key role in that transformation, particularly in building heating and other low-temperature uses.

Annual global heat pump sales increased by 13% from 2020 to 2021, and by 34% in Europe. This year is expected to be another record year, driven by new policy incentives. For example, the REPowerEU plan targets to double the current deployment rate of heat pumps, leading to the installation of 30 million additional units between 2022 and 2030. A growing number of markets in the European Union have banned the installation of fossil fuel boilers in new homes, and some are introducing bans on replacing oil and gas boilers in existing homes. In the United States, the IRA aims specific rebates and consumer tax credits at home energy supply improvements, including heat pumps. Heat pumps are going to be key to the decarbonization of residential heating; rising gas prices also provide new opportunities for this technology in industry (mainly food and paper).

In 2023 we expect more significant announcements from manufactures to expand production capacity, as well as M&A activity in what is a very fragmented industry. In the near term, innovation will focus on solutions that bring down upfront costs, and on smart and flexible features that make heat pumps easier to install and operate efficiently.

> The heat sector is a laggard in the energy transition, but heat pumps are set to change all that, providing the lion's share of domestic heating by 2050. Heat pumps can use electricity three times as efficiently as standard electric heating.

*Modern renewables include direct and indirect final consumption of bioenergy, solar thermal, and geothermal, as well as renewable electricity used for heating. This figure excludes traditional uses of biomass such as wood fuels, agricultural by-products, and dung that are burned for cooking and heating. These account for about 14% of energy used for heat; the rest comes from fossil fuels.

Clean Energy Technology Service

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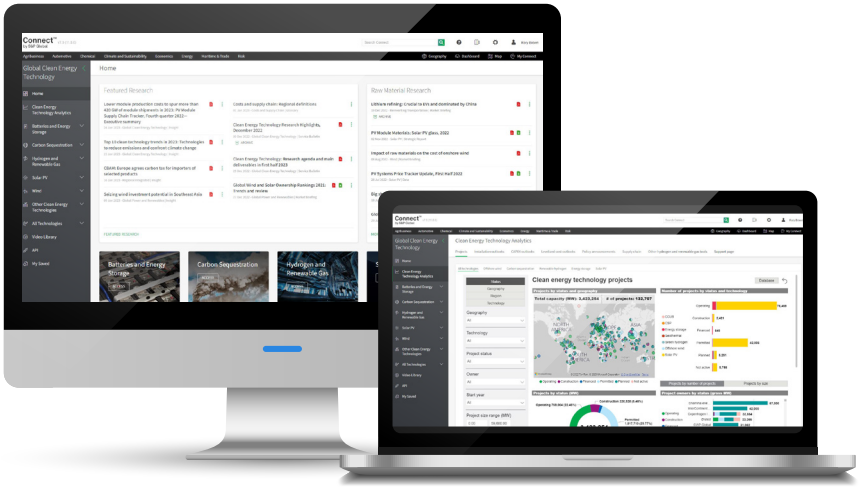
- Levelized cost of hydrogen and renewables gas production
- Capacity outlooks for power generation, solar PV, onshore and offshore wind installations, storage and hydrogen production
- Emerging trends: drivers and inhibitors on the outlooks
- Corporate strategies and business models
- Global databases of projects



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