



Powering Renewables - Key Trends and Themes

FROST & SULLIVAN WHITEPAPER PREPARED FOR WFES

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WORLD FUTURE
ENERGY SUMMIT



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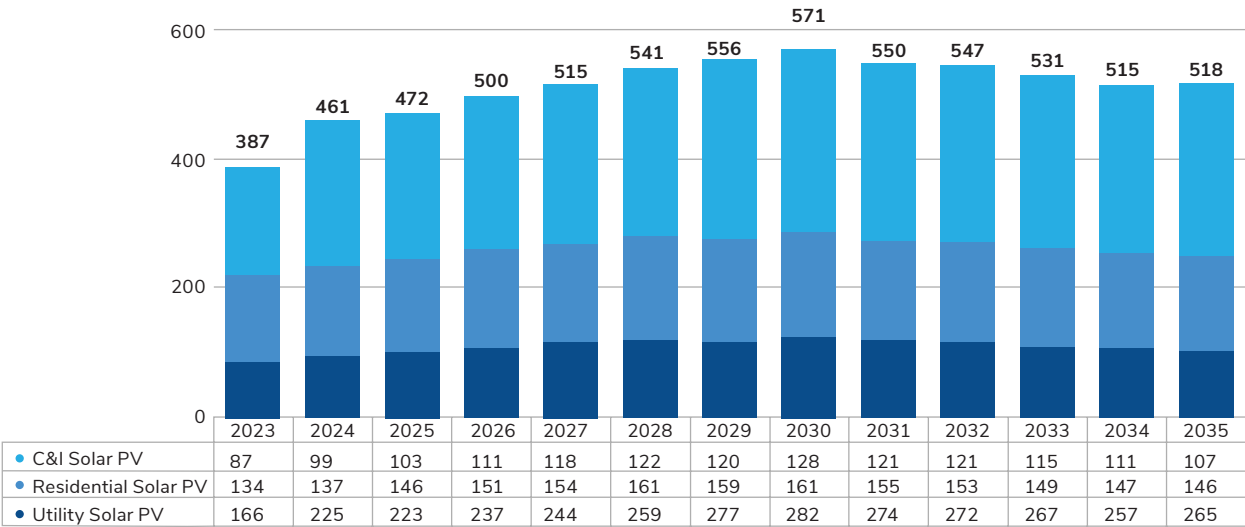
Solar PV Dominates

Solar photovoltaic (PV) technology is the leading source of power generation investment, with \$461 billion projected to be invested in 2024 across the residential, commercial, industrial and utility sectors. Project costs have declined in 2024, particularly given the module oversupply in the value chain. Solar has relatively easy project development and installation, short lead times, and low operational costs. Storage and technological advancements have also made solar PV an attractive choice.

China dominates total capacity additions. Europe’s installations continue to be strong. In the United States, the Inflation Reduction Act provides a long-term framework for renewable investment at the federal level, and any efforts to defund this by the new administration are unlikely to have a significant impact because of the competitiveness of solar PV vs. fossil fuels and the renewable generation targets set by many US states.

Growth will remain high across the decade—Frost & Sullivan forecasts \$571 billion to be invested in 2030—despite further reductions in project costs.

Solar PV Forecast by Segment, Investment (US\$ Billions), Global, 2023 - 2035



Source: Frost & Sullivan



Growth Opportunities

Energy companies need to capitalise on and monitor opportunities, including strategic partnerships with established developers or inorganic growth through acquisitions that target developing countries or technologies that could improve the operational performance of existing or future solar assets.

As assets age, servicing revenue growth will continue to outpace new project investment. Performance guarantee contracts will increasingly be the contract offering of choice, where service providers guarantee an output of electricity and suffer penalties if this is not achieved. To ensure that this does not happen, digital technologies will be increasingly deployed.

Innovative ownership business models will be required in markets where financing has become much tighter for potential customers, resulting in a growth in leasing and outcome-based models such as prepaid electric usage (pay-as-you-go) and energy-as-a-service (EaaS). These models will also be important in markets with huge potential but low finances, such as Africa.

Long-Term Fundamentals for Offshore Wind

2023 was a challenging year for offshore wind. Although investment increased from \$61.0 billion to \$62.4 billion, capacity additions were lower, mainly because of the Chinese market. Installation rates in other geographies increased. More concerning, though, was the cancellation of several major projects in Europe and the United States. A tight supply chain meant that equipment and project costs soared, at a time when financing costs also increased. The regulatory landscape did not provide the support needed to reassure investors. A prime example of this was an auction round in the United Kingdom that resulted in no bids being submitted.

This is likely to be the low point for the industry, and the medium- to long-term growth prospects remain strong. Regulators are already taking action; the United Kingdom increased the capacity payments for projects, the result was 5.3GW of projects awarded. In February 2024, the UAE renewable developer Masdar acquired a 50% stake in the 3GW Dogger Bank project. Cost inflation looks to have peaked in 2024, although global uncertainties around trade tariffs could threaten further increases. For European countries with a coastline, offshore wind will enable them to take the share of renewable energy in their power mixes to the next level, and for many of them there are few practical alternatives. For APAC, offshore wind will be particularly attractive because many countries lack the space for substantial deployments of onshore wind. Floating wind will enable those nations with steep coastal shelves to develop viable projects, although this market will not take off until the 2030s.



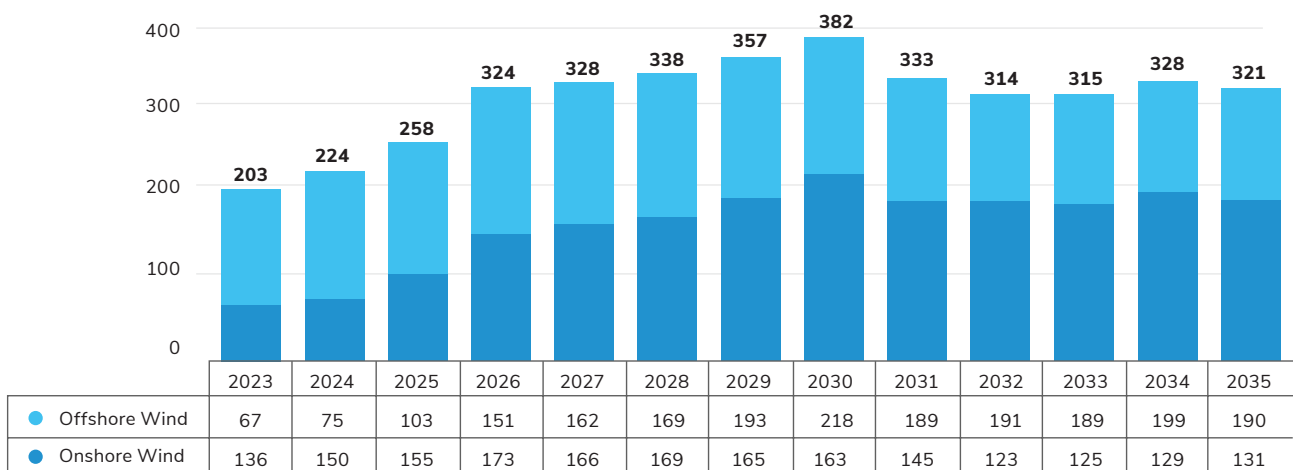
Growth Opportunities

Cost reduction will be a key priority for the industry in 2025. The levelised cost of offshore wind remains attractive because of the relatively high amounts of electricity generated, but capital costs increase in prominence when financing costs are higher. In reality, the industry is dependent on pricing trends for commodities and the uncertainties around tariffs, but increasing investment in the entire offshore value chain will help. A lack of vessels that can transport turbines to their locations has driven up cost projections.

Digital technologies will continue to play a significant role in the industry's development. Digital twins allow OEMs and independent service providers (ISPs) to simulate the operations of their offshore wind assets/systems in real time under different operational scenarios, which helps them make clear, informed decisions, improve operations, and reduce operational costs and downtime.

Offshore wind has likely remained dominated by a small number of OEMs, with high barriers to entry. Long-term service contracts are a key source of revenue for the OEMs, but there are opportunities for ISPs. Operators are keen not to be dependent on a small pool of service suppliers and are looking for alternative providers when the contracts allow. OEMs have started offering multibrand servicing to defend their share of the O&M market.

Wind Power Forecast by Segment, Investment (US\$ Billions), 2023 - 2035



Source: Frost & Sullivan



Growth for Onshore Wind

Solar PV and offshore wind have largely stolen the headlines in 2022 and 2023. In contrast, onshore wind had a much lower profile despite investment of \$135 billion in 2023. Cost inflation ended in 2024, although costs have only slightly decreased. Revenues are forecast to be \$150 billion in 2024. The leading global OEMs have faced significant pressure in the past few years, with some recording zero profit and some substantial losses.

The fundamentals of the market remain strong. Most countries need a mix of renewable energy sources to decarbonise their electricity mix. Offshore wind has natural geographic limitations. Solar PV also has some limitations, but these are often mitigated in an electricity mix that includes onshore wind. Concerns about climate change and energy security have steadily improved the prospects for onshore wind in countries where regulations had moved against it. European nations that have very low deployment rates have become more favourably inclined to onshore wind since Russia's invasion of Ukraine, although there is still significant local opposition. The US Inflation Reduction Act provides long-term certainty for investment. China remains strongly committed to the technology and is investing billions of dollars in grid infrastructure to bring power from the windy west to the populous east.

Growth Opportunities

There is significant growth potential for onshore wind, but reducing costs will be a priority for the industry. Commodity price inflation pressures will ease, but additional efforts are needed to improve the overall cost efficiency. Part of this relates to the core materials and components, and OEMs need to do what they can to reduce costs, in part so they can rebuild profit margins. One example is the use of nanotechnologies that can reduce blade corrosion and, as a result, downtime.

Developers and operators need to keep up the political pressure to increase the pace of permitting approvals, which continues to be slow. OEMs considering manufacturing investment need to be clear that a country must have a supportive policy to improve the business case.

As with offshore wind, digital technologies will continue to play a significant role in industry developments improving the operational efficiency of assets.



Reshoring of Equipment and Component Supply Chains

The 2010s saw China establish its dominance of the solar PV industry; for polysilicon production it has 7 of the 10 largest companies. The wind industry is more globally balanced, but many global developers have relied on Chinese facilities as a linchpin of their global supply chain as a way of driving costs lower.

However, the market dynamics are now changing. Energy security has become a prominent megatrend, and this stretches from the electricity generated to the equipment and components used in a solar plant or a wind farm. Relations between Europe and China, the United States and China, and many Asia-Pacific nations and China have gradually deteriorated since 2015. Whilst there is still significant co-operation and many companies remain committed to China as a hub for manufacturing, there is also a strong political and economic will to increase domestic manufacturing. The threat of trade tariffs is placing further pressure on the industry.

For the wind industry, turbine size is also a factor. In 2010, the average size of an onshore turbine was 1.8MW; by 2022, this had increased to 3.2MW, meaning all components are larger. Offshore turbine sizes now reach 12MW. This makes the cost of transportation significantly higher.

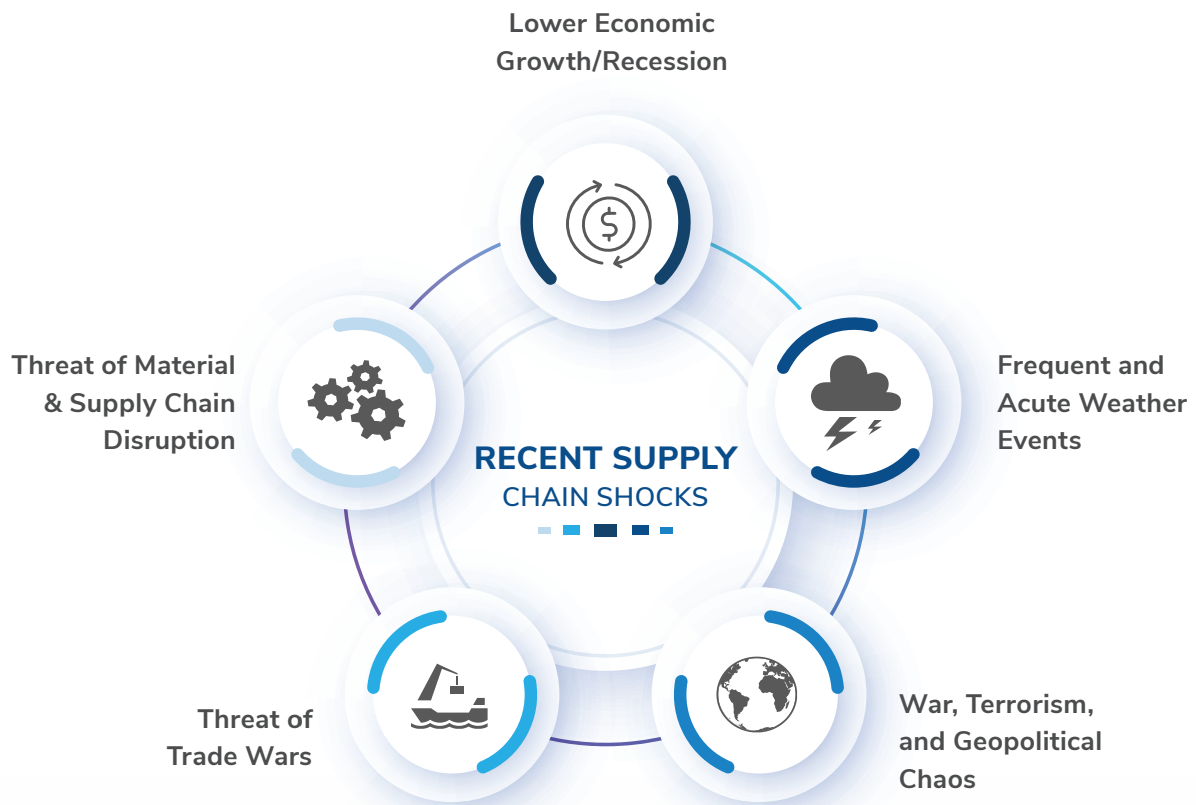
Growth Opportunities

The US Inflation Reduction Act provides specific incentives for solar PV and wind related to tax credits for developers, but these are tied to a certain percentage of the components being domestically manufactured, linked to overall job creation. How this situation evolves in 2025 is still uncertain. The EU's Net Zero Industry Act introduces local content requirements for projects although these have yet to be clearly defined. This is a clear growth opportunity for those manufacturers that have been hesitant to invest in the past. First Solar, AE Solar, Iberdrola, FuturaSun, CS Wind, Siemens Gamesa, Vestas, and Enel are amongst the companies that have made announcements on new plant construction or the expansion of existing facilities.

It creates a significant investment opportunity for banks and private equity to fund or acquire stakes in some of these companies. It also creates a growth opportunity for those companies that manufacture the machines and components used in these plants and for the logistics companies that would transport finished components to a project site.



Key Drivers of Reshoring/Nearshoring, 2025



Source: Frost & Sullivan





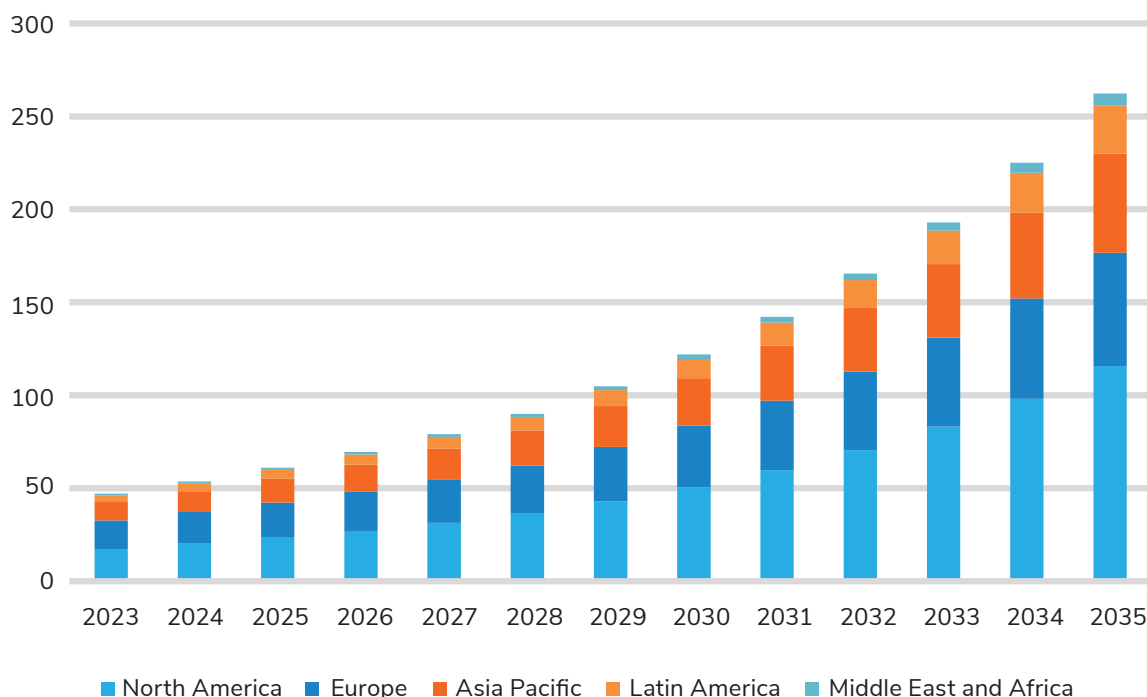
Rise of PPAs: Alternative Financing Options

Efforts to decarbonise electricity generation and industries continue to gain momentum as businesses look to minimise their emissions. Access to low-carbon power is a significant element in achieving this. Some countries already have a significant percentage of renewable generation, but many still lag, making it hard for businesses to guarantee that their electricity supply is coming from renewable energy sources.

Power purchase agreements provide a solution. Companies commit to purchasing an amount of electricity at a guaranteed price for a period of time. The guarantee supports the business case for a developer and ensures that they can attract needed financing. A total of 53.6GW of PPAs are forecast to be awarded in 2024; this is forecast to reach 122GW by 2030.

The key customers driving this are the global technology giants: Amazon, Meta, Alphabet (Google), and Microsoft have been the largest PPA customers for a number of years. They need to power data centres that are extremely energy intensive, and they have publicly committed to clean energy initiatives that go beyond most corporates.

Corporate Clean Power PPAs by Region, Global, 2023-2035



Source: IEA



Growth Opportunities

The direction of market development is clear; PPA growth will continue to be strong in 2024. PPAs provide risk mitigation for companies that face either financial penalties or reputational damage by not reducing their carbon footprints. They are an effective way to finance energy investment because of the certainty they provide.

For developers already offering PPAs, increasing the scale and coverage should be a priority. PPA activity has been strongest in North America, followed by Europe, with Asia-Pacific trailing. More focus needs to be on increasing the penetration of PPAs in the Asia-Pacific market, which also has the highest growth rate for data centre investment because of its strong economic and population growth.

Those companies not offering PPA contracts should make efforts to gain the competencies required to provide them. In an era of higher financing costs for businesses, these contracts will be even more important.

Combined Offering of Renewables and Batteries

Renewables are vital for decarbonising the electricity mix, but there are increasingly times when renewable generation is exceeding demand, meaning that electricity output has to be curtailed. This means that electricity is wasted, and revenue is lost, because the electricity could be sold later at an attractive premium.

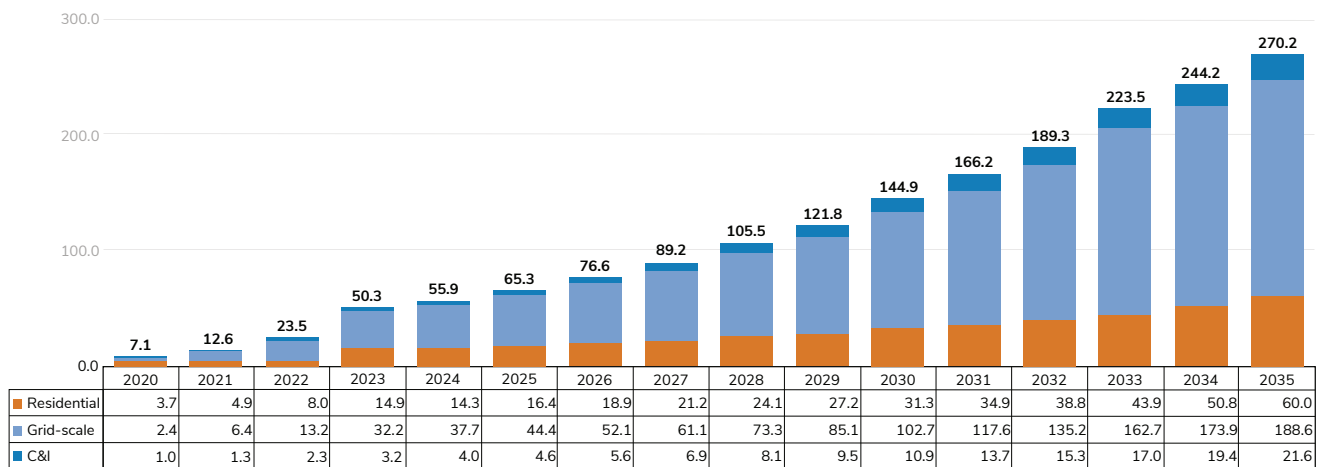
Deploying battery energy storage (BES) is the key solution for this challenge. Besides maximising renewable output, it brings stability to the grid and provides backup during outages. Global market revenue was \$50.3 billion in 2023, and Frost & Sullivan forecasts this to increase to \$150 billion by 2030.

These advantages mean that new renewable projects are increasingly being deployed with BES. Specific country or US state mandates are part of the reason for this, but the business case is strong for renewables + storage simply because it maximises the value of the assets.

The largest market for storage is for grid-scale projects. Residential is the second-largest market, followed by the commercial and industrial (C&I) sector. Project design is more complex, customised to unique challenges, and requires powerful controls to co-optimize rate structures, incentive programs, and reliability requirements. It is this sector that has the highest rate of growth.



BESS Market by Segment, Capex (US\$ Billions), Global, 2020 - 2035



Source: Frost & Sullivan

Growth Opportunities

Depending on the tariff structure and market design, companies using BES can obtain significant savings in demand charges and peak shaving while increasing resiliency and reducing their carbon footprint if tied to a distributed generation system.

BES vendors should assess the drivers in each market and prioritise geographical areas with high electricity prices and demand charges, a large base of industrial and commercial facilities, low power quality, and considerable differences between peak and normal hours.

Frost & Sullivan recommends partnerships between battery suppliers, optimisation software providers, and local energy service companies (ESCOs) or equipment rental suppliers. The offering should include powerful energy management systems able to optimise battery use across desired applications (spinning reserve, grid services, and renewables smoothing) and maximise their value.





AI-powered Software to Optimize Battery Dispatch & Unlock Margins

BESS integration offers significant potential for long-term growth due to the fundamental market drivers. However, low margins concern packers and integrators, which also see increasing competition from cell manufacturers' vertical integration.

Many integrators are moving their business focus to the software + services space, given that it provides a recurrent revenue stream with higher gross margins and up/cross-sell opportunities. As electricity markets increase in complexity, so do the opportunities for batteries to display their wide set of attributes and the need for advanced software to co-optimize them. AI-based software platforms are rapidly becoming a crucial component of BES systems—BTM and FTM—and a growing revenue area.

While some large asset owners opt to develop their own trading and optimization platforms, that is not the norm for the industry. As electricity markets get more complex and deeper in terms of opportunities for BESS services, advanced optimization software and services will become a must-have for virtually all assets.

Growth Opportunities

Besides integrators, pure software vendors with energy trading backgrounds and large asset owners dominate the battery optimization and trading software industry.

Market participants leverage AI and ML to support forecasting and optimization in combination with experts' insights. While some companies opt for SaaS delivery models, others stick to asset management contracts combining software with human proficiency.

Given the expected increase in BESS and evolving energy industry regulations, there is ample room for market share growth.

Companies must continue fine-tuning forecasts, increasing automation and integration levels, and deploying aggressive marketing, partnering, and brand recognition strategies to attain market leadership and stave off consolidation.



Demand Management and Virtual Power Plants

With the growth in renewable energy systems (RESs) and distributed energy resources (DERs), managing the grid becomes more complex. Utilities and grid operators must manage the availability of renewables against demand to ensure grid stability.

The variability in load also provides significant new revenue opportunities. Storing electricity for use at a later time can help households and businesses reduce electricity costs. Selling excess output at a later time of high prices brings additional revenue.

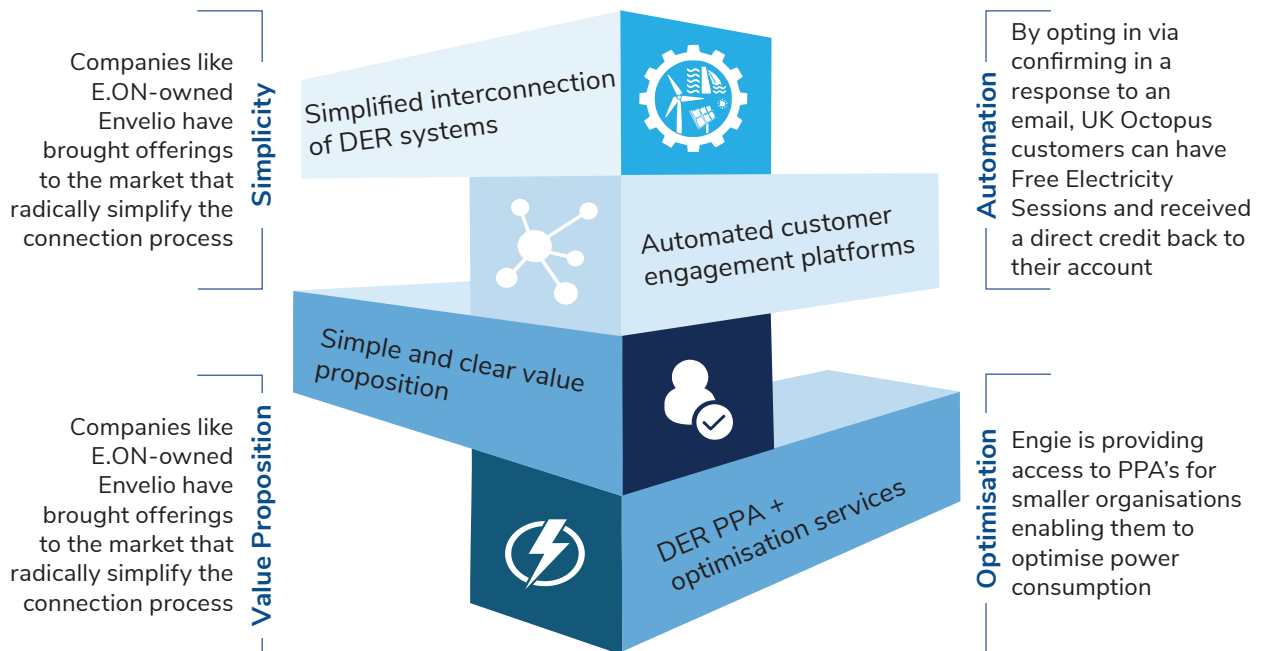
Better management of when electricity is used can also provide savings. Shifting a portion of demand across relatively short time periods can have a significant impact on system stability and provide revenue opportunities.

Much of this is achieved through software. A virtual power plant (VPP) platform aggregates, manages, and optimises connected decentralised DERs, energy storage systems (ESSs), and controllable loads, all of which are connected and controlled via a central system (VPP software). The aggregated assets form a single imaginary power plant that can be dispatched during peak demand, providing greater flexibility to the grid.





BESS Market by Segment, Capex (US\$ Billions), Global, 2020 - 2035



Source: Frost & Sullivan

Growth Opportunities

With the increasing share of RESs in the European energy mix, utilities and VPP aggregators will have to redefine their roles in the energy value chain. The evolving needs of different prosumers will push utilities and aggregators to reorient, restructure, or reformulate business strategies and models around these consumers. An increasing number of customer-centric technologies will facilitate the transition toward VPP.

VPP platforms will leverage AI and ML algorithms to manage power generation assets, understand customer behaviour, and adjust output levels depending on demand and forecast consumption.

Through a VPP platform, users can enable bidirectional electricity between electric vehicles (EVs) and the grid, allowing more intelligent charging of EVs and pushing energy stored in the EVs back to the local grid during peak demand. Connecting hundreds of EVs could form a VPP utilised as a cost-effective grid-balancing mechanism.



Advanced Servicing Propositions

With an increasingly competitive power market, asset performance is vital to maximising revenue. The age profile of assets is increasing; many of the combined cycle gas turbine plants in Europe, North America, and the Middle East are more than 20 years old. Wind farms and solar PV installations are starting to approach the end of their operational lifetimes without further investment. Many of these older plants have lower efficiency levels, meaning that the amount of electricity generated is lower and returns are lower.

The challenge, though, is how much to invest in assets. Gas-fired power plants are under pressure from renewable energy in many markets, so whilst there could be an operational case to invest, the business case may not be there. Utilities and IPPs have multiple investment priorities, and advanced servicing solutions—whilst desirable—may not always make it high enough on the list.

Advanced servicing propositions are also being deployed to new assets so that operational efficiency is higher from day one. OEMs are offering these services as part of their standard maintenance packages.

Growth Opportunities

Proving the business case for advanced servicing is imperative. Operators need to see a clear business case for the investment they will make. This could mean incremental investment on smaller-scale projects that deliver a clear ROI that then unlock further investment. Building operator confidence is key. Large, one-size-fits-all solutions will not be attractive to many vendors.

A multibrand servicing solution is vital for the wind sector, as many operators now use multiple wind turbine OEMs in their portfolio.

Gas plant operators are primarily attracted to any solution that can further improve flexibility, as these assets increasingly operate in a flexible as opposed to a baseload mode.

Large-scale repowering of renewable assets will become a significant growth area, so service providers need to build their service offerings now. Including advanced services as part of this will be attractive.



Grid Digitalization and Distributed Intelligence

Rising distributed rooftop solar, storage, and EV charging demands require utilities and grid operators to deploy digital solutions that ensure reliable power flows. Another element of T&D network digitization consists of grid modernization initiatives to replace or overhaul the aging fleet of assets and address anomalies based on data and actionable insights. Increasing penetration of IoT devices and sensory networks across utility infrastructure improves digital solutions' adoption.

Digitalization is imperative with the increasing penetration of DER and customer touchpoints. Greater adoption of smart equipment generates enormous amounts of data for insights—stemming from big data analytics.

Distributed intelligence is becoming the norm in the power distribution and retail industry, with smart meter and switchgear manufacturers adopting this technology in their product offerings to enable more efficient and cost-competitive solutions. Information technology-operational technology (IT-OT) convergence, grid, and data complexity have resulted in one-stop solutions demand and offerings.

Growth Opportunities

Intense competition will be likely between traditional grid equipment manufacturers, software and analytics start-ups, Internet of Things (IoT) solution providers, and integrated energy companies. Cross-industry collaborations and partnerships will help implement a full-fledged digital grid ecosystem.

Digital intelligence is transitioning to the grid edge. This provides proactive real-time data access, real-time decision-making, and device response as events occur. IoT capabilities are expanding from sensing to actuating. Data processing taking place at the sensor level will enable lower reliance on central analytical platforms, which spare communication networks' capacity to transmit data to the head-end.

T&D investment in making assets connected and inter-operable will likely be the chief focus for asset owners moving forward, as they address increasingly varied supply and maintenance activities. Big data's crucial outcome is actionable data. Today's smart utility use cases require synchronized asset interactions in response to rapidly changing network conditions. Rather than upgrading physical infrastructure, utilities will invest more in connectivity infrastructure.



Future Technology Trends

Innovation will continue within the energy sector, with materials fundamental to growth. Seemingly mature technologies like solar PV will see greater deployment of cells with materials that enable higher efficiencies, further advancing its dominance. The wind industry, focused on cost reduction, will see new materials help it achieve its goals. For battery energy storage, it is again materials that hold the key. Lithium will retain its overall dominance, but sodium-based solutions will make major inroads in the 2030s because of its natural abundance. Materials will also play a substantial role in the development of grids, as technologies with higher level of conductivity mean more electricity going through the existing network.

Companies to Watch in the Industry

Masdar: Many would historically associate the UAE project developer with a significant domestic project in the UAE, but the company has rapidly become a key player in the global renewable energy industry, both as an investor and developer of projects. With a focus on large-scale investments, Masdar has taken a 49% stake in the Dogger Bank South project in the UK, one of the largest in the world. It has also acquired Terra-Gen, one of the largest developers in the US, and in November, 2024 it acquired a 70% stake in Terna Energy, a major developer in Greece. Masdar has a target to control 100GW of renewable energy assets by 2030. Masdar is also focusing on markets outside of Europe and North America, we no region out-of-bounds if the project-scale and conditions are right.

ACWA Power: The Saudi Arabian based developer has built up a portfolio of assets across the Middle East, Africa and Asia. Historically focused on conventional power and water projects, renewable investment is now a major priority. This includes investment in green hydrogen; it is active in the NEOM project, which when completed will be the world's largest for renewable hydrogen. Further hydrogen projects are under development in Egypt and Uzbekistan.



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