



COMBATTING THE ENERGY CRISIS WITH SMART GRIDS

Whitepaper

KEY VERTICAL MARKETS



1.1 Introduction

In the past few years, the landscape in energy distribution has shifted and the needs of the market have become increasingly complex. Concerns around how energy is created and utilised, coupled with the broader considerations of climate change transformed market expectations towards renewable energy. Over 2022, problems in the global energy supply chain, the war on Ukraine and the subsequent energy crisis, have underlined the increasing necessity of renewables, such as solar and wind power, translating into the advent of alternative energy generation. Nonetheless, renewables do not generate electricity continuously, and therefore, the energy systems must be more actively managed, and energy generated must be better stored and distributed safely and efficiently. Moreover, when ageing infrastructures and systems are considered, modernisation of energy management systems, most crucially of the electric grid, becomes a must. This also means initiatives around grid modernisation, such as metering infrastructure and smart meter roll-outs, are critical as precursors to the smart grid, which can manage traditional and alternative energy generation and prevent blackouts and burnouts or restore energy quickly in case of such events occurring.

Juniper Research defines the smart grid as:

'A responsive electric grid whose layers are modernised by IoT technologies and related appliances and devices, which, by enabling a two-way information exchange, digitally monitors and responds to consumption patterns, integrates various types of renewable sources and the actions of actors by optimising operation of all elements throughout the value chain.'

The smart grid's responsive and automated nature leveraging IoT adapts to changing supply, as well as demand patterns, by ensuring communication throughout the

value chain without overly relying on separate operators. It is an integrated management mechanism to coordinate supply and demand, and oversee efficient and sustainable energy distribution. Therefore, the smart grid is not a simple upgrade of the traditional one but almost a complete overhaul in the sense that it transforms roles and interactions of all components and actors within the grid's ecosystem. One of the key areas of such transformation is, as mentioned, the supply side of electricity, whose market centralisation has become a key contest topic in recent years.

Centralised and decentralised markets possess incentives as well as constraints for renewables supply, regulated by different mechanisms and tariffs. In essence, decentralisation of supply can be considered as moving production means away from national to regional and local levels, with combining multiple energy sources as a basis for generation. This allows for the electricity market to yield multiple benefits, namely, increased conversion efficiency and flexibility in generation to meet local demands, consumption patterns, and better energy management for households and businesses. Moreover, at the market level, local and regional electricity generation encourages smaller-scale utilities to be connected to a distribution network, enabling them to sell surpluses back to the same network. The smart grid is, therefore, critical to facilitating these transactions by assisting integration of advanced generators and storage systems to the traditional grid. As such, the smart grid empowers customers to become prosumers (users who both consume and produce) through its two-way distribution capabilities.

In terms of the demand side of electricity generation, elements of the smart grid, such as smart meters, also grant prosumers the ability to choose between different electricity providers based on competitive pricing, as well as adjusting their electricity use according to feedback received, reducing the risk of incorrect or overinflated billing. By automatically monitoring energy flows and adjusting to the changes in supply, smart grids inform smart meters, which in exchange provide more comprehensive information to end users in ways that traditional meters are not able to. In most practical terms, this eliminates estimated bills and ensures accuracy in meter readings. Smart metering is an essential infrastructure component of the smart grid, and also helps utilities obtain more accurate information about consumer habits, pinpoint energy waste, and establish incentives to promote greener energy usage.



Moreover, the smart grid's two-way information flow enables the development of self-restorative capabilities; protecting energy supply against disturbances in supply. It has anticipatory features deployed by the constant monitoring of the system in its entirety and self-assessment functionalities, including risk assessments based on the detection of weaker points throughout the entire grid. Self-restoration is achieved through communicating with other components of the system to detect and mitigate failures. This capability is provided, for instance, through a mix of intelligent devices (ie transformers, electronic devices, terminal units) based on part wired and part wireless connections. These capabilities also point out to another vital feature of the smart grid, namely, its decentralised nature, which does not necessitate a top-down operational control or regulatory mechanism. As such, power outages cannot have ripple effects, as they are detected either in real- or near-real-time and solved cellularly.

The smart grid, very broadly, can be viewed as a network, interconnecting all layers in the system seamlessly to transfer uninterrupted and quality electricity to the customer domain, as well as integrating other domains to ensure continuity of supply. It achieves this primarily via its communication and network layers. In fact, these layers connect the power generation, supply domains and service areas to each other and the physical infrastructure which comprises of equipment. This equipment includes RES (Renewable Energy Sources) and DER (Distributed Energy Resource) generators such as photovoltaic, wind generators, advanced batteries, and other storage systems at the power generation layer; electric vehicles, PEVs (Plug-in Electric Vehicles) and other plug-in hybrid electric vehicles (PHEVs) at the customer domain, as well as the components for AMI (Advanced Metering Infrastructure) including smart meters, inverters, and sensors.

1.2 Key Areas in the Organisation of Smart Grid

Key areas in the smart grid involve the IoT aspect of the system as all elements are connected to the communications layer of the smart grid, making it essential to provide an overview of smart grid communications and the main enabling technologies.

1.2.1 Networks in Smart Grid:

- **LANs (Local-area Networks):** LANs interconnect smart devices and applications in small or limited areas such as homes, buildings, and substations. They comprise of SNs (Sensor Networks) and other short-range technologies; connecting them to NANs (Neighbourhood-area Networks), which will be explained below.
- **HANs (Home-area Networks):** Operated in a small area, HANs consist of broadband Internet connections used to share data between smart meters and other smart devices in households to pave the way to efficient energy management. Smart devices mentioned for these energy management systems include sensors, actuators, and home displays. They enable consumers to participate in energy generation and consumption by using PLCs (Power Line Communications), as well as wireless networks (Wi-Fi and other lower-energy networks such as ZigBee). They are essentially private networks located in the customer domain.
- **ANs (Access Networks):** Like private networks such as HANs, ANs aggregate a large number of users and provide access to the main networks.
- **NANs:** A cluster of HANs and LANs can be connected to a wider range of local networks called NANs, enabling transmission of data from multiple networks to local utility data centres for management and analytics. The transmission is established through medium-voltage lines or wireless technologies. These networks are also referred to as FANs (Field-area Networks).
- **WANs (Wide-area Networks):** The last layer for connecting granular networks and NANs to a wider network and all other layers for electric generation, such as generation and distribution, is WANs, whereby the network collects data to transmit it to substations and utility companies. WANs can utilise a variety of



merging communication methods to effectively transfer this data such as wireless and cellular networks and PLC.

- **Enterprise Network (Data Level):** The enterprise network covers the bulk generation and operational level, and refers to the processing and analysis of all collected data. It relies on measurement systems that monitor and control the entirety of the grid to be able to distribute the collected data. These systems are called WAMS (Wide-area Measurement Systems) based on PMUs (Phasor Measurement Units) and PDCs (Phasor Data Concentrators) to obtain data from various system components and inform a final layer of applications where, through a central PDC, such data is translated and transferred into synchronised data for the use of more advanced applications.
- **External (Social and Economic) Networks:** External networks are the non-technical aspect of the smart grid covering the market and service provider domains, leading to new business models in electricity generation intertwined with technologies. In the past few years, thanks to the advancement in IoT, market vendors have become active influencers for other layers by devising solutions (ie smart grid software management solution vendors).

i. Technologies/Networks Merging Communication Infrastructure for Smart Grid

As mentioned, merging technologies/networks for smart grid communication infrastructure are crucial to achieve effective and safer transfer of data to WANs and beyond.

- **PLCs:** PLCs are physical infrastructures enabling data exchange through electrical power lines through a carrier signal embedded within the cables. The use of PLCs is widespread, with well-established communications and interoperability standards and the most common use-case being Broadband-over-Power Line devices which features an integrated broadband layer over PLC.
- **Cellular Networks:** The most commonly available form of networks, cellular network technologies such as 3G, 4G and 5G, present an alternative to other forms. Nonetheless, unlike PLC, they are not exclusive to smart grid communications.

- **Wireless Networks and Protocols:** Wireless networks are used in all area networks except for NANs, albeit with limited capacities in some (ie Wi-Fi for HANs in customer applications).

1.2.2 Enabling Technologies & Devices

In the smart grid, enabling technologies and devices sit at the intersection of hardware and software/communication layers to ensure continuous and seamless interaction between different components.

- **Smart Sensors:** Smart sensors provide analogue signal processing of recorded signals, digital representation of the analogue signal, address and data transfer through a bidirectional digital transfer system, manipulation, and computation of the sensor-derived data. As such, smart sensors do not only enable data collection, but also process data to lead to actionable information, used for remedial and/or predictive functions throughout the grid.
- **PMUs, Synchrophasors, and PDCs:** PMUs are smart sensors measuring both magnitude and angle of voltage and current, with their measurements capable of being synchronised through GPS (Global Positioning System) in high precision. Values measured by GPS-enabled PMUs are also referred to as synchrophasors, informing and updating other systems on the health of the grid. PDCs, on the other hand, are the connectors between PMUs and WAMs. They collect, sort, and store the data required as well transmit them to the advanced application stages which lends itself to other management and information systems such as outage and distribution management systems.
- **WAMs:** WAMs comprise of PDCs to aggregate, and relay measured data for grid stability assessments, fault detection, remedial controls, as well as to supporting more accurate state estimations. These systems are regarded as essential to providing efficiency and reliability to the smart grid by seamlessly integrating high-speed synchrophasor measurements with other data sources and power system simulation capabilities.
- **Smart Meters and AMI (Advanced Metering Infrastructure):** Smart meters and AMI are building blocks of the smart grid. AMI refers to the system gathering and distributing information for consumption and regulation of electricity, thus,



improving customers' contribution and is an amalgamation of hardware, software, meter and data management systems and smart meters as its inception component. Consisting of hardware and software management and control systems, a smart meter enables the two-way communication and electricity flow between utility providers and customers. Connectivity and data management for smart meters are the most vital points, as the former necessitates reliability for secure information flow, while the latter depends on compatibility with applications, such as billing and CIS (Customer Information System) provided by utility companies to ensure electricity flow and consumption are presented accurately.

- **DAUs (Data Aggregator Units):** Data from households, LANs and HANs are collected through DAUs integrating a gateway for NANs to enable data transfer to local utility data storage units, as well as providing NANs an opportunity to connect with WANs.
- **V2G (Vehicle-to-Grid) Technologies:** Tied to the smart grid capabilities of RES integration, effective DM and smart charging, V2G can be defined as a technology that enables energy to be pushed back to the power grid from the battery of an electric car. In this respect, EV and PHEVs can simultaneously contribute to reducing the pressures on load by monitoring their usage and feeding excess electricity back to the smart grid.

1.2.3 Microgrid

Neither an enabling technology nor a device, the concept of microgrid is an important one although not considered a component or extension of the smart grid system. A microgrid is a DES (Distributed Energy System) that can be described as an electrical system that includes multiple loads and distributed energy resources that can be operated in parallel with the broader utility grid or a small, independent power system serving a discrete geographic footprint, such as a college campus, hospital complex, business centre, or neighbourhood. It is a self-sufficient system that can operate both as connected to a grid or on island mode, off-grid. They are also ideal for providing electricity to remote and underdeveloped areas with little to no access to a central grid.

1.2.4 Smart Grid Software Architecture

Smart grid software architecture connects a traditional power system automation with DERs and cloud computing. One example of the power system automation architectures is legacy SCADA (Supervisory Control and Data Acquisition) systems which are made up of hardware and software elements that help utility companies control and supervise processes at local or remote locations by monitoring, gathering, and processing real- or near-real-time data, and interacting with other system components such as sensors. SCADAs are now web and cloud based, which makes them highly compatible with smart grid architecture. Smart grid software architecture, in this sense, can be referred to as the application layer which delivers various smart grid applications to end users based on its existing information infrastructure. This layer contains EMS (Energy Management Systems) including DR (Demand Response) and customer-facing applications, such as pricing applications that transmit pricing information to smart meters, appliances and EVs. DRs, through the application layer for instance, convey information to smart applications in households and reduce the load on the grid in peak times.

1.3 The Benefits of Smart Grid Deployment

Thanks to its extensive features in the accommodation of RES (Renewable Energy Sources) through its communication capabilities, investing in smart grid deployment yields significant benefits for the environment and society. These benefits are summarised below.



Figure 1: Smart Grid Benefits

Smart Grid Benefits



Increased Network Resilience



Improved Efficiency



Increased End-user Involvement



Easier Use of Renewables



Accelerated Decarbonisation

Source: Juniper Research

- Dealing with the Energy Cost Crisis:** In the context of the current energy cost crisis, the benefits of the smart grid become even more pronounced. The smart grid significantly reduces the cost to serve consumers, thereby allowing utility companies to be more competitive in retail pricing for end users despite potential rises in wholesale prices. It achieves this in two ways; firstly, smart grid information transmission advises utility companies on consumer behaviour to generate accurate billing information, helping them in the settlement of transactions, thereby, cutting administrative costs. Secondly, energy companies can now offer dynamic pricing and multiple rate plans to their consumers based on data transmitted and decentralised electricity generation. As discussed previously, for utilities and/or energy companies, the smart grid lends itself to sophisticated business and pricing models, such as net metering and time-of-use pricing, deployed with the assistance of smart meters, which extend to end customers for better prices. Consumers, therefore, have the option of aligning themselves with cost-effective rates and can get incentivised for using energy more consciously. For instance, in the UK, the National Grid ESO (Energy System Operator) declared in late August 2022 that homes with smart meters will be able to receive a discount on their energy bills provided they avoid using high-powered devices at times of peak demand (ie EVs).
- Greater Environmental Sustainability:** Smart grid offers improved energy efficiency via two-way communication, resulting in reduced emissions. This enables the provision of cleaner energy for EVs and PHEVs (Plug-in Hybrids) and increased integration of RES, which have been at the centre of the smart grid's promise in assisting to achieve greater environmental sustainability. By improving the amount, and consistency, of the intermittent renewable energy provided to the energy system, smart grids increase renewables capacity, and help decarbonise the grid. In a similar vein, techniques such as distributed generation, assist in reducing carbon emissions by better integrating energy from renewable sources such as solar and wind. The smart grid also incentivises localised renewables generation, for instance, via solar PVs (Photovoltaics), providing an alternative energy source to meet local demands, thereby alleviating demand pressures put on national grids. The impact of the smart grid on business-side energy demand and management, is also an important consideration. The smart grid allows for different modelling based on data to optimise energy efficiency. Furthermore, businesses can now incorporate RES and improve on their existing electricity use,



either in manufacturing processes or simply in facilities, through data generated by smart grids. At a granular level, the smart grid assists in communicating energy efficiency to customers/end users in practical terms. This is achieved by smart metering, which helps households monitor and measure electricity consumption, and in doing so, it also allows collection and analysis of collective data, especially in urban areas, to identify patterns leading to adoption of sustainable practices.

- **Ability to Meet New Energy Demands and Peaks:** The smart grid and increased use of renewables have led to growing connectivity of customers/end users to electricity grids, also raising their expectations for a reliable and efficient system in tandem. Customers now enjoy their newly assumed prosumer capabilities, translating into intermittent energy supply to the grid, whose supply patterns are more difficult to regulate. Moreover, consumer demand is now more intricate, specifically with the proliferation of systems/products that utilise electricity. It is thus essential for the grid to be able to respond to new demands and peaks effectively. The smart grid achieves this response in two ways; firstly, by triggering actions that minimise or and/completely avoid power outages and restore energy back more rapidly if outages occur, and secondly, distribute electricity more efficiently thanks to its communication capabilities to ensure supply-demand balance and mitigate peaks. This capability is called DR, which is a method to encourage consumers to decrease their consumption for shorter intervals to be able to store electricity to be used either in emergencies or at peaks, which can involve both energy conservation and load shifting. Through measurement and monitoring of supply by smart meters, a central unit, called an aggregator, decides on the supply by comparing signals from the service provider and the demand and electricity generation. Meeting new energy demands and possible peaks is, therefore, facilitated without straining the electricity supply in the grid.

An advancement of DR is called ADR (Automated Demand Response), defined as systems which automatically detect the need to shed load, send signals to participants, and control all devices that use electricity within a home or business. ADR is still under development and its integration to smart grid systems remains a challenge. Nonetheless, thanks to the data provided via smart meters, suppliers are enabled to feed data back to customers in real- or near-real-time to achieve the balance between supply and demand in current smart grid systems. Another aspect of demand management is the integration of RES into the generation and

distribution layers of the smart grid. RES generation and storage allow to meet new, and perhaps more dispersed, patterns of consumption demanded by emerging technologies, such as EV charging, necessitating designated charging stations and at-home charging facilities. Such stations/facilities have the potential to significantly increase the electric load, impacting local and neighbourhood networks negatively. With the smart grid, the load impact can be mitigated without straining the other components of the network, consumption can be monitored, and utility companies can collect EV-specific data and troubleshoot in charging stations owing to its communications infrastructure. Similarly, real-time data provided by the grid helps reduce energy waste at the end-user level by incentivising consumers to cut electricity use according to peak periods, contributing to a better balance in supply.

- **Efficiency for Energy Companies:** Thanks to advancements in the smart grid, energy companies now have much improved ability to increase their operational efficiency in providing electricity to business and individual consumers. In addition, data collected within the smart grid helps energy companies to predict supply needs more accurately, while also opening possibilities for new business models utilising functionalities such as time-based pricing, load management, budget billing, high-usage alerts, push notifications, and web services for customer energy management. Another related benefit of smart grid deployments is the assistance they provide in countering rising wholesale electricity costs. By integrating RES and enhancing flexibility in managing customer demand, the smart grid helps balance increased demand with market prices, enabling companies to provide stable pricing for end users. This benefit also extends to other ancillary services or technologies of the smart grid, for instance, battery energy storage systems, which can produce and store energy at off-peak prices, thereby better managing supply and ultimately enabling to reduce the costs for end users.

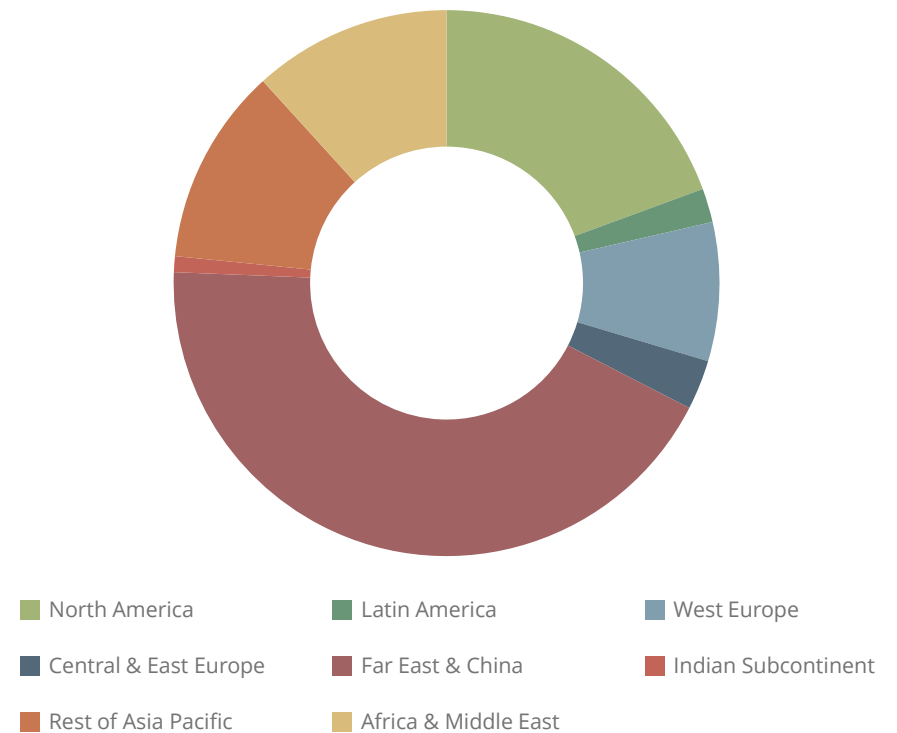


1.4 Forecast Summary

Cost savings from smart grid deployments will exceed \$125 billion globally in 2027; increasing from just over \$33 billion in 2022. This 279% growth will be driven by rising energy prices, with smart grid technologies playing a critical role in increasing network efficiency and optimising resource management. The abilities of AI-based analytics are crucial to maximising benefits of new renewable energy sources, by actively balancing load and optimising energy transmission.

- Smart grid deployments are key to the decarbonisation of electricity production. Smart grids will enable energy sources that produce electricity based on external elements, such as solar and wind power, to meet energy requirements more effectively, by actively balancing load and predicting surges in demand & production.
- By leveraging AI, electricity networks can ensure that spikes in demand are predicted and mitigated. Smart grid vendors must focus on enhancing their models to more accurately predict usage patterns to maximise these benefits.
- Smart grid deployments will result in an almost 700 million MMT (Million Metrics Tons) reduction in CO₂e (Carbon Dioxide Equivalent) emissions globally in 2027; falling from 214 million in 2022. This will be central to meeting stringent climate change goals, alongside updating generation capabilities to feature more renewable sources, including wind and solar.
- Smart grid vendors must develop data ingestion engines that can analyse and interpret structured and unstructured data from disparate sources, including smart meters, network data and weather forecasts, to maximise emission reductions.

Figure 2: Total Smart Grid Energy & Emissions Cost Savings in 2027 (\$bn): \$125 Billion



Source: Juniper Research



Order the Full Research

Discover in-depth analysis and crucial evaluation of how the requirements of the energy grid are rapidly changing in this brand-new report. Featuring invaluable insights into how technology is rising to meet challenges by introducing advanced, AI-enabled analytics, this extensive research includes strong coverage of key trends driving smart grid forwards. Covering 60 countries for an extensive list of metrics, the report also includes a Competitor Leaderboard with 18 smart grid vendors.

Key Features

- **Market Dynamics:** Provides a detailed assessment of how the smart grid market share and market growth is evolving, what benefits it can deliver and what the barriers are to future growth within smart city projects in the energy sector, featuring:
 - Smart grid adoption and the resulting software spend, energy savings and cost savings.
 - Smart metering adoption and the resulting shipments, hardware revenue and connectivity revenue.
- **Future Outlook & Regional Analysis:** Future outlook and comprehensive analysis of the key countries and regions deploying smart grid technologies in smart grid network management, encapsulated by our future outlook for deployment.
- **Benchmark Industry Forecasts:** 5-year forecasts are provided for smart grid adoption, software spend, energy savings and cost savings. Additionally, smart metering forecasts are included, such as the number of smart meters in service, the shipments of smart meters, hardware revenue, connectivity revenue, and connectivity splits, including 2G, 3G, 4G, 5G, LTE-M (Long-term Evolution Machine-type Communication) and NB-IoT (Narrowband Internet of Things). The regional market revenue forecast data is also split by 8 forecast regions and 60 countries.

- **Juniper Research Competitor Leaderboard:** Key player capability and capacity assessment for 18 smart grid vendors, via the Juniper Research Competitor Leaderboard featuring major players in smart grid systems including:

- CISCO Systems Inc.
- Fujitsu
- IBM Corporation
- Oracle Corporation
- Schneider Electric
- Siemens AG

What's in this Research?

1. **Market Trends & Strategies:** Detailed evaluation and strategic recommendations for the smart grid market, analysis of different technologies involved and a comprehensive assessment of trends shaping future prospects.
2. **Competitor Leaderboard:** An in-depth analysis of 18 smart grid vendor capabilities, via the Juniper Research Competitor Leaderboard (PDF).
3. **Data & Forecasts:** Market sizing and evaluation by region, with 5 year forecasts for smart grid adoption, software spend, energy savings and cost savings. Additionally, smart metering forecasts are included, such as the number of smart meters in service, the shipments of smart meters, hardware revenue, connectivity revenue, and connectivity splits, including 2G, 3G, 4G, 5G, LTE-M and NB-IoT (PDF).
4. **Interactive Forecast Excel:** Highly granular dataset comprising over 20,900 datapoints; allied to an interactive scenario tool, giving users the ability to manipulate Juniper Research's data.
5. **harvest Digital Markets Intelligence Centre:** 12 months' access to all the data in our online data platform, including continuous data updates and exportable charts, tables, and graphs.



Publication Details

Publication Date: November 2022

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