# GRIDLOCKED: THE BARRIERS TO SMART GRID MARKET DEVELOPMENT

Whitepaper

SUSTAINABILITY & SMART CITIES

JUNIPER RESEARCH

## 1.1 Introduction

The landscape of energy distribution has shifted drastically, and market needs have in turn 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. Whilst the market has stabilised since the massive variability witnessed in 2022 due to the Russian invasion of Ukraine, recessions, and cost-of-living increases across many developed markets, many countries and regions have regained focus on becoming self-sufficient energy producers through renewable energies, combined with optimising the quality of energy produced. This has resulted in a series of funding initiatives for electrical grids, with smart grids being a major priority. There are limitations to the road to self-sufficiency; renewables do not generate electricity continuously, and therefore, the energy systems must be more actively managed. In turn, energy generated must be better stored and distributed safely and efficiently. Moreover, when ageing infrastructures and systems are considered, the 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.

The IEA (International Energy Agency) defines smart grids as 'an electricity network that uses digital and other advanced technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demands of end users.' This definition can be supplemented by the EU's (European Union) definition, which highlights the information provision capacity which 'when coupled with metering systems, smart grids reach consumers and suppliers by providing information on real-time consumption.'

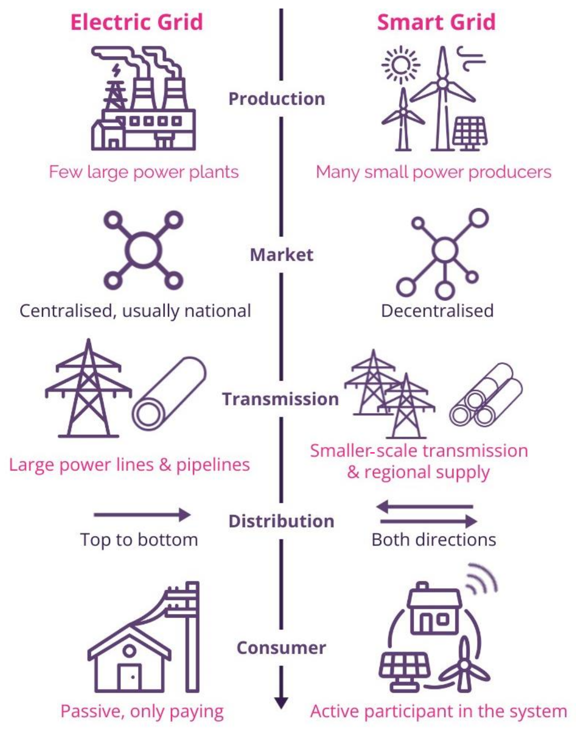
Considering these definitions, Juniper Research defines the smart grid as

*'An electric grid whose layers are modernised by IoT (Internet of Things) technologies and related appliances and devices. Smart grids function by enabling a two-way information exchange, digital monitoring, and responses to consumption patterns through smart meters and other appliances. Furthermore, smart grids can also integrate various types of renewable sources to produce and distribute more environmentally friendly energy.'*

The smart grid's responsive and automated nature leveraging IoT adapts to changing supply, as well as demand patterns, by ensuring communications throughout the value chain, without overly relying on separate operators. It is an integrated management mechanism to coordinate demand and supply, 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.

In this regard, smart grids differ from traditional electric grids in all stages of the energy production and distribution process, detailed in figure 1.

*Figure 1: Electric Grid vs Smart Grid*




*Source: Juniper Research*

One of the key areas of such transformation is, as mentioned, the supply side of electricity, whose market centralisation has become a key 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; combining multiple energy sources as a basis for generation. As a result, the electricity market benefits due to an increased conversion efficiency and flexibility in generation to meet local demands, consumption patterns, and better energy management for households and businesses. 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 through its two-way distribution capabilities.

Smart grids and elements of them, including smart meters, tailor to the demand side of electricity generation by granting prosumers the ability to engage at a greater level to their electricity usage. This includes allowing end users to choose between different electricity providers based on competitive pricing and adjusting their electricity usage according to feedback received, which in turn reduces the risk of incorrect billing. By automatically monitoring energy flows and adjusting to the changes in supply, the smart grid informs smart meters, which in exchange provide more comprehensive information to end users in ways that traditional meters are not able to. Put simply, 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.

The two-way information flow aspect of smart grids is a factor that facilitates the development of self-restorative capabilities, protecting energy supply against supply disturbances. 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 enabled through a mix of intelligent devices, including transformers, terminal units, and other electronic devices.

### 1.2 Challenges Surrounding Deploying Smart Grids

Utility companies and other parties related to smart grids face challenges that reduce the rate of effective adoption, development to infrastructure, and overall efficiency of grids. Utilities especially might struggle adopting renewable energy sources due to being tempered by obstacles these companies face when adding them to their portfolios. High capital costs, grid modernisation, digital transformation, and regulatory uncertainties have been long-term challenges to smart grids, with them offering their own complexities that limit the ability to effectively develop and utilise smart grids.

#### 1.2.1 Infrastructure Investment Costs

In recent years, investment costs for grid and related infrastructure have decreased significantly. Despite this, the barrier for entry still requires sufficient capital, especially in regards to renewable energies. As many countries are pushing for the adoption of renewable energy production due to sustainability targets, investments in wind, solar, hydro, and other renewable energy sources are a necessity, and scant few countries offer some form of subsidiaries to help cover the cost for infrastructure. Given the importance of renewable energy production in smart grids, the slowed rate of investment therefore decreases the rate of which the market at large is able to develop. A myriad of other problems relating to infrastructure investments can occur because of this; countries with non-nationalised energy sectors will require contracts with major technology companies to work on grids which can be incredibly expensive. This in turn can result in a fractured offering, where certain grids will be operated and maintained by certain companies and therefore lacks a holistic consistency across an entire region.

Another note regarding investment costs is ensuring that grids located in volatile climates, such as those prone to extreme weather conditions, are of a standard where they will not take significant damage during such events. This is a problem for a multitude of reasons, with one of the most pivotal being those prone to health complications as a result of insufficient energy provisions, such as the elderly susceptible to the cold, to those on life support. In a similar vein to extreme weather, smart grids are prone to damage from electromagnetic events. These can result from natural phenomena like geomagnetic disturbances from solar storms or weapons capable of creating electromagnetic pulses. These can disrupt and harm electronics and computers, with the capability of causing significant damage to critical electronic infrastructure within the grid, such as transformers.

Events such as these require sufficient investment in order to reduce any potential downtime the grid might experience, and are thus important considerations to infrastructure investment.

#### 1.2.2 Intermittent Power Production

Environmentally friendly energy production is partially accomplished through renewable energies such as wind and solar. However, these sources of energy can be inconsistent depending on the country or region, resulting in a non-continuous production of energy. This is a major challenge for periods of high-energy demand from end users, and thus necessitates the use of real-time energy consumption data to balance supply and demand, forecast generation, and more. Tangentially related to intermittent power production is the intermittent transfer of power to end users in the form of packet loss. Packets are units of data, and therefore packet loss resulting in end users not receiving energy also disrupts the network; possibly even causing a loss of connectivity. Packet loss typically occurs through route instability, and therefore necessitates the inclusion of various software that detects faults in real-time, sending automatic alerts to quickly mitigate the issues.

#### 1.2.3 Grid Integration and Complexity

One of the biggest hurdles to the expansion of smart grids and the market at large is the complexity and integration of various solutions for grids. Integration methods manage the variable production of renewable sources to maintain system reliability, as well as increasing the overall efficiency of systems. Adding new solutions such as different energy sources requires substantial investment of capital, time, and resources which only exacerbate the complexity of the grid. This is not only the case for energy production and distribution, but even the case for changing the software that is utilised to manage grids or specific aspects of them.

### 1.2.4 Security

Grid security is a major concern, with bad actors utilising numerous techniques to disrupt grid operations or to obtain data. Cyberattacks in particular can be incredibly difficult to deal with; grid systems were formerly isolated from the Internet, but have become increasingly connected in the past two decades, and even more so within recent years due to developments like cloud-based infrastructure. Developments like this have offered additional routes for bad actors to take when attacking the grid. Examples of approaches bad actors take when attacking networks include spearfishing, sending emails with links or attachments that include malicious code that gives them access to a corporate network, as well as the exploitation of virtual private connections to networks. In addition to this, attackers can also compromise the supply chains of industrial control systems by manipulating products, including the hardware and software, before receipt by the end consumers, and finally they can gain access to industrial control systems in cases where systems have direct Internet connections. Whilst this could be a major concern, instances like these are scant, and power outages are more likely to occur from natural instances. As it stands, regulations surrounding security for electrical grids is varied across the globe, where some countries and US states lack any focused cybersecurity standards. However, the US government did pass the Securing Energy Infrastructure Act in an effort to bolster grid security in July 2019.

### 1.2.5 Scarcity of Resources

The increasing adoption of renewable energy generation has been able to mitigate plenty of issues surrounding the reliance on fossil fuels. However, the materials that are used to produce zero-emission or low-emission forms of energy generation, such as lithium for energy storage batteries are often difficult to procure. In the meantime, not only will new ways to generate eco-friendly electricity be a priority, but fossil fuels will still be relied upon. Despite this, with countries distributing fossil fuels and energy produced by them shifting to green energy solutions, the scarcity of these resources will result in a fluctuation of availability, and thus prices drastically vary. This challenge is likely to subside as other metals become suitable for energy storage solutions, such as cobalt and other rare minerals including iron-nitride super magnets, and magnet-free machines that are currently under development.

### 1.2.6 End-user Awareness & Acceptance

Despite the normalisation of smart grids and adjacent technology in many markets through the likes of smart meters and other technologies, the understanding of the importance of smart grids in relation to environmental benefits, to the potential financial cost savings is still not perfect. Emerging markets will require effective educational approaches from government bodies to ensure that misinformation is combatted. More importantly, understanding how data acquired through smart meters and any other monitoring devices is paramount to ensure acceptance to these technologies is sufficiently high. Regulations surrounding data protection and use vary across countries and regions, and therefore parties beyond utility companies might utilise this data in some form, such as government or law enforcement. Instances like these will likely dissuade a significant proportion of the population from accepting smart meters for their homes, and as a result, countries must find a compromise to how data is utilised. In addition to these, acceptance can be increased through collaborative partnerships, such as through community engagement in the decision-making process and addressing concerns.

## 1.3 The Benefits of Smart Grid Deployment

Despite the challenges the market faces, there are plenty of benefits to smart grids that warrant persevering through the obstacles. 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.

### 1.3.1 Reduction in Financial Cost

The cost for electricity can vary for a multitude of reasons, but are typically a reflection of the cost to build, finance, maintain, and operate generation facilities and electricity grids. Following this, the actual cost of electricity for power companies varies by the minute, based on wholesale energy market prices, the cost of demand, and production, which is affected by season, weather, and even time of day.

With this in mind, smart grids and the presence of smart meters in end users' homes means that many have the option to enrol in a variety of pricing plans that allow users to control how much electricity they use at different times of the day or week. By choosing when and how much electricity is used, users are able to effectively budget without sacrificing cost or convenience. For example, a household might subscribe to a time-of-day rate plan, where the energy provided to the household from the grid shifts accordingly, such as during off-peak times. This does not only reduce cost for end consumers due to receiving energy during off peak, but also for utilities by reducing strain the grid would otherwise experience. Alternatively, a standard subscription plan also differs from a traditional flat-rate plan. Consumers pay a flat price each month a year regardless of how much energy is used. This kind of plan is beneficial to those who might consistently exceed average energy usage, but is designed for convenience first and foremost. Beyond end users, utilities are able to save money through the aforementioned reduction of grid strain as a result of users switching when they use the bulk of their electricity needs. However, automation systems within the grid network itself are able to facilitate with reduction costs. For example, aspects such as automated detection of faults in real-time allows for efficient fixes for the problem, reducing downtime and therefore unnecessary costs to utilities.

### 1.3.2 Added Consumer Control & Engagement

The added control that consumers have in regards to how they utilise electricity when connected to smart grids is in itself a positive relative to traditional power distribution. Not only is added control capable through the selection of what kind of payment plans end users utilise for electricity consumption as previously mentioned, but the ability to see real-time data for electricity usage means that users can feel like a direct part of the distribution network rather than simply an end user that solely receives it. Utilities that provide end users with real-time data pertaining to their energy use result in a shift in consumer behaviour. Consumers can either be active or passive in their engagement with grid-related services, and the facilitation of active engagement is fostered when perceived control from consumers is greater. Increasing the perceived control in consumers can be enabled by offering solutions and products that users can choose from and dictate the use of these products. This paradigm shift from a purely passive, reactive user to one that is proactive facilitates the idea that users have a greater level of interaction with the larger electrical network, which is true to a degree. However, it is important that perceived involvement in the grid is significantly higher when users are given the resources to make informed decisions of their own, which in turn promotes satisfaction. This phenomenon is backed by research assessing various technologies related to smart grid, meters, and buildings, such as energy storage systems integrated into houses; increasing consumer satisfaction as a result of decreased electricity cost and closer interaction with the electrical grid by utilising one. Not only this, but end users that have installed solar panels are able to put the electricity generated back into the grid so that it can be used for other purposes, which is another benefit to a two-way distribution model with smart grids rather than a traditional grid. Additionally, smart grids are a necessity to meeting energy demands and manage power supply to provide consumer satisfaction in terms of security, reliability, and quality of electricity supply.

### 1.3.3 Improved Power Reliability

The improved power reliability from smart grids has similarities to the benefit of cost savings, but contains enough to distinguish itself from that. The similarities include aspects such as automatic fault detection within the grid and the autonomous rerouting of the power distribution. This means what could have been a lengthy outage is turned into a momentary one. In addition to informing utilities of the problem, smart grids also automatically diagnose issues before sending a service, allowing service personnel to arrive at the site fully prepared rather than having to gauge what equipment is needed first. The reliability of power has also affected smart grids and smart meters. Meters monitor not only the energy used, but the voltage being delivered, which in turn is data that utilities use to ensure their equipment is working as intended.

### 1.3.4 Reduction in Negative Environmental Impacts

Smart grids are capable of significantly reducing air pollution from the electric utility sector, which is especially important given the increasing population sizes in urban areas. The efficiency of tasks completed through the smart grid is significantly greater than traditional electrical grids, which is part of the reason how these reductions in negative environmental impacts are able to occur. This is an important consideration when realising that the reliance on fully renewably sourced electricity is still in development in most countries and regions, and therefore reliance on fossil fuels is still present. Increased efficiency means that fewer carbon emissions are emitted, and thus pollution is decreased.

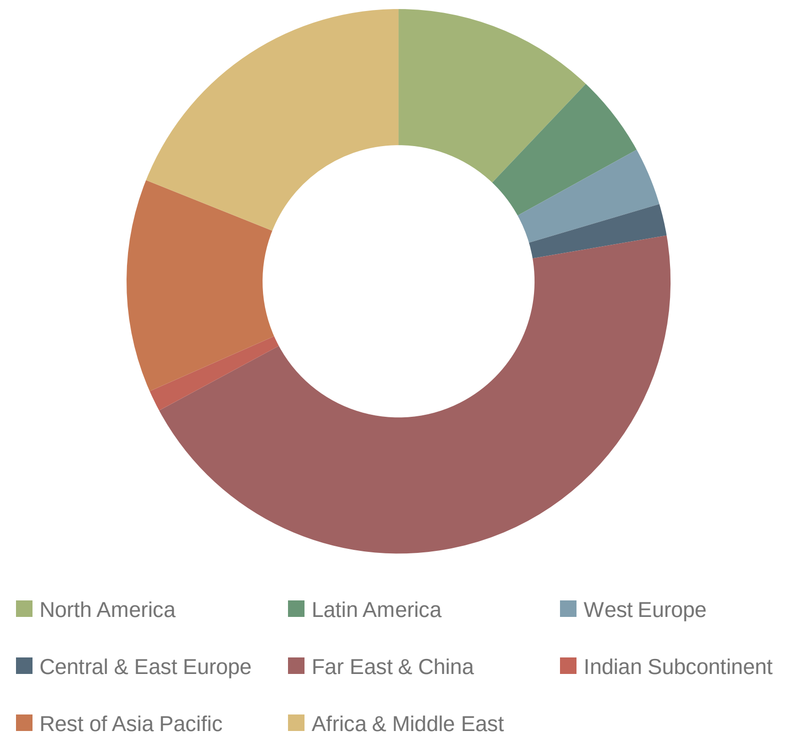
Ultimately, smart grids are not just better for the environment due to integrating RES such as solar, wind, hydro, and geothermal, but how it conducts the transmission and distribution of this created electricity, with added benefits when factoring in multi-pathway transmission from end users too.

## 1.4 Forecast Summary: Total Embedded Finance Revenue

It is forecast that financial savings from energy and emission costs due to smart grids will reach $290 billion by 2029, increasing 249% from $84 million in 2024; benefitting utilities and consumers. This growth is driven by increasing investment in solutions from governments, including the US, China, and Europe, with BESS (Battery Energy Storage Systems) becoming a focal point for the market.

- The market shift to prioritising BESS efficiency and solutions is facilitated by the need to meet climate goals and reduce reliance on fossil fuels. Since renewable energies do not meet current demand, ensuring excess energy is not wasted is crucial for reducing carbon emissions. BESS demand is at an all-time high, and investment in battery research is accelerating at an unprecedented rate, and both of these mean energy storage is pivotal for the immediate and upcoming future of the smart grid market.
- AI (Artificial Intelligence) applications within the smart grid are expanding further, despite AI being used extensively across grid processes. Generative models trained on customer energy data can create scenarios for utilities to develop future grid strategies. For instance, calculating energy output requirements based on houses adopting solar technologies allows utilities to plan future grid investments. Applications such as this have the potential to save utilities even more money due to the reduction of grid burden, more efficient processes, and more.

*Figure 2: Total Smart Grid Energy & Emissions Cost Savings ($m), Split by 8 Key Regions, 2029*




*Source: Juniper Research*

## Order the Full Research

Discover invaluable and perceptive analysis of this fast-evolving market in this latest report. Featuring forecasts to 2029, covering not only smart grids, but smart meters, this research enables stakeholders from utility companies, grid operators, energy companies, and technology manufacturers and developers to understand future growth, key trends, and the competitive environment.

### Key Features

- **Market Dynamics:** Insights into key trends and market expansion challenges within the smart grid market. Addressing challenges posed by hardware and digital technologies relating to electrical grids products and services, ongoing consumer fears regarding security of data, the benefits of increasing regulatory involvement and investment from governments, and how efficient smart grid projects are compared to traditional electricity grids. The research also includes the Juniper Research Country Readiness Index assessing the market readiness and growth across all 60 countries featured in our forecast, plus a future outlook.
- **Key Takeaways & Strategic Recommendations:** In-depth analysis of key development opportunities and findings within the smart grid market; accompanied by strategic recommendations for stakeholders.
- **Benchmark Industry Forecasts:** The business overview into financial service providers includes forecasts for total revenue of smart grids and smart meters. A plethora of additional forecasts are included for both the smart grid and smart meter markets.
- **Juniper Research Competitor Leaderboard**: Key player capability and capacity assessment for 20 smart grid vendors via the Juniper Research Competitor Leaderboard, featuring market size for key players in the smart grid market.

### What's in this Research?

1. **Market Trends & Strategies:** Detailed analysis and strategic recommendations for the smart grid market; analysing the various segments of the smart grid market, and a Country Readiness Index assessing how each country stands in terms of their respective smart grid landscapes.
2. **Competitor Leaderboard:** In-depth analysis of 20 vendor capabilities, via the Juniper Research Competitor Leaderboard (PDF).
3. **Data & Forecasts:** The forecast suite features a summary of smart grid and smart meter markets. The forecasts include revenue, energy and costs saving potentials due to smart grids, smart meter shipments, smart meters in service, and many more, with the forecast period spanning from 2024 to 2029.
4. **Interactive Forecast Excel:** Highly granular dataset comprising over 21,000 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 (ONLINE).

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