Smarter Grids

Powering decarbonisation through technology investment

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Contents

Foreword

Energy transition is a critical imperative facing countries as they chart a course towards actualising their net zero ambitions. In the short term, energy security continues to be an important issue amid an inflationary economy and ongoing geopolitical uncertainties. In the medium to long term, countries need to address the energy trilemma of security, affordability and sustainability.

Energy independence and the need to decarbonise the economy by transitioning from fossil fuels is a key policy and business opportunity driver. Many countries not only have strategic roadmaps for expanding renewable energy generation, but they are also charting pathways for alternate energy options including green hydrogen and energy storage. These changes have contributed to the renewed urgency to strengthen the grid.

Reducing the carbon intensity of electricity generation and consumption requires additional action beyond renewable energy integration. The introduction of advanced technologies allows the grid to run more efficiently. Improved efficiency means less electricity is deployed towards satisfying the same energy demand profile. This in turn leads to emission reduction from power generation. The integration of smart technologies into the grid system, such as artificial intelligence-based data aggregation, is at the core of smart demand-side management and power decentralisation.

The electric power industry is now catching up to the level of digital transformation that has permeated the communications industry due to the integration of advanced communication systems into the grid. This technology forms the bedrock of the smart grid revolution, allowing the grid to adapt quickly to the growing diversity and disparity in the energy mix across continents.

Billions of dollars are being invested in smart electricity grids, including in the research and development of smart grid technology. The expansion of renewable energy (RE) assets is intricately linked to the growth of smart grids investment across the globe. In 2022, China accelerated smart grid investment with the State Grid Corporation of China (SGCC), budgeting more than RMB500 billion for ultra-high-voltage projects, increasing the digitisation of its grids and upgrading the distribution network's ability to cope with China's RE expansion.

This report examines smart grid technology through the lens of deployment strategy, carbon reduction, investment and policy. We hope it provides you with valuable insights and we welcome the opportunity to discuss our findings further.

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Executive summary

Digitisation, decarbonisation and decentralisation are three core benefits of a smart grid. Through advanced artificial intelligence (AI) and cloud technology, a smart grid can enable the bidirectional flow of energy and communication, which helps to promote energy efficiency through enhanced precision in balancing electricity demand and supply, as well as the integration of decentralised energy sources. The combination of these three core benefits ultimately accelerates the decarbonisation of the electric power sector.

This report analyses how smart grid technology enhances the operational and energy efficiency of the grid and better integrates renewable energy (RE), resulting in a significant reduction in emissions. This report evaluates smart grid technologies, the policies that support its implementation and the investments incentivised by these enabling policies.

By focusing on investment flows through country-level case studies, the report analyses how the energy market structure of the UK, China and the US – representing liberalised, vertically integrated and hybrid electricity markets respectively – impact the depth, scalability and adaptability of smart technology into various aspects of the grid. This analysis is made taking into account countries' electric power regulatory structure, national decarbonisation goals and historic emission trajectory.

Key observations from our study include:

Smart grids are revolutionising the power sector, enabling better operational efficiency and integration of distributed energy resources (DER).

Digital transformation in the electricity sector is currently being driven by a number of factors such as rapidly expanding electricity demand, the maturity of advanced technology and a desire to fortify the grid against cyberattacks and physical damage. Climate change and the associated need to efficiently incorporate more RE into the energy mix has also provided momentum. Smart grids integrate digital and cyber infrastructure to enhance the performance of the system's sensory, communication, data management and security functions. The ultimate goal in implementing such systems is to ensure a more efficient, green, resilient, clean, affordable and reliable grid.

The focus of energy savings and grid efficiency continues to shift from consumer power saving and behavior modification to an AI and data-enabled grid demand response.

Studies show that population growth in various markets across the globe is causing electricity demand to continue to trend upwards. This in turn has an impact on the ability for jurisdictions to strive towards climate change goals. While energy transition remains the primary goal, energy efficiency has been identified as a significant source of potential emissions reduction in the power sector. The International Energy Agency (IEA) projects that countries with well-developed policies that support energy efficiency in grids could save up to 15% of their total electricity generation.[1] Smart grids are increasingly improving operational efficiency through enhanced precision in Demand Side Management (DSM).

Electricity consumers have more autonomy because of smart meters, photovoltaics (PV), vehicle to grid (V2G) and microgrids.

Consumers increasingly have access to more information about their energy use and sources. This information enables them save energy and contribute to energy efficiency. Consumers can also generate additional revenue by participating in electricity supply as "prosumers". This flexibility is especially important for industrial consumers, who are levied with increasing emission costs and taxes, and are exploring pathways to reduce the carbon intensity of their production processes. The advancement of RE integration through PVs, battery energy storage systems (BESS) and microgrid technology provides a clear path towards reducing the carbon intensity of industrial processes.

The advancement of the Internet of Things (IoTs) and blockchain are shaping the evolution of smart grid technology.

Intergovernmental alliances and innovation institutes such as the International Smart Grid Action Network (ISGAN), are working to develop technology that enhances the consumer experience and bridges the communication gaps between energy supply and demand. However, technology segregation remains an issue. As this technology matures, public entities, consumers and third parties will have increased capabilities to interact with the grid. The integration of IoT in areas such as V2G and microgrids enables peer-to-peer trading of electricity (prosumerism). Digital enhancements in remote lighting, heating and cooling in places like malls, airports and even homes, will also help to cut down emissions and provide more consumption data that is essential to DSM.

Smart grids, which are typically funded by governments, institutional investors and other private investors, are increasingly benefitting from sustainable finance and carbon reduction regulations.

In 2021, climate-tech companies raised a total of $165 billion from global public equity markets and private investors.[2] The market size for smart grid technology in 2021 was $36.9 billion and projected to hit $55.9 billion by 2026.[3] Green and sustainable finance has become a major channel for raising capital for smart grids. For instance, in 2021, carbon neutral bonds issued by State Grid Corporation of China (SGCC) raised RMB15 billion to help finance smart grids projects.[4] SGCC also issues sustainability-linked bonds to source working capital for the repair and maintenance of transmission lines, as well as the management of the grid system.[5] Corporates, policymakers, financial institutions and utilities all have a collective role to play in ensuring the development and scaling of digitised, efficient, low-carbon grids.

Smart grid investment has thrived in liberalised, hybrid and vertically integrated electricity markets, however market features impact growth in certain aspects of the grid.

Investment in grid technology is tied to broad national strategic decarbonisation goals and access to finance. The highest levels of grid investment, advancement in grid technology and deployment of grid infrastructure currently exist in the UK (and generally across Europe), the US and China. However, electricity market features can cause several aspects of the grid to advance faster than others. For instance, China has invested significantly in ultra high voltage (UHV) transmission lines that span longer distances and integrate more RE, while markets like the UK promote consumers' flexibility in supplier choice , enabling the wide deployment of smart meters. In the US, cutting-edge innovation driven by competition has helped to advance remote heating, ventilation, and air-conditioning (HVAC) systems.

There are differences in the scalability and depth of smart grid technologies being deployed in various markets.

For example, China's vertically integrated electricity market enhances its ability to carry out piloting and testing in designated controlled zones and upscale the implementation of advanced transmission and distribution (T&D) technology. As a result, we see China's UHVDC T&D projects expanding even beyond its borders. In markets like the UK and US, competition is driving technology innovators to develop more and more advanced digital grid products. In contrast, less competition in markets that are more vertically integrated can impact the depth of technological advancement in those markets.

COVID-19 impacted investment in grid infrastructure and smart meters

The impacts of COVID-19 rippled through every aspect of the global economy and the electric power industry was no exception. Lockdowns caused supply chain issues that impacted the viability of new projects and the pace of existing ones. As parallels are drawn between this and the investment downturn in smart grids, it is also acknowledged that investment in this infrastructure is long-term, and the structures have an average life span of above 30 years. This indicates that there will be peaks and valleys in the grid investment trajectory.

Introduction

Background

Electricity generation is the largest source of energy-related carbon emissions, accounting for 36% of global emissions.[6] These numbers are expected to rise further with the electrification (including hydrogen production) of hard-to-abate industries, such as shipping, aviation, cement and steel, if cleaner electricity sources are not used. As a result, electricity grids are being upgraded and infused with digital infrastructure that enhances the efficiency, affordability and reliability of electricity. The global effort to address climate change has accelerated the urgency of this transformation.

Improving the energy efficiency of grids has been identified as a large potential source of emissions reduction for the power sector. According to IEA figures, total energy losses across global grid infrastructure led to the emission of around 1 gigaton of carbon dioxide in 2018.[7] An analysis of nine large markets, including China, the EU and the US, reveals how improved energy efficiency standards helped to save about 1,500 TWh of electricity in 2018, equivalent to that year's total generation of wind and solar power in those markets.[8] This not only highlights the extent of energy loss that occurs throughout the generation and transmission process; it also shows the ability of advanced grid technology to mitigate these losses.

Smart grid technology enhances the operational efficiency of the grid and its ability to transmit energy with minimal loss. When developed and scaled, smart grids help address four main challenges facing the power sector: modernisation, decarbonisation, digitisation and electrification.

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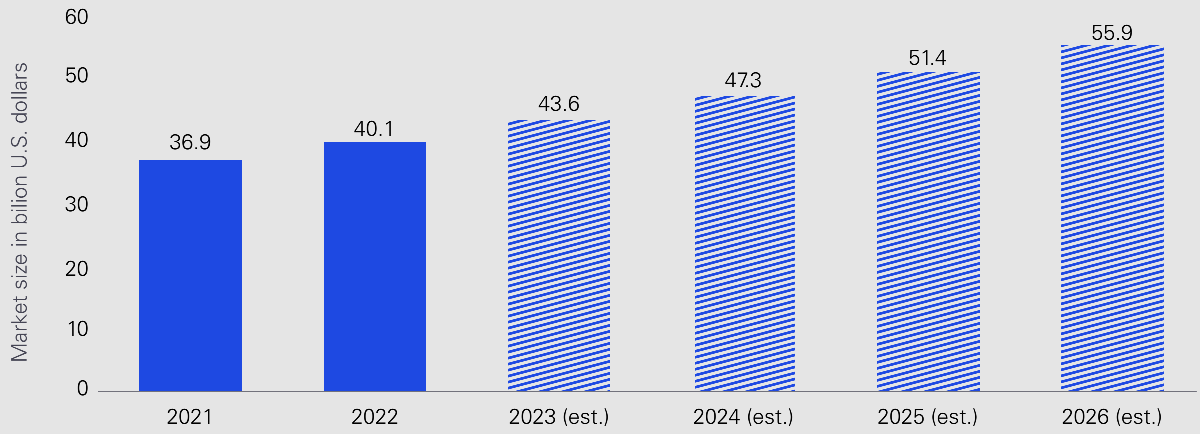
Funding smart grids

Expanding energy efficiency requires a functional synergy between policymakers, financial institutions, electric utility companies, grid technology innovators and consumers. Over the years, there has been substantial growth in smart grid investment, driven by the development of ecosystems that connect climate-tech companies with grid operators, utility companies, governments and sustainable finance with the goal of incentivising grid investment. In 2021, climate-tech companies raised a total of $165 billion from global public equity markets and private investors.[9] The market size for smart grid technology in 2021 was $36.9 billion and projected to hit $55.9 billion by 2026.[10] Part 1 of this report examines the primary smart grid technology available and outlines the considerations for developing an effective implementation strategy.

Figure 1: Smart grid technology market size worldwide, 2021-2026 (forecasted)

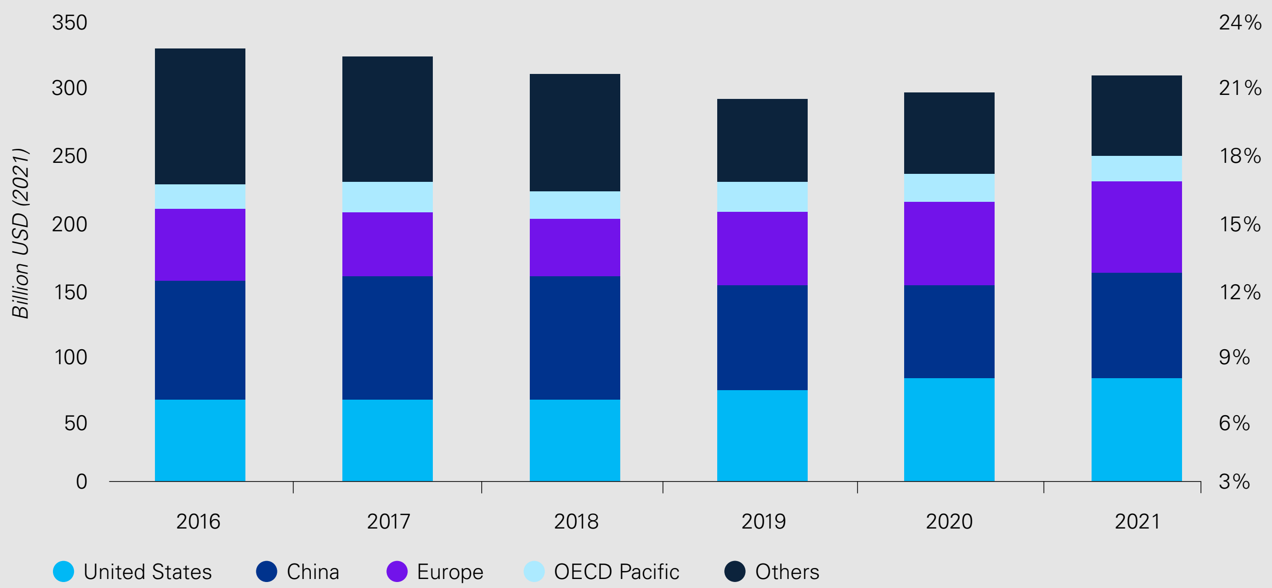


Source: Statista[11]

Analysing smart grids in three key markets

This report assesses the global smart grid outlook from the perspective of three case studies: China, the UK and the US. These three markets combined make up a substantial portion of the global investment in electricity grids (see Figure 2 below). They also represent the three major forms of electricity markets, namely liberalised, vertically integrated and hybrid respectively, that can impact the manner, direction and pace of policy and investments. The innovation, policy and implementation journeys in these markets are generally applicable to similar electricity markets in other jurisdictions.

Figure 2: Investment spending in electricity networks by region, 2016-2021



Source: IEA[12]

Smart grids, smart policies

Across global markets, policies are being developed to incentivise smart grid investment and supporting technological advancement. The operational efficacy of the grid is based situation specific issues such as, the age of existing infrastructure, energy mix, national climate goals, tariffs, and energy security, as well as the overall organisation of the electricity market. The challenge for regulators is to develop policies that balance energy security priorities, while incentivising smart grid investment and advancing net zero targets. These policies, as explored in the three case studies, are discussed in Part 2 of this report.

Smart grids, smart partnerships

To create application synergies, policies related to smart grids are typically developed in consultation with relevant research institutes that support the development, validation and roll out of smart grid technology. These include the IEA's International Smart Grid Action Network (ISGAN), the National Institute of Standards and Technology (NIST), the Institute of Electrical and Electronics Engineers (IEEE), GridWise Alliance and the European Research Infrastructure supporting Smart Grid (ERIGrid). These research centres accelerate innovation by providing a repository of cutting-edge research and a technological coalition of several stakeholders.

Meanwhile, in the US, advocacy groups such as the GridWise Alliance draft policy principles that form the basis for identifying, exploring and developing new policies at every tier of government. The group also lobbies the US Congress to boost smart grid investment.[13] In the EU, ERIGrid has created a holistic, cyber-physical systems-based approach through a coalition of 18 European research centres that develop common methods, concepts, and procedures for validating and testing smart grid configurations.[14]

Part 1
Smart grid technology

What makes a grid smart?

Making grids smarter entails the systematic integration of advanced software and hardware technology into an electricity network across the value chain that digitises the monitoring, balancing, decentralisation and the bi-directional flow of information and energy. It also includes AI-enabled security, resilience and repair as well as consumer autonomy, transparency and overall energy efficiency.

Figure 3: Types of smart grid technology

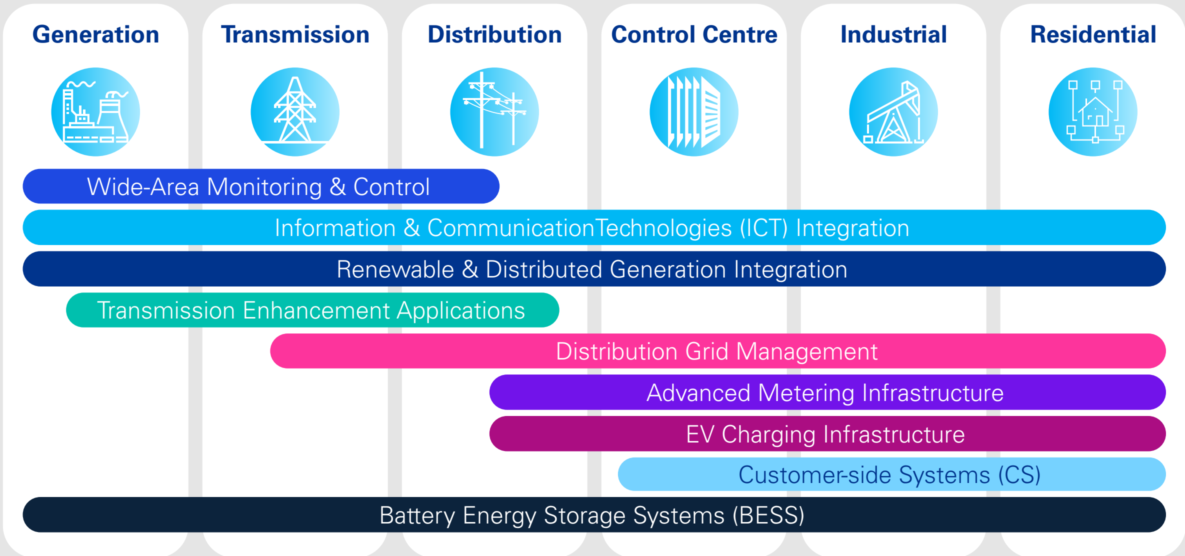
Technology	Hardware	Systems and software
Wide-area monitoring and control	Phasor measurement units (PMU) and other sensor equipment	Supervisory control and data acquisition (SCADA), wide-area monitoring systems (WAMS), wide-area adaptive protection, control and automation (WAAPCA), wide-area situational awareness (WASA)
Information and communication technology integration	Communication equipment (Power line carrier, WIMAX, LTE, RF mesh network, cellular,), routers, relays, switches, gateways, computers (servers)	Enterprise resource planning software (ERP), customer information system (CIS)
Renewable and distributed generation integration	Power conditioning equipment for bulk power and grid support, communication and control hardware for generation and enabling storage technology	Energy management system (EMS), distribution management system (DMS), SCADA, geographic Information system (GIS), Distributed Energy Resource Management Systems (DERMS)
Transmission enhancement	Superconductors, FACTS, UHVDC	Network stability analysis, automatic recovery systems
Distribution grid management	Automated re-closers, switches, breakers and capacitors, remote controlled distributed generation and storage, transformer sensors, wire and cable sensors, hardware (servers, storage etc) for Operational Technology (OT) deployment	Geographic information system (GIS), distribution management system (DMS), outage management system (OMS), workforce management system (WMS)
Advanced metering infrastructure	Smart meter, in-home displays, servers, relays	Meter data management system (MDMS)
Electric vehicle charging infrastructure	Charging infrastructure, batteries, inverters	Energy billing, smart grid-to-vehicle charging (G2V) and discharging vehicle-to-grid (V2G) methodologies
Customer-side systems	Smart appliances, routers, in-home display, building automation systems, thermal accumulators, smart thermostat	Energy dashboards, energy management systems, energy applications for smart phones and tablets

Enabler: Internet of Things (IoT) technology

IoTs are primarily physical objects (or groups of such objects) with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems over the internet or other communications networks. IoT-enabling technologies are typically digital processes, computation methods, or systems that enhance system operation, improve business value, and accelerate technology adoption.

Source: IEA[15], KPMG Analysis

Figure 4: Smart grid technology areas across the electricity value chain

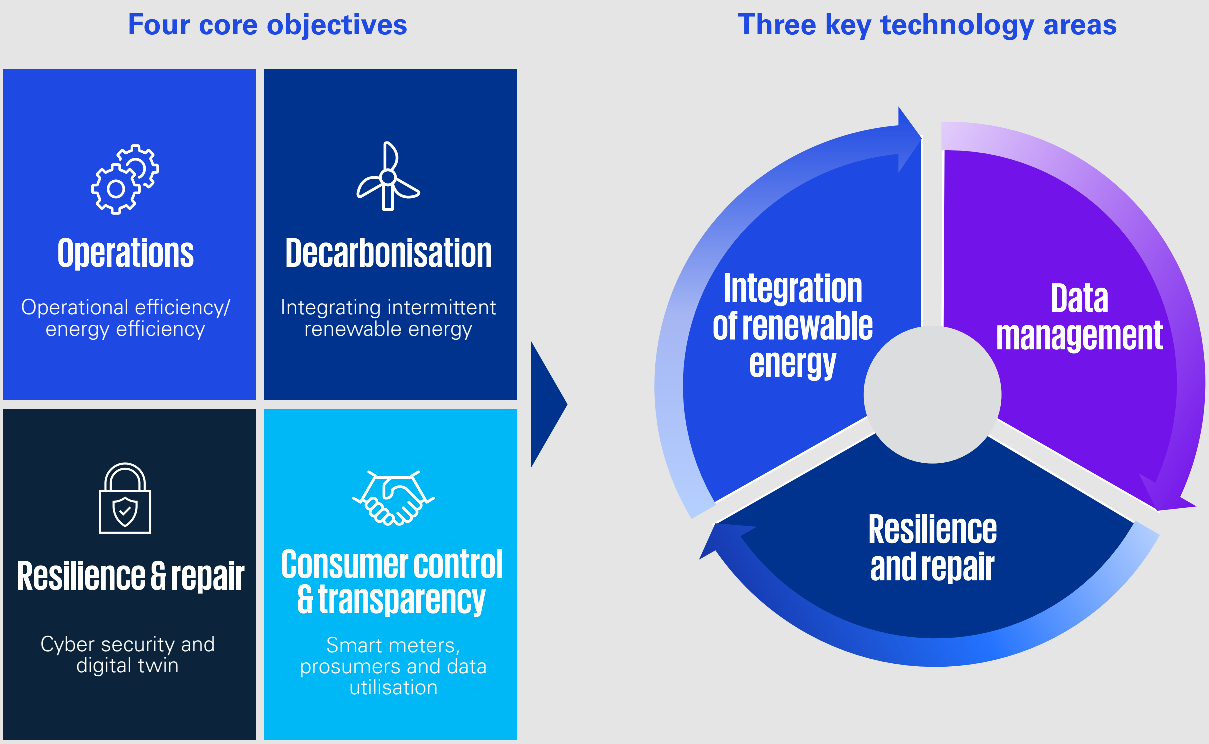


Source: IEA[16], KPMG China

Smart grid technology focus areas

The goal of the digital enhancement of the grid is to achieve operational efficiency, minimise costs and environmental impacts while maximising system reliability, resilience, visibility, flexibility and stability.[17] This report identifies four core smart grid objectives in relation to three technology focus areas.

Figure 5: Four core objectives and three key technology focus areas for smart grids



Source: KPMG China

Integration of Renewable Energy

The International Energy Outlook projects that electricity consumption in non-OECD countries will increase by up to 70% between 2018 and 2050; signifying an upward trend in global electricity demand.[18] RE has been increasingly deployed towards meeting this demand. Global solar and wind energy penetration is projected to increase from 2,300TWh in 2019 to 45,000TWh by 2050.[19] To cope with the exponential growth in electricity demand from conventional and RE sources, technology is improving the ability of the grid to integrate large scale intermittent RE.

Key issue: power loss across long-distance transmission

A growing population, electrification of hard to abate sectors, rural electrification and rapid urbanisation is creating a rise in demand for sustainable and affordable electricity to be transmitted across longer distances.

Power loss along long-distance transmission and a lack of sufficient energy storage systems (ESS) to reduce load cycles are key challenges faced by the industry. The International Energy Agency estimates that total energy losses across global grid infrastructure led to 1 gigaton of carbon dioxide emissions in 2018. Legacy distribution grids (LDGs) typically struggle to accommodate the long-distance transmission of energy from DERs. Typical LDGs cables could cause a significant amount of power loss, occurring in the form of heat across the line.

Enhancing the integration of distributed energy resources (DER), primarily RE, is a major grid target. A Distributed Energy Resource Management System (DERMS) connects individual DERs and helps to optimise and aggregate their operations based on real-time grid conditions fed into the distribution management system (DMS). Essentially, this provides solutions that manage consumption levels of dispersed DERs, either through an aggregator or directly.[20] This harmonises the flow and expansion of RE into the grid. Advancements in extra high-voltage direct current (EHVDC) and ultra-high-voltage direct current (UHVDC) offer an efficient solution to reducing power loss and cost when carrying energy, particularly dispersedly generated energy, over longer distances.

Microgrids allow for the creation of smaller clusters separate from the central grid (decentralisation), providing organisations with greater control of the source and use of their energy. Microgrid users can improve energy efficiency and, with some limitations, operate semi-independently from conventional energy providers. This reduced dependency allows users to reduce costs by curtailing peak usage and reasonably insulate themselves from blackouts.[21] Through IoT technology, advances in microgrids continue to transform electricity distribution and enable greater integration of RE IoT-enhanced microgrids give individual users the platform to accurately monitor their energy use and trade their excess power where permissible. However, building and maintaining microgrids pose some challenges that impact large-scale utility companies and the centralised grid.[22]

Microgrids peer-to-peer trading of electricity elevates consumers to electricity-producer status, i.e., "prosumers". Prosumerism occurs when technology, is used to enable consumers to store and sell excess power.[23] For instance through a blockchain-enabled web-based book-keeping system, residents can make peer-to-peer transactions.[24] Accordingly, prosumers can sell excess generated power back to the grid or to other homes connected to the same grid/microgrid.[25]

Battery energy storage is the most common and accessible Energy Storage System (ESS). Lithium-ion batteries make up 90% of the global grid battery storage market. Battery Energy Storage Systems (BESS) can operate drawing charge directly from the grid typically off-peak or in many cases deployed alongside solar panels.[26] In addition to regulating the intermittency of RE, BESS equipped with anti-islanding protection would isolate BESS from the network during faults.[27] Digitised BESS have emerged as an effective solution to alleviate RE intermittencies.[28]

Electric vehicles storage (EVS) is increasingly part of the smart home concept. Although EVs are not primary sources of storage for the grid, IoT-enabled smart grids and smart homes now integrate EVS as a form of supplementary energy storage, particularly for DER. If connected to the grid, parked EVS has the potential to deliver the energy that is stored in their batteries through the concept of vehicle to grid (V2G).[29] V2G utilises grid integrated EVS reserves to support peak power shaving and voltage frequency regulations.[30] When implemented on a broad scale, large EV fleets connected to the grid can not only alleviate transportation dependence on fossil fuels, but prompt the upgrade of EV technology on the consumer front to accommodate this extended application into DSM.

Resilience and repair

Smart grids consist of a combination of two layers, a cyber layer and a physical layer.[31] The cyber layer consists of the monitoring software and applications. The physical layer, including field devices ranging from smart sensors to remote terminal units (RTUs), are devices that can be used to monitor and control different processes in the grid.[32] Through the support of networking protocols, IoT technologies can quickly identify inefficiencies and damage in the system. This creates new opportunities in data management, ranging from enhanced cybersecurity utilising machine learning (ML) to project models of potential cyber threats before they even happen, to optimising DSM impacting energy prices.

Key issue: advanced monitoring and repair

- The deployment of smart meters, V2G, G2V and other forms of prosumer enablement would have greater implications for Distributed Energy Resource Management (DERM). System adaptation to enhance the monitoring status of the network and its ability to respond and recover quickly from problems such as voltage imbalance, electricity congestion and power outage stemming from DER is essential.
- Grids are increasingly vulnerable to physical and cyber-attacks. These attacks could cause large-scale power outages, threatening communication and national security. The repercussions could include loss of life and significant economic losses.

Grid monitoring is an essential preventative process that ensures the continuous delivery of electricity along the system with reduced risk of downtime.[33] By relaying information from the site to the maintenance monitoring centre (MMC), physical interferences and inefficiencies can be projected onto a digital twin for easy identification of affected areas. IoT technologies provide improvements that centralise the information collected about the health and efficiency of power grids.[34] Once a potential threat is identified, CM software acts to dampen out oscillations in the power grid and reroute power through the grid, avoiding overloading fuses in the power lines.[35] These increases can be done without human intervention, minimising disruptions in the grid.

Advanced grid technology improves the monitoring and control of large grid transmission systems. Phasor Measurement Units (PMU) are developed to sample current and voltage multiple times within seconds. Equipped with communications technologies and IoT, the information is then relayed to the MMC, providing an instantaneous snapshot of the power system at any given time. New software aided by ML can also be used to help decrease unexpected power oscillations, avoiding unproductive flows of current and energy waste, as well as enabling a 'self-healing' smart grid.[36]

The digitisation of smart grids has also enabled the integration of digital twin as a means of increasing power systems adverse climate resilience.[37] Through digital twin technology, information collected from PMUs can be projected in real-time and presented in a digestible manner to resolve inefficiencies. Digital Twins also enable distribution planning models with geographic information systems (GIS) to increase efficiency and accuracy when integrating grid models with data from external sources that cannot be obtained internally, such as weather conditions.[38] Digital Twin technology provides a seamless connection between distribution planning models and external information systems, cutting down the average time needed for model creation of grid systems by 90%.[39]

The vast information and data processed by smart grids requires a resilient secure cyber-physical connection to run its computerised network technology and process the data it collects daily.[40] This data is sensitive and susceptible to cyber threats such as malicious data breaches. More so, bad actors could use breaches to cause substantial disruptions or blackouts. To combat these threats, Human Centric (HC) precautions such as authentication, training and awareness of threats are now insufficient to mitigate these elevated risks. Non-Human Centric approaches (NHC), such as ML, play an important role in detecting and identifying data traffic on a scale that HC approaches are unable to process.[41] ML can be used to model potential attack behaviours based on sets of historical data with high levels of accuracy, and has been a leading alternative in the field of cybersecurity. In terms of smart grids, ML is directly applicable through data analysis of inbound and outbound data traffic of both the cyber and physical layers to create a reconstruction of a data-driven model, identifying and capturing anomalies on both layers.[42]

Data optimisation and management

The digitisation of grid components and assets has resulted in access to vast amounts of data regarding every part of the grid. Using a digital monitoring platform, utility companies can analyse, compare, and evaluate consumers' energy usage, including the time of day, weather conditions and other data to identify patterns, with enhanced accuracy.[43] In particular, predictive weather forecasting enables data companies to more accurately anticipate seasonal energy demand and pre-emptively prepare to meet this demand. This data can also help set goals for RE providers and storage systems, resulting in a more effective usage of BESS to balance the intermittency of RE generation.[44]

Artificial Intelligence (AI) is the driving 'intelligence agent' behind smart grids. Its functions range from maximising energy output to monitoring the natural environment impacting the grid infrastructure.[45] DSM is a pivotal function of smart grids that utilises AI and the data collected in smart grids to maximise their efficiency.[46] As discussed earlier, DSM can be used to ensure the optimum use of power generators, prevent instability and level peaks. The peaks in energy demand can put utility providers under delivery strain. Through AI and smart meters installed in users' homes and offices, algorithms can more accurately predict and anticipate changes in energy demand.[47]

Smart meters improve DSM by providing consumers with close to real-time data on energy usage, alongside pricing.[48] Smart meters reflect the pricing of energy, including during peak periods, so that consumers can control and reduce energy consumption (load shifting) at peak periods, or switch to battery stored capacity (peak shaving) during peak hours. More so, smart meters support vehicle-to-grid (V2G) and grid-to-vehicle (G2V) smart charging.

Key issue: efficient aggregation, management and application of data

- The advanced predictive functions of smart grids are driven by increased data, consumption visibility, flexibility and interaction enabled by devices such as smart meters
- AI and cloud computing enable the effective aggregation, storage and utilisation of data

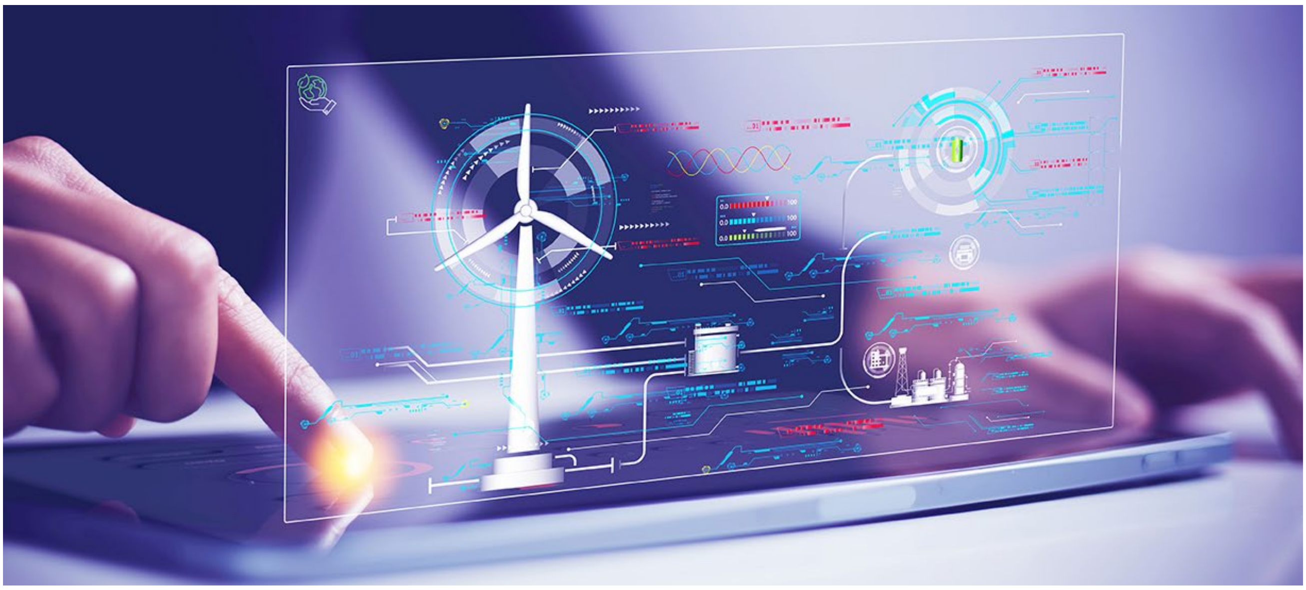
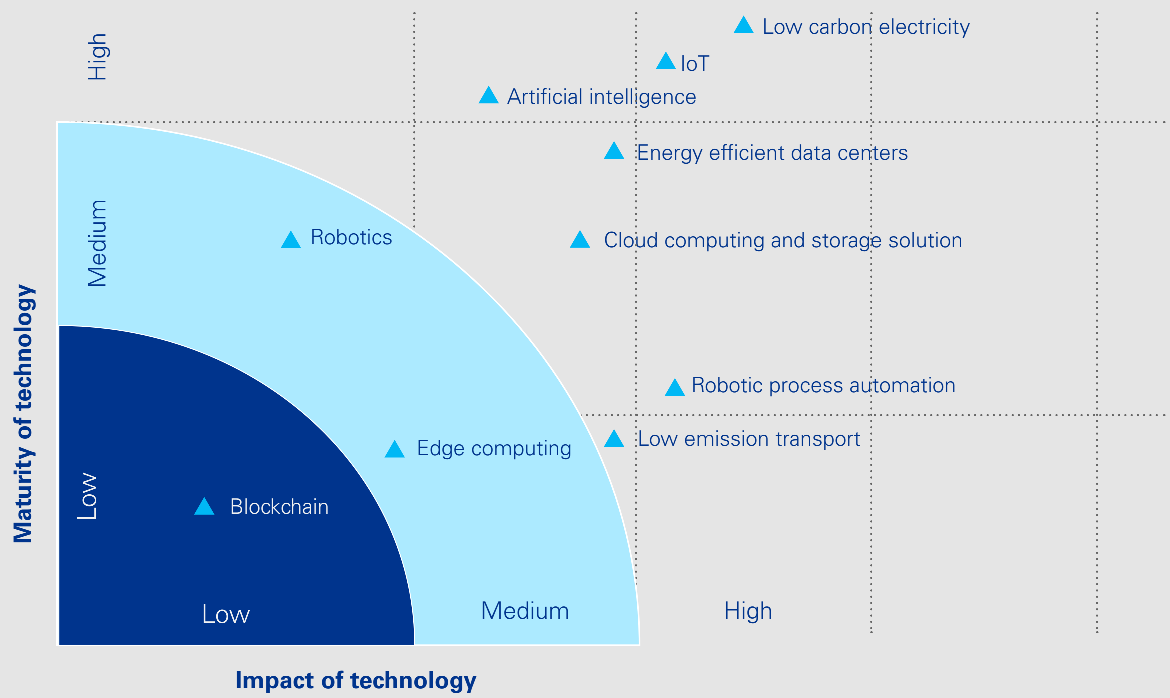


Figure 6: Maturity and impact of enabling technology for smart grids



Source: KPMG

The convergence of energy transition, digital technology and sustainability offer great opportunity for innovation in the power sector. Energy conservation through better demand-side management and integration of renewable energy into the grid are some of the key benefits that can be leveraged by countries across market types through implementation of smart grid solutions.

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Strategy and implementation

A forward-looking smart grid implementation strategy requires collaboration between governments, financial institutions, utility companies and smart grid technology innovators. Efficiently operationalising smart grids would require a multi-stakeholder approach across all phases i.e., from planning to roll-out.

Key issue: navigating smart grid technology integration

- Utility companies are directly impacted by the growth and scale of smart grid technology. Integrating this technology across their value chain would involve outlining an implementation strategy that incorporates internal and external stakeholders. Liberalised electricity markets would require strong policy incentives to drive partnerships between several distinct generation, transmission and distribution companies as well as other stakeholders.
- Decarbonisation and decentralisation attributes of smart grids technology creates a role for banks, asset managers, institutional investors, and corporates. As financial institutions continue to invest in smart grids, they are also encouraged to upgrade their assets with energy efficient retrofits.

Figure 7: Strategy flow for operationalising smart grids

01 Stakeholder mapping and engagement	02 Maturity assessment	03 Planning and Implementation roadmap	04 Pilot and roll-out
Government and policymakers both on a national and district level are key strategy drivers	Assess maturity of smart grid technology already deployed within the interconnection	Technical assessment of smart grid hardware and software to be installed and its integration with existing systems	Depending on the technology, pilots could be conducted in test zones to assess impact
Utility companies (for liberalised markets multiple generation and distribution stakeholders)	Assess maturity of the available smart grid technology in the market ready to be deployed	Assess and initiate change management protocol as it impacts personnel, operations and customers	Define roll-out timetable for instance AMI deployment in sections. Define milestones and contingencies
Interoperability mapping: Connecting hardware and software developers with large infrastructure operators relevant to the grid	Assessment of policy that support investment, tech transfer, product import, cloud hosting and computing	Define and assess installation priorities, such as wide-area monitoring and control systems before AMI	Deploy technology alongside personnel, maintenance, upgrades and service subscription
Cross-sectoral engagement involving manufactures, mass transport sector, large infrastructure operators, smart grid research institutes, grid consultants	Assessment of access to finance such as government subsidies and decarbonisation incentives, sustainable finance such as transition loans and private investment	Develop business case, project plan and define procurement process. outline technology, provider(s), costs, workflow, duration and maintenance/ service subscription	Commence data-based consumer management and commence communications management to all stakeholders
TARGET: Set clear measurable smart grid deployment and development roadmap in line with net zero goals	**TARGET:** A clear understanding of the smart grids implementation landscape from a policy, technology and finance perspective	**TARGET:** Smart grid project plan and change management plan	**TARGET:** Integrate smart grid technology into the grid. Ensuring that the process is efficient, forward looking, dynamic and avoids duplicity and waste

Source: KPMG China

Part 2

Case studies: Markets and regulations enabling smart grid investment

Across global markets, three key factors generally tend to influence the process of raising capital, investing in and upscaling smart grid infrastructure:

- The decarbonisation goals of a country, territory or jurisdiction and its net zero implementation strategy;
- The regulatory structure and character of the Electricity market;
- Access to capital and technology from both the public and private sectors;

In this section, the above factors will be discussed in three case studies that represent the three electricity market structures most prevalent across global markets: vertically integrated (China), liberalised (UK), and hybrid (US).

China – Vertically integrated electricity market

Background

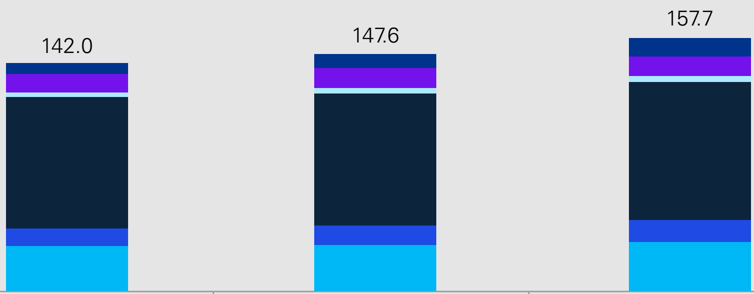
With ambitions to reach peak emissions by 2030 and achieve carbon neutrality by 2060, China has set policy objectives to scale down the consumption of coal and fossil fuels and integrate more renewable energy into its energy mix.

In pursuit of these goals, China has rolled out several national policies across all sectors.[49] These included improving energy efficiency in the electric power sector, strictly controlling fossil fuel consumption and phasing down coal by the 15th Five-Year Plan.[50] These objectives, among others, are contained in the "Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy (Working Guidance)" and the "Action Plan for Reaching Carbon Dioxide Peak Before 2030" rolled out in 2021.[51]

As of 2021, China was able to grow energy from wind and solar farms to reach 290 million kW (a 34.6% increase) and 260 million kW (a 24.3% increase) respectively.[52] At the start of 2022, China's installed capacity of renewable energy totaled 1.06 billion kW, accounting for 44.8% of total installed power generation capacity.[53]

China has developed smart grid technology that has been widely deployed across the country. Projects include the database power system built by China Southern Power Grid (CSG) that connects power supply information to grid, load and energy storage information.[54] This enhances DSM and energy efficiency.

Figure 8: China's total primary energy consumption, along with bifurcation by fuel



	2019 (exajoules)	2020 (exajoules)	2021 (exajoules)
Renewables	6.8	8.5	11.3
Hydro-electricity	11.3	12.5	12.3
Nuclear energy	3.1	3.3	3.7
Coal	81.8	82.4	86.2
Natural Gas	11.1	12.1	13.6
Oil	27.9	28.7	30.6
Total	142.0	147.6	157.7

Source: BP, BP Statistical Review of World Energy 2022[55]

China's investments in its transmission and distribution network support the transfer of higher amounts of green energy across provinces and regions, while mitigating transmission loss. As a result of these improvements, China's transmission loss was reduced from 6.31% in 2010 to 5.26% in 2021.[56] In 2020, the State Grid Corporation of China (SGCC) built the world's first VSC-HVDC grid project in Zhangbei, realising flexible DC transmission with a total capacity of 9,000 MW to support a more stable supply of multi-type clean energy. Its four terminals allow capacity to be maximised by collecting clean power from Zhangbei and Beijing, and regulating fluctuations of wind energy with local pumped-storage hydropower from plant in Fengning.[57]

Another major T&D project is the 2,383 kilometres Jiuquan - Hunan ±800kv UHVDC transmission line built to transmit solar and wind energy from farms in Gansu Province. Gansu, in the northwest of China, is now capable of delivering green energy generated from its wind and solar resources eastward to consumers in Hunan Province through the Jiuquan - Hunan ±800kV UHVDC transmission line. This line, commissioned in 2017 by SGCC, travels more than 2,383 kilometres.[58] The Gansu Dispatching Center measures and tracks real-time data on energy generation to efficiently distribute energy and minimise transmission loss along the lines.[59]

China also plays an active role in international collaboration on smart grids. This extends beyond its borders in line with its pledge to support clean energy along the Belt and Road by helping developing countries combat climate change.[60] For instance, SGCC has built UHVDC transmission lines in Brazil to help energy be transferred more efficiently and safely.[61] China is also involved in the Asia Super Grid (ASG), initiated in 2017 by the Renewable Energy Institute in Japan. Although this project is at a very early stage, ASG aims to share the RE among different Asian countries to secure mutual benefits. China plans to contribute to the 366km submarine power cable that will transmit energy to South Korea and Japan.[62]

China plans to reduce national energy consumption by 13.5% per unit of GDP by 2025 according to its 14th Five-Year Plan. To achieve these goals, smart grids have attracted significant attention. In particular, the 'smartening' of rural grids are a great opportunity for green investment that aligns with China's national and global decarbonisation goals.

Frank Mei
Partner, Head of Risk Consulting, KPMG China

Evolution of China's energy market

Although China's energy market has several players across all streams, the market is primarily dominated by state-owned enterprises (SOE) and comprehensively regulated. As of 2020, SOEs were responsible for 90% of energy generation and almost all of the T&D infrastructure is owned by the state.[63]

Two major market reforms have facilitated China's transition into a vertically integrated market. Before 2002, State Power Corporation (SPC) was the only utility corporation and owner of all grid infrastructure in China. Its control of the entire energy sector, from generation to electricity price setting, resulted in operating inefficiencies, low generating capacity and inefficient demand side response. Rural areas in particular suffered from supply shortages and infrastructure that was highly vulnerable to natural disasters.[64]

In 2002, the government issued Document No.5, a power system reform scheme that aimed to separate SPC into five generation companies, two grid companies and four power service entities. An energy market emerged following the introduction of competition between generation companies in selling electricity to State Grid Corporation of China (SGCC) and China Southern Power Grid (CSG), the two major grid enterprises. The State Electricity Regulatory Commission (SERC) was established to serve as the policy maker and regulator of the market.

However, this reform also brought challenges which affected the market and consumers. The reformed pricing mechanism led to high electricity costs for consumers, particularly industries. The National Development and Reform Commission (NDRC) set high on-grid prices reflected by the generation companies. Local government control resulted in suboptimal power system planning across provinces.[65]

The State Council issued a second major reform in 2015 under Document No.9 to increase the transparency of the pricing mechanism, develop more integrated power system planning and encourage higher utilisation of RE.[66] The reform has increased competition in the distribution and retail market and enhanced overall energy efficiency. Generation companies can sell power to grid enterprises at a transaction price directly negotiated between the generation companies and consumers, therefore significantly lowering the electricity price within a transparent pricing mechanism.

Reliable electricity is critical to economic growth, especially when the world is accelerating its transformation to the digital economy. China generated over 8,500 TWh of electricity last year, accounting for 1/3 of global output. China joins the rest of the world in the transition to greener and more efficient electricity production and transmission through its advancement in smart grid technology. This is certainly a major trend to watch.

Kevin Kang
Chief Economist, KPMG China

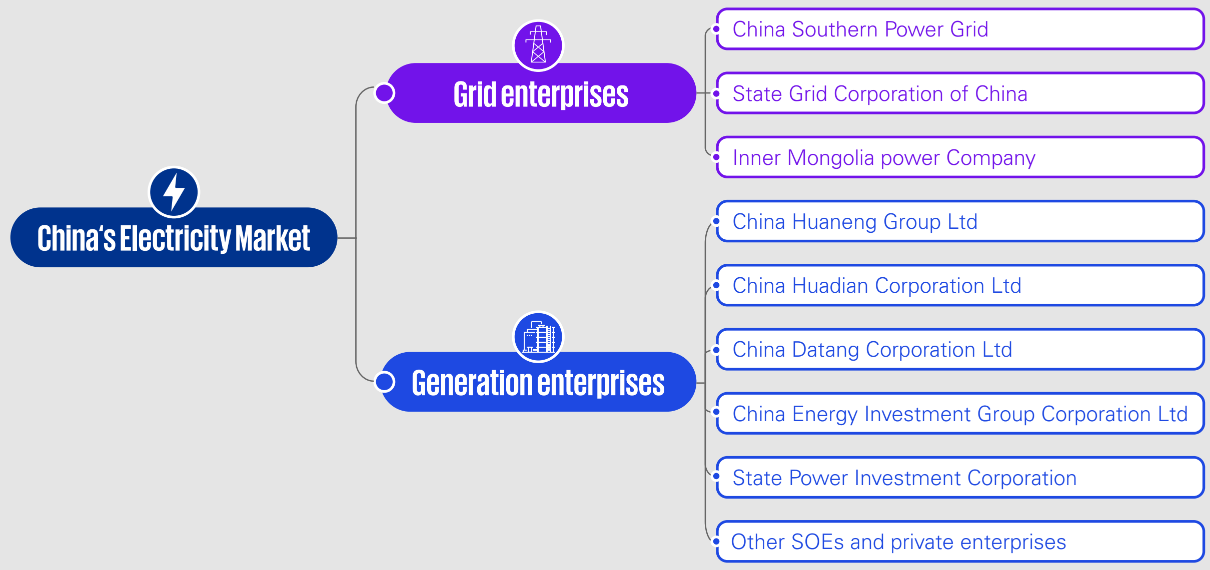
Regulation and investment

Key players

All the key players in generation and T&D are SOEs. The big five SOEs account for about 45% of generation capacity, with another 45% held by four smaller SOEs along with several provincial SOEs.[67] In terms of T&D, transmission is almost 100% state-owned. The percentage is primarily shared between SGCC, CSG and Inner Mongolia Power Company (IMEP), with SGCC holding more than 80%.[68] These three key players also dominate the distribution sector. Advances in DSM and RE has fostered some development of prosumers, leading to a growing share of independent power supply.[69]

The biggest market player, SGCC, has been increasing its investment in electricity networks and transmission lines over the years. SGCC has upscaled the development of smart grid compliant UHVDC and flexible AC transmission lines. In distribution, the advancement in smart grid infrastructure has fostered DSM, which will facilitate the expansion of EVs, V2G and smart meters.

Figure 9: Key players in China's electricity market



Source: KPMG China

Key investors

SGCC is the country's biggest investor in smart grids with several projects and research institutes. In addition to government support, SGCC issues carbon neutral bonds to help finance these projects. In 2021, three periods of carbon neutral bonds were issued.[70] The bonds raised RMB15 billion to finance three projects. SGCC also issues sustainability-linked bonds to source working capital for the repair and maintenance of transmission lines, as well as management of the grid.[71]

Key regulators

The government retains a considerable degree of control over China's energy market through a series of regulations. In addition to national energy laws enacted by the National People's Congress (NPC), the NDRC under the State Council coordinates energy planning with the national development strategy. It primarily formulates economic and social development plans, managing investments in energy, setting energy consumption targets and controlling energy prices. The National Energy Administration (NEA), under the NDRC, formulates and implements key energy policies and development planning for the energy sector.[72] It is also the main regulatory body for approving energy investment projects and proposing market reform and fiscal spending to the NDRC for authorisation.[73] In addition, the State-owned Assets Supervision and Administration Commission (SASAC), under the State Council, administers all SOEs and state-owned assets across the energy sector.[74]

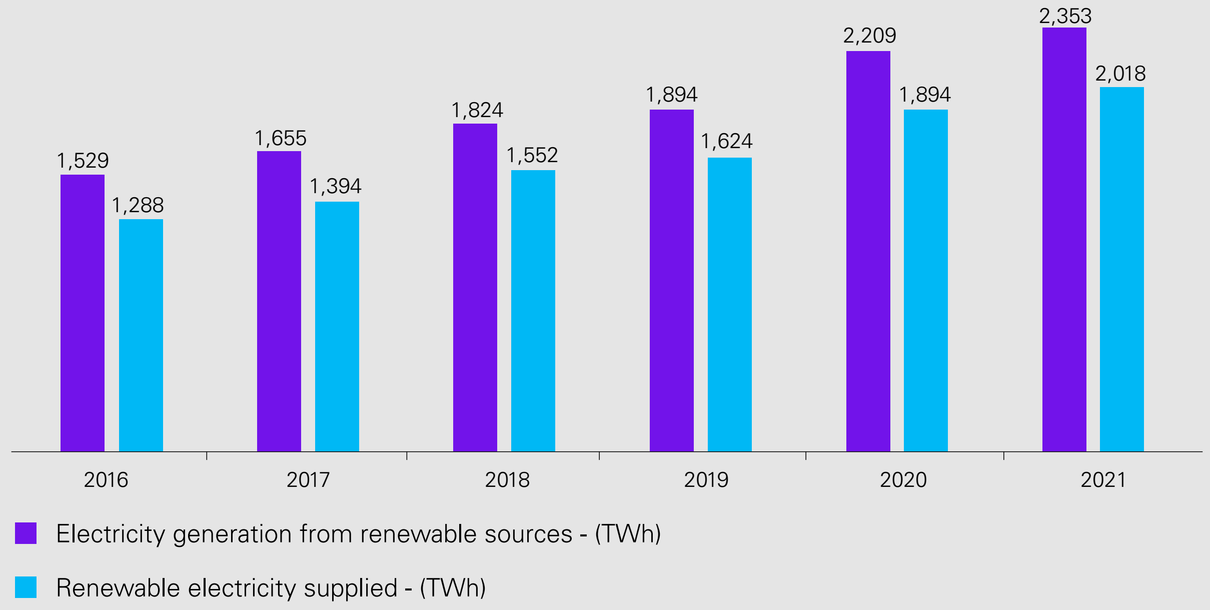
Government and financial regulators also play an essential role in supporting the growth of China's green finance sector through building a unified classification system or taxonomy.[75] In 2021, a domestic taxonomy, the "Green Bond Endorsed Project Catalogue", developed by the People's Bank of China (PBoC), the NDRC and China Securities Regulatory Commission (CRSC), came into effect as the unified principles and criterion for green projects.[76] Also, the China-EU common ground taxonomy developed in 2021 is recognised in both jurisdictions. In addition, initiatives to strengthen the authenticity and reliability of green bonds have been enforced to prevent "greenwashing". In 2021, the Green Bond Standards Committee released Operational Rules for Market-Based Assessment and Certification Institutions for Green Bonds, China's first regulations on third-party green verification to ensure a standardised, transparent evaluation of green bonds.[77]

Impact on smart grid investment

Greater regulation of China's green finance market has resulted in greater access to green bonds and other financial tools, which is critical for enabling China to achieve its carbon neutrality goals more efficiently. In 2021, China became the second largest issuer of green bonds, following the US, with the total value of green bonds issued reaching $68 billion.[78] An increasing interconnection between domestic and international policies has allowed faster growth of a more transparent, standardised green bond market, enabling key players to attract private investments through various financing tools. CSG raised over RMB1 billion by selling 84.7 million shares on the Shanghai Stock Exchange in December 2021.[79] The variability within the vertically integrated structure allows for some inflow of private investments to support smart grid development.

Energy consumption, emissions and the role of renewables

Figure 10: China's electricity generation and transmission from renewable sources

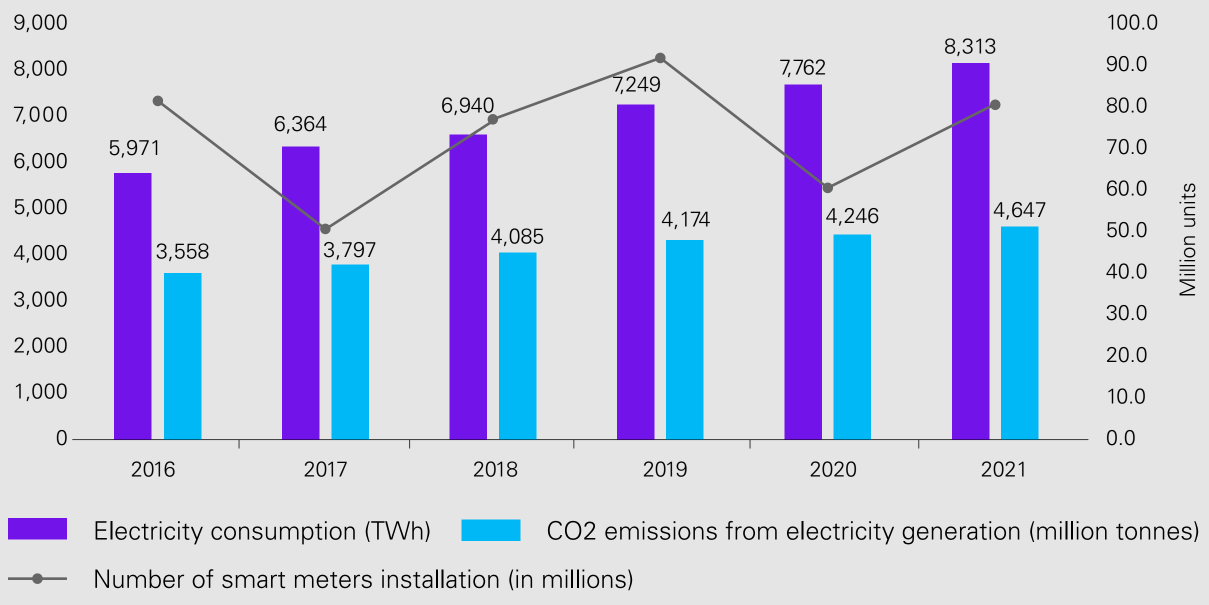


Source: EIA and China Energy Portal, KPMG China Analysis[80]

In line with its national net zero strategy, China has significantly grown its capacity to generate and transmit RE. This growth has been steady and is projected to continue as RE attracts more investment.

Although the total amount of renewable energy supplied increases annually, it is unlikely that China's total electricity consumption (see Figure 11 in the next page), which shows steady growth, can be satisfied primarily by RE in the immediate future. Essentially, a RE growth rate of 9.4% is not expected to meet a power consumption growth rate of 39%. This indicates that in the coming years, China will continue to rely on fossil fuels to meet its energy needs.

Figure 11: China's GHG emissions with respect to electricity consumption

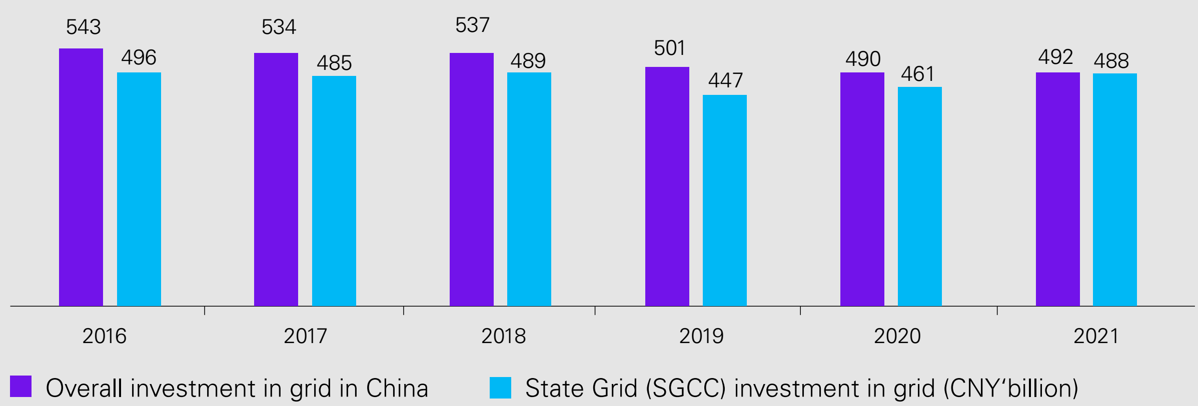


Source: China Electricity Council and AskCI, KPMG analysis[81]

As electricity consumption grows annually, an annual increase in CO_2 emissions from electricity generation is also anticipated. However, the amount of CO_2 emissions generated in relation to electricity consumption per TWh in 2021 (0.56 MT CO_2 per TWh) is below 2016 levels (0.59 MT CO_2 per TWh).

Although the substantial decline in smart meter installation in 2020 could be attributed to the economic downturn caused by COVID-19, the sharp recovery in 2021 is a result of the investment and economic recovery from the start of the 14th installment of China's Five-Year plan (2021-2025).

Figure 12: China's investment in grid



Source: China Electricity Council and SGCC[82]

SGCC is the largest electric utility company in the world. Consequently, with its dominant position, SGCC accounts for 93% of China's total investment in grid infrastructure. While the slight decline in 2020 is attributed to the economic downturn caused by the pandemic, the 2021 numbers show some recovery in investment.

China is one of the largest investors in T&D globally, with a total investment of RMB492 billion ($69 billion) in 2021. This enables the country to continue to upscale advanced grid technology both domestically and overseas.

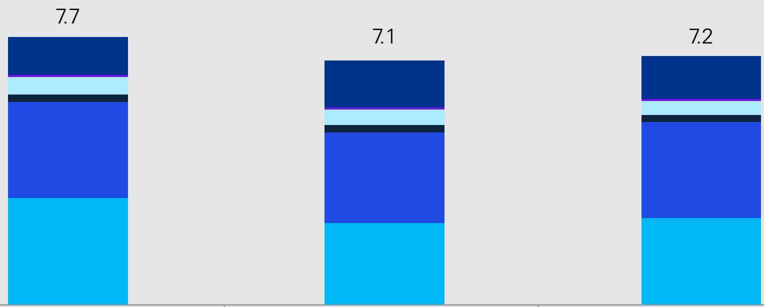
United Kingdom – Liberalised electricity market

Background

The privatisation and subsequent reform of the energy sector in the UK in the 1990s created a liberalised Great Britain (GB)[83] energy market. This energy market connects England, Wales and Scotland, excluding Northern Ireland.

Achieving energy security alongside a low carbon economic transition is at the core of the UK's ambitious goal to reach net zero by 2050 and peak emissions in the power system by 2035.[84] Achieving this will involve big changes in the way the UK supplies and uses energy.[85] These changes include adopting and scaling smart energy saving technologies, such as heat pumps, EV, smart meters, smart appliances etc.[86] With these goals in mind, there is still a significant portion of fossil fuel in the UK's energy mix.

Figure 13: Total UK primary energy consumption, along with bifurcation by fuel



	2019 (exajoules)	2020 (exajoules)	2021 (exajoules)
Renewables	**1.1**	**1.4**	**1.2**
Hydro-electricity	**0.1**	**0.1**	**0.1**
Nuclear energy	**0.5**	**0.5**	**0.4**
Coal	**0.2**	**0.2**	**0.2**
Natural Gas	**2.8**	**2.6**	**2.8**
Oil	**3.1**	**2.4**	**2.5**
Total	**7.7**	**7.1**	**7.2**

Source: BP, BP Statistical Review of World Energy 2022[87]

With the Climate Change Act 2008[88] and the announcement of the net zero targets in 2019[89], the UK became the first major economy in the world to pass laws to ensure the country ends its contribution towards global warming by 2050. The government identified three ways to help achieve this target, namely incentivising investors to choose low carbon initiatives, getting consumers to choose low carbon options, and improving energy efficiency.[90]

The British Energy Security Strategy reiterates the UK's vision to produce 95% of its electricity from low carbon sources by 2030. In 2022, National Grid reported that renewable energy (RE) currently makes up around 32% of electricity generation in Great Britain.[91] It included generation targets for 50GW of wind by 2030, 70GW of solar by 2035, and an additional 24GW of nuclear by 2050.[92] The government anticipates that liberalisation would best position the UK to implement the most cost-efficient pathway towards decarbonisation.[93]

To encourage consumer participation and the use of low carbon technologies, the government has implemented demand-side measures to establish industry confidence in both the feasibility and profitability of decarbonisation. This creates structures that support consumers opting for low carbon energy saving options.[94]

Evolution of the UK Energy Market – Focusing on Great Britain

The Electricity Act of 1989 put the UK on the path to liberalisation. The Central Electricity Generating Board, which owned the generating assets in Great Britain, was split into new companies, which were subsequently privatised. The transmission assets in England and Wales were transferred to National Grid, while those in Scotland were transferred to Scottish Power and Scottish Hydro Electric.

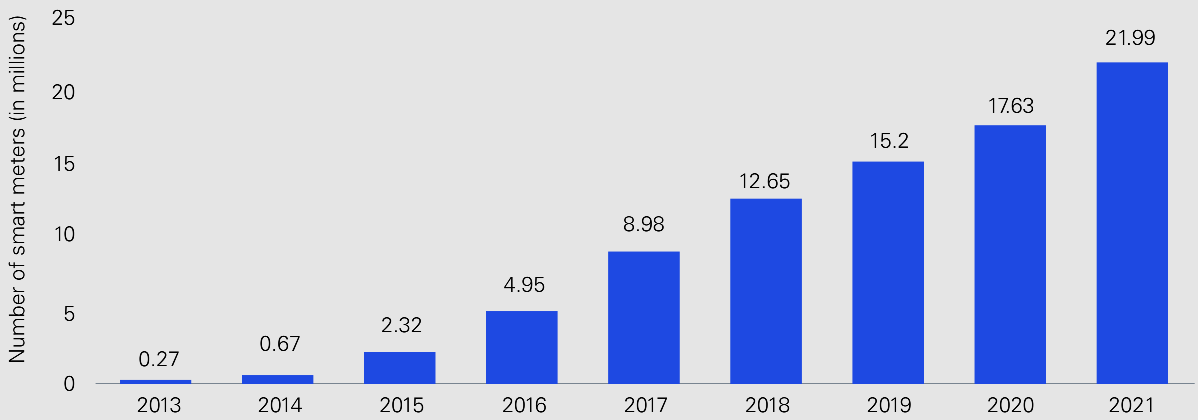
These three transmission network owners are licensed by the regulator Ofgem (the Office of Gas and Electricity Markets) to own and operate the electricity transmission system. They are responsible for new connections, as well as maintaining the infrastructure that facilitates large power flows around the country, from power stations and renewable generators to demand zones.

The 14 licensed distribution network operators (DNOs) responsible for maintaining the lower voltage substations are owned by eight different companies. These DNOs are each responsible for specific regional areas and operate as geographical monopolies. There are several independent DNOs (IDNOs) operating smaller networks within the DNO areas. There are multiple active energy suppliers that purchase energy at wholesale prices and trade the volume by breaking up the supply into multiple contracts to consumers. This offers UK consumers several suppliers to choose from and gives them the flexibility to change suppliers to reflect both their low cost and low carbon preferences.

Liberalisation in the retail market not only provides flexibility for customers to change electricity suppliers, it also restricts vertical integration by ensuring transmission and distribution are independent from generation and supply entities.[95] The unbundling requirement (part of the EU third energy package now transposed into UK law) generally increases competition.[96]

As the UK continues to reduce power generated from coal and gas and expand the integration of renewable energy sources, the grid system in Great Britain is evolving to meet these demands. The country's liberalised market has several attributes that impact its ability to develop and scale smart grid technology; liberalisation also affects which part of the grid gains accelerated operationalisation and policy-stimulated investment. As a result, smart meters have seen growth in deployment.

Figure 14: Number of domestic smart meters in operation in Great Britain from 2013 to 2021 (in millions)



Source: Statista[97]

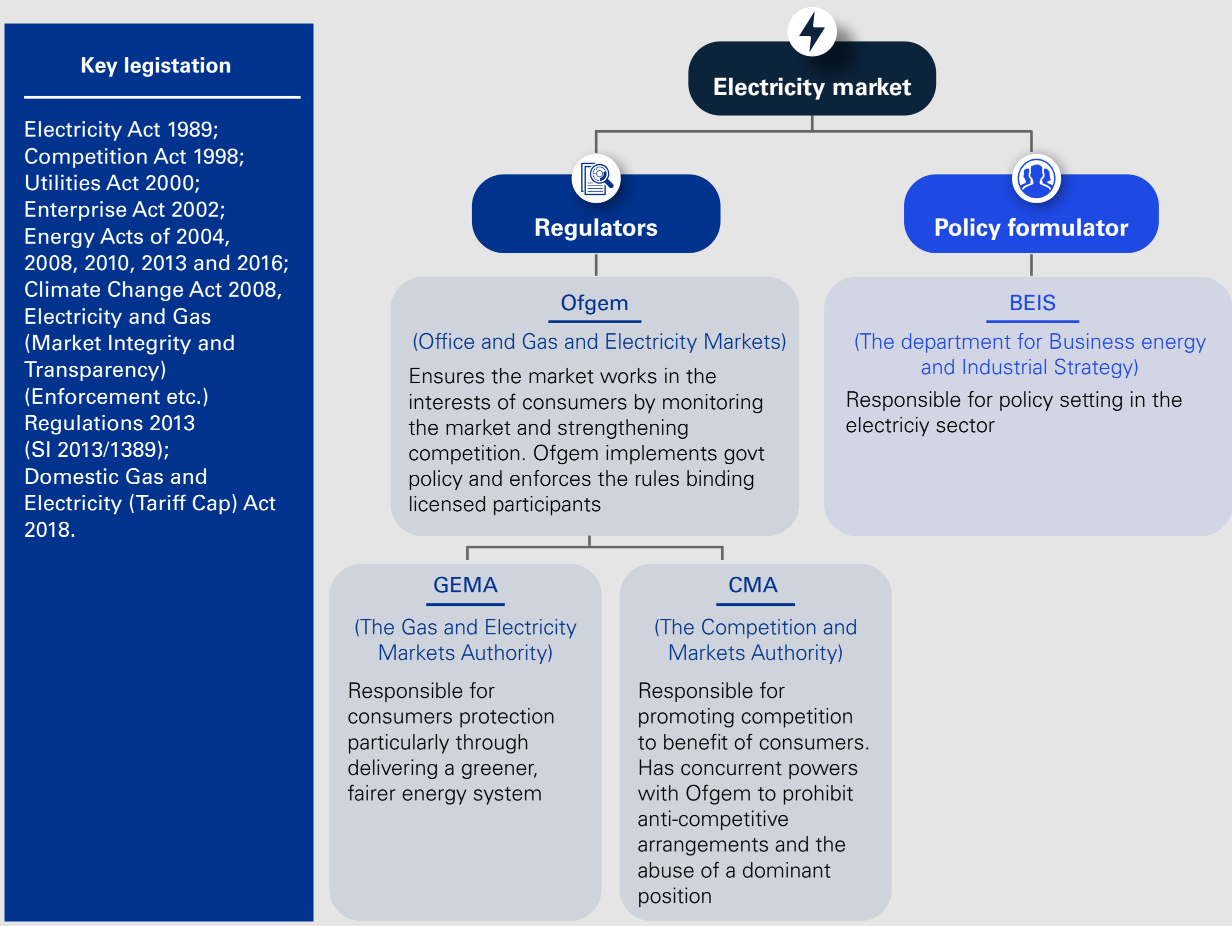
Regulation and investment

The UK regulatory environment balances consumers' best interest with the implementation of net zero goals. Ultimately, net zero targets are driven through regulatory strategies that include investment incentives, emission deterrents, fair play, subsidies and access to finance.

The transmission owners and DNOs are regulated by a central energy regulator who sets a funding allocation to determine the amount they are allowed to invest in their networks. This mechanism is known as "RIIO", which stands for Revenue using Incentives to deliver Innovation and Outputs. Introduced in 2013, the RIIO framework has been fundamental to the deployment of smart grid technology in the UK by rewarding those network owners who invest in grid-related innovation to help drive efficiency in the construction and operation of the network, as well as specifically measuring the carbon impact of network investment decisions.

Key regulators

Figure 15: UK energy policy and regulatory framework



Source: KPMG China

Investment and supporting regulatory policies

Regulators also provide financial pathways to inject public finance and private investment into incorporating emission reduction and energy efficient technologies, like smart meters, home insulation and heat pumps. For instance, the Department for Business, Energy & Industrial Strategy (BEIS) runs the Energy Entrepreneurs Fund (EEF), which seeks to promote clean tech and energy efficient technologies across all sectors, such as floating offshore wind projects and the building of Britain's largest solar farm.[98] As at 2021, around £102 million of grant money was invested in over 214 companies.[99]

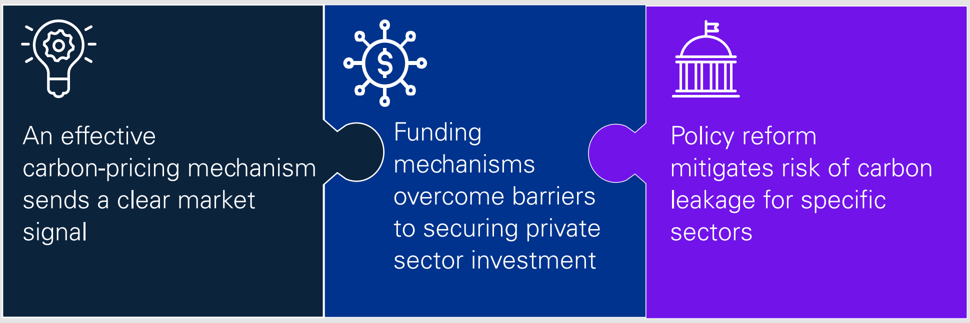
Policy strategies like the Home Upgrade Grant and the Social Housing Decarbonisation Fund raised more than £1.2 billion to support low-income households install energy efficient devices. Additionally, energy costs are cut for consumers who install technology that enhances energy efficiency, such as heat pumps and insulation, while they also gain access to green finance products, such as green mortgages.[100]

Smart meters also enable consumers to access "smart tariffs" as part of an innovative adjustment to the billing protocol. The "time-of-use" tariffs (smart tariffs) deployed by suppliers, such as Octopus Energy, enable real-time energy use records through in-home displays (IHD). Time-of-use tariffs also alter the energy bill to reflect wholesale energy prices. These tariffs reward consumers financially for using less electricity at peak times and vice versa.[101]

Schemes such as Contracts for Difference (CfDs), which replaced the Renewables Obligation (RO), have also been deployed to incentivise the sale of generated renewable energy or low-carbon electricity. The CfD stipulates that the generator is paid the difference between the "strike price" (a price for electricity reflecting the cost of investing in a particular low carbon technology) and the "reference price" (a measure of the average market price for electricity in the British market).[102] The goal of this is to incentivise investment in the generation and transmission of RE by ensuring its profitability.

The UK Emissions Trading Scheme (UK ETS) was developed in response to exiting the EU ETS post-Brexit. The UK ETS cap aligns with the government's net zero commitments and signals to investors that investing in products or energy sources that reduce their carbon intensity will yield returns under the scheme.[103]

Figure 16: The UK government's framework to unlock investment in low carbon technology



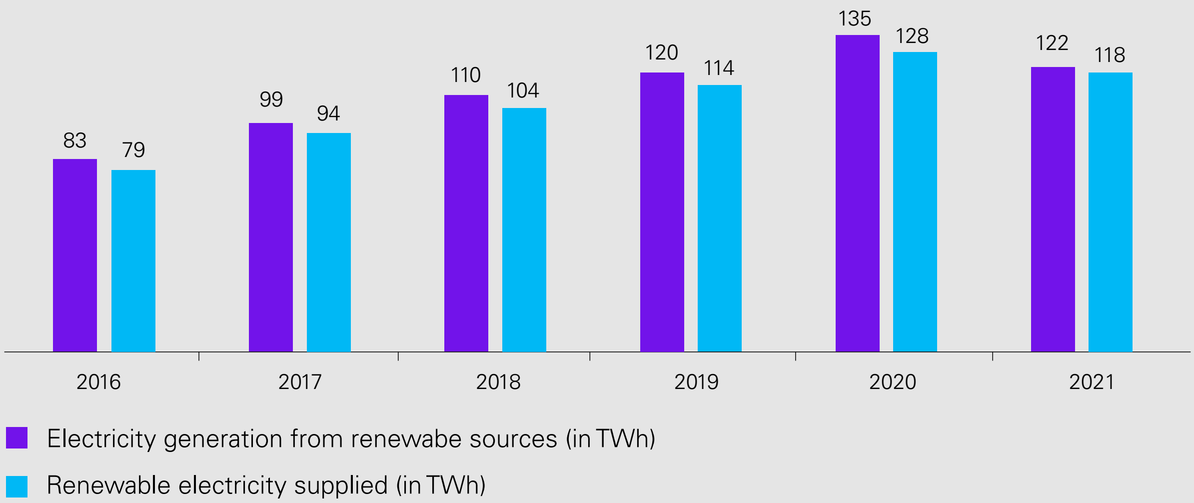
Source: HM Government, Industrial Decarbonisation Strategy[104]

UK and EU joint smart grid investment

The 2022 energy crisis in Europe, exacerbated by the Ukraine situation, has amplified the need to diversify energy sources and accelerate RE development. The EU's REpowerEU plan and the 10-point plan to reduce reliance on Russian natural gas proposes: the acceleration of wind and solar projects; the acceleration of energy efficiency in buildings; encouraging thermostat adjustments in buildings; innovation and investment etc. In recent years, investments have been made to support interconnector projects across European countries. Through a joint venture between National Grid and Statnett, North Sea Link (NSL), a cross-country transmission project, was recently completed. NSL was built with a 720km HVDC interconnector that supports clean electricity transmission between Northumberland in the UK and the Norwegian village of Kvilldal.[105] The company has previously developed four interconnector projects across Europe, connecting the UK with countries including Belgium, France and the Netherlands.[106] Analysts anticipate that energy security will be prioritised in the short term to address the security of supply. However, in the long term, with initiatives like the REpowerEU plan, it is projected that RE integration and energy efficiency will continue to form the basis of Europe's energy security strategy.[107]

Investment, emissions, and electricity consumption in the UK

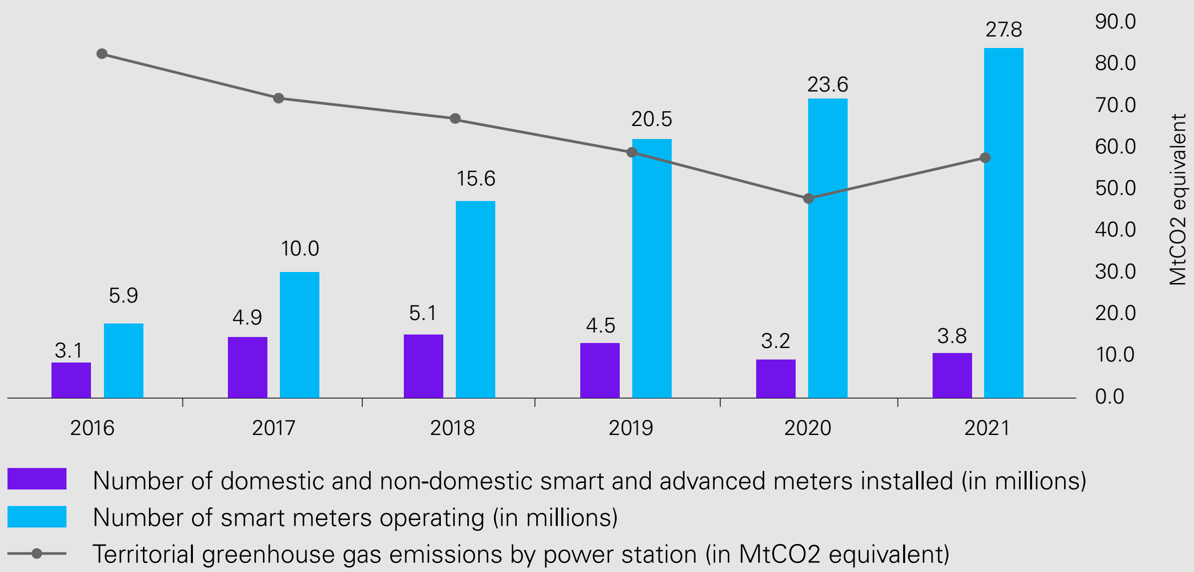
Figure 17: Renewable electricity generated and supplied in the UK



Source: UK energy 2022, UK Government, UK energy in brief 2022[108]

The upward trend of RE in the UK indicates the advancement of the UK's net zero strategy. The drop in these figures from 2020 is attributable to several factors, including a global economic downturn from COVID-19, inflation and rising energy costs. Energy security is of critical importance, and as the UK faces rising energy costs, exacerbated by the current Ukraine situation, it is anticipated that RE deployment will be impacted. Although the conflict could potentially intensify renewable energy investment in the future, current energy security needs are increasing the import of fossil fuels. While the UK aims to scale up RE and diversify energy sources, it is yet to be seen how this will be executed, given the current economic and energy cost climate.

Figure 18: Number of smart meters and GHG emissions by power station in the UK

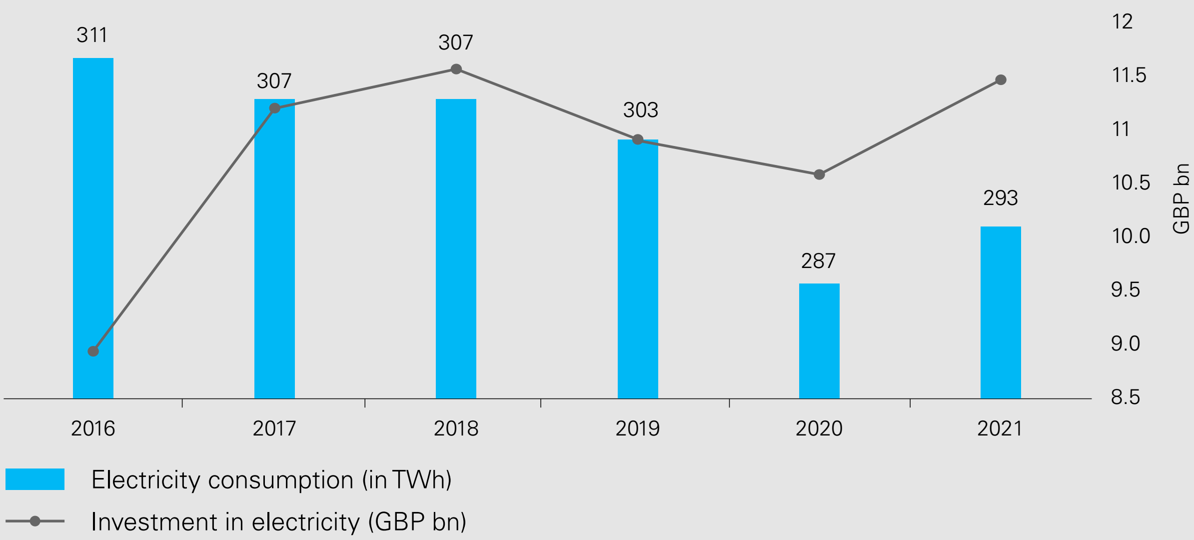


Source: UK energy 2022, UK Government[109]

Competition in the UK's liberalised market means increased private sector and supplier participation. This impacts the availability of multiple suppliers with smart meter packages. As a result of the UK's smart meter rollout and schemes, such as smart tariffs, smart meter patronage in the UK increased substantially year-on-year. This increase in smart meters happened alongside a yearly reduction in GHG emissions. In 2020, the UK government projected that smart meter users could save up to £250 on their bills with an estimated carbon reduction of 45 million tons.[110] However, these projections are impacted by the 2022 energy crisis in Europe stemming from the ongoing situation in the Ukraine. Enhanced visibility from smart meters enables better energy savings and reduced emissions. As smart meter rollout continues, more data would give a clearer picture of the impact of smart meters on carbon reduction.

Investment in electricity infrastructure increased in 2021. However, the highest investment was made in 2018, with a substantial decline in 2020. The 2020 drop could be attributed to the economic stagnation at the height of the COVID-19 pandemic, with a post-pandemic investment recovery in 2021. Electricity investment increased by 8.6% from GBP10.5 bn in 2020 to GBP11.4 bn in 2021.

Figure 19: UK Electricity Consumption and Investments in electricity



Source: UK Energy Statistics, electricity supply[111]

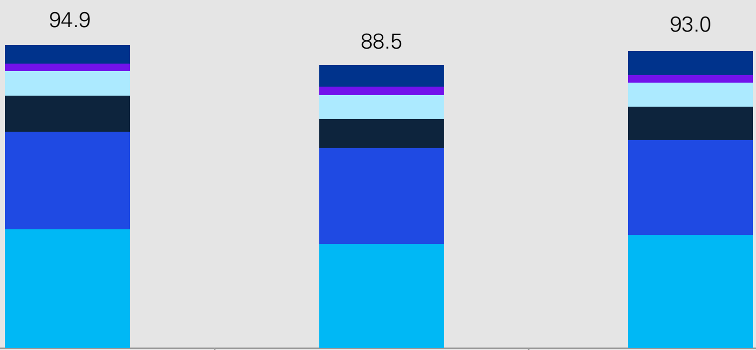
United States – Hybrid electricity market

Background

The US aims to have a 100% carbon-free power sector by 2035 and achieve carbon neutrality by 2050.[112] To realise these goals, experts project that more than 1 million miles of new transmission infrastructure will have to be built within three decades.[113] Accordingly, the US Congress passed the Infrastructure Investment and Jobs Act in 2021 which earmarks $65 billion to operationalise smart grid and clean energy technology investment.[114] The Inflation Reduction Act of 2022, which came into law in August 2022, represents the largest energy investment in US history addressing climate change.[115] It allocates $369 billion to modernise the US energy system and hit emissions reduction targets in 2030. Together, both Acts invest more than $430 billion into revamping the US energy system and infrastructure.[116]

In 2021, the US was the second largest carbon emitter from electricity generation behind China, at 1.57 billion metric tons of CO2. Coal and natural gas are currently the main sources of electricity generation in the US, although renewables have seen considerable growth and coal usage as a source of electricity has declined over the years.

Figure 20: US total primary energy consumption along with bifurcation by fuel



	2019 (exajoules)	2020 (exajoules)	2021 (exajoules)
Renewables	5.7	6.7	7.5
Hydro-electricity	2.5	2.7	2.4
Nuclear energy	7.6	7.5	7.4
Coal	11.3	9.2	10.6
Natural Gas	30.6	30.0	29.8
Oil	37.1	32.5	35.3
Total	94.9	88.5	93.0

Source: BP, BP Statistical Review of World Energy 2022[117]

The complex US grid and electricity market is set up to ensure competition and guard against market manipulation. The 48 contiguous states in the US are divided into three main interconnection networks: the Eastern Interconnection, which operates in states east of the Rocky Mountains; the Western Interconnection, which covers the Pacific Ocean to the Rocky Mountain states; and the Texas Interconnection (ERCOT).[118] These three interconnected power grids function independently of each other, although there are instances of power exchange between them.

Within the three grids, the actual operation of electricity is controlled by the balancing authorities.[119] They manage the grid from electricity generation to consumption, maintaining the efficiency of the electric grid system.[120] There are 66 US balancing authorities that each operate a portion of the grid, consistently balancing supply and demand, and assuring federal reliability standards are met.[121] Most balancing authorities are regional entities, such as Independent System Operators (ISOs) and Regional Transmission Operators (RTOs). The rest are electric utilities.[122]

Evolution of the US energy market

The US electricity market is trending towards a much less-regulated system. Deregulation of the US electricity market was initiated by the Public Utilities Regulatory Policy Act (PURPA) in 1978 to introduce competition to the electricity energy market for higher efficiency.[123] The process of deregulating the US electricity sector started in the late 1990s. The Energy Policy Act of 1992 marked the key event that allowed more independent producers to enter the open market.[124] Since then, state governments have initiated different restructuring methods. That said, not all the states are deregulated. Thus, the market structures, as well as the approaches taken in promoting deregulations, vary from state to state. Some states' electric sectors are restructured, such as Texas, while some states, like California, have partially regulated markets.

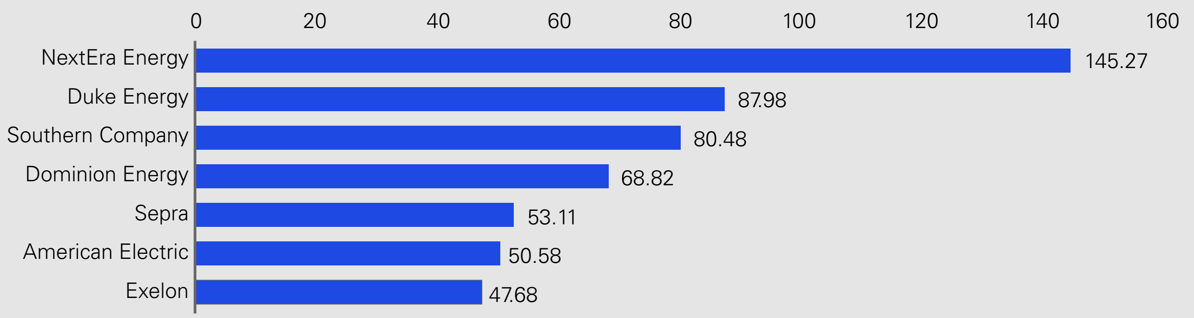
Overall, the US energy market is considered to be hybrid, i.e., made up of states with vertically integrated markets, unregulated, and partially regulated markets. Geographically, the US electric energy market is fragmented.[125] Cases that exemplify the vertically integrated market and the deregulated market, namely North Carolina and ERCOT (Texas) respectively are further discussed below.

ERCOT: deregulated market

The Electric Reliability Council of Texas (ERCOT) covers almost all parts of Texas, consisting of a single balancing authority. The ERCOT grid serves 26 million electricity customers within Texas and covers about 75% of the state's land area.[126] In contrast to other states in the US, most of Texas' electricity market is not under the jurisdiction of the Federal Energy Regulatory Commission (FERC). While ERCOT has two Direct Current (DC) ties with the Eastern Interconnection, such ties are not considered to result in interstate commerce. Therefore, the Public Utility Commission of Texas (PUCT or the Commission) solely regulates the electricity market within ERCOT. This has resulted in greater coherence in the retail and wholesale markets, more regulatory certainty, and closer coordination between legislative authorities and regulators involved in restructuring the power industry within ERCOT.

In addition to being the nation's largest electricity consumer, Texas is also the highest national power sector carbon emitter. Consequently, Texas has made considerable efforts towards reducing the sector's carbon intensity and expanding its renewable energy, such as solar, biomass and hydroelectric power.[127] Coal was reduced to 18% in 2021, from a high of 36% in 2011. Given the size of the market, Texas' transition towards a cleaner and smarter grid system will substantially impact the US. In particular, Austin has set a community-wide goal to reach net zero by 2040. Electricity utility companies, such as Austin Energy, have also developed climate protection plans that incorporate smart grids as a means to achieving a carbon-free future. This binds local utilities and major electricity market players in the state.

Figure 21: Electric power industry carbon dioxide emissions in the United States in 2020 by selected state (in million metric tons)



Source: Statista[128]

Oncor, which operates Texas's largest electric distribution system, has made substantial investments in infrastructure and cutting-edge technology to produce a safer, smarter, and more dependable electricity grid. In terms of renewable energy integration, in 2021 through 80 RE generators, Oncor provided approximately 15,500 MW of RE capacity to the ERCOT grid. This interconnection represents approximately 34% of all ERCOT wind generation.[129]

With regards to improving energy efficiency, in 2021, Oncor introduced a programme that incentivises participation in ENERGY STAR-certified and Department of Energy (DOE) Zero Energy Ready Homes. This certification requires homes to meet specific energy efficiency requirements, under which new homes must be at least 10% more efficient than standard homes, with additional incentives for installing Solar PV, heat pump water heaters, EV chargers, and thermostats.[130]

North Carolina: vertically integrated market

North Carolina has a more vertically integrated electricity market. There are a limited number of electricity provider options for residential consumers and industrial customers. Duke Energy Carolinas and Duke Energy Progress are the dominant electricity providers in North Carolina. Their activities span across the value chain, from electricity generation to transmission and distribution to consumers. Duke Energy Carolinas owns 20,100 MW of energy capacity, supplying electricity to 2.8million residential and industrial customers and supplying up to 90% of North Carolina's electricity.[131] Dominion Energy North Carolina, another electricity generation entity, supplied the balance, accounting for less than 10%.[132]

As a dominant integrated utility, Duke Energy owns and operates transmission systems while also being responsible for bulk power system reliability. This demand and supply balancing function could, in theory, enable Duke Energy to actualise its net zero goals by incorporating RE through digitised transmission systems and accumulating real-time condition monitoring data. However, this integration does not negate the functions of the balancing authorities that are responsible for grid operation and stable electricity supply.[133]

Duke Energy announced its net zero targets in 2019. It plans to collaborate with stakeholders to achieve net zero by 2050, securing cleaner electricity for its consumers through smarter solutions and advanced technology.[134] Its primary strategy involves modernising its electric grid. Duke Energy is investing in long-term efforts to provide a smarter and more resilient grid infrastructure. These efforts include expanding RE capacities, DSM, ensuring blackout prevention, and promoting greater consumer transparency and control. Duke Energy's Fort Bragg solar facility energy security project is part of a $36 million contract that focuses on infrastructure modernisation, HVAC, and boiler system improvements. Overall, its wind and solar capacity increased from 8,800 MWs in 2020 to more than 10,500 MWs by the end of 2021. It is projected to generate 16,000 MWs of renewables by 2025 and 24,000 MWs by 2030.[135]

Regulation and investment

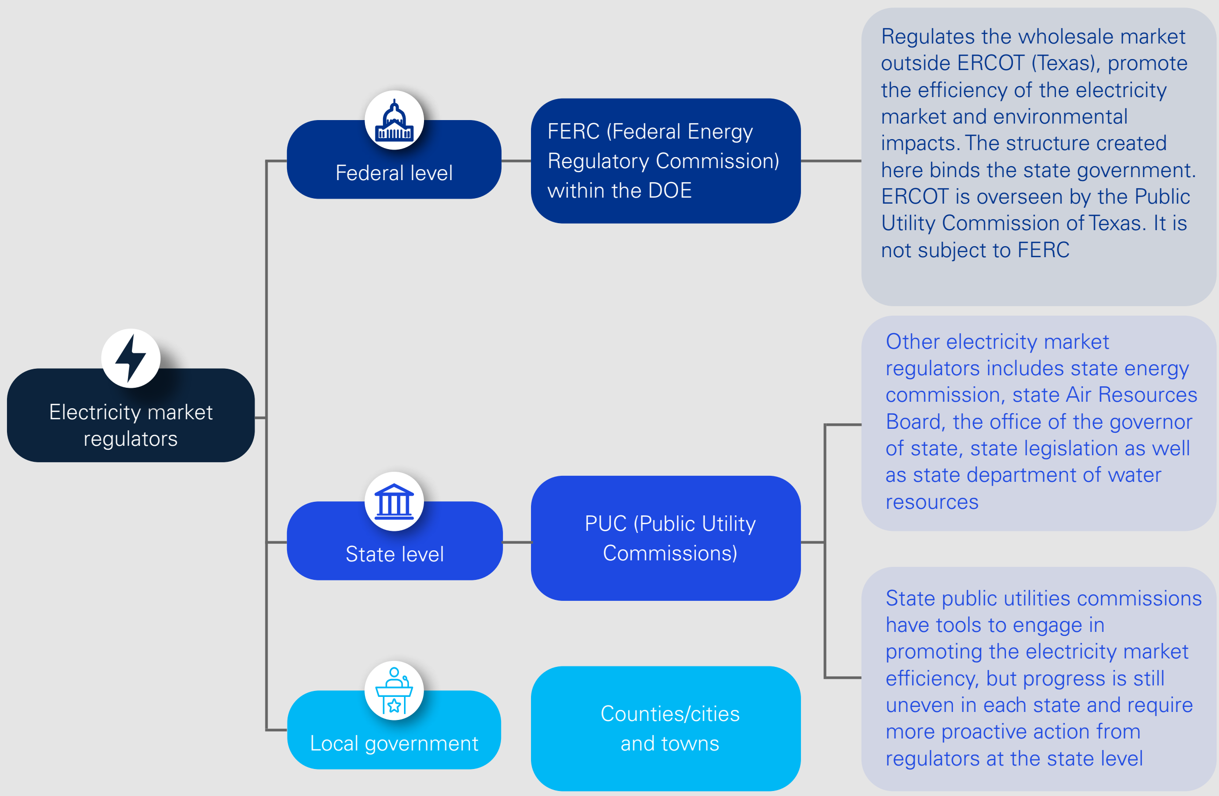
The US has a federally structured smart grid programme that promotes increased partnerships between the DOE and large companies. The Energy Independence and Security Act of 2007 (EISA) requires the DOE's Office of Electricity to report on the status of smart grid deployment and related challenges every two years.[136] Alongside private sector capital, the American Recovery and Reinvestment Act of 2009 (Recovery Act) supports more than 130 projects across the country that deploy smart grid technologies. The technology deployed enables utilities to improve the effectiveness and efficiency of their operations, particularly relating to mitigating power outages, DSM, peak levelling, and enhanced customer participation through smart meters. Accordingly, in implementing the EISA, the Recovery Act has allocated $4.5 billion towards grid modernisation. Several large programmes, such as the Smart Grid Investment Grant (SGIG) programme and the Smart Grid Demonstration Program (SGDP), were developed by EISA to operationalise the deployment of these funds.[137] In 2021, Section 40107 of the Infrastructure Investment and Jobs Act allocated $3 billion, expanding the SGIG program.[138]

Despite these policy-backed investments, impaired structural transformation stemming from policy dissymmetry poses challenges to US smart grid deployment.[139] The decentralised nature of systems that incorporate more renewable energy, as well as increased consumer participation, requires a policy synergy across the three major interconnection networks in the US to significantly adapt the future grid to emerging technology and changing demands.

Key regulators

The US regulation system contains three layers: federal, state, and local government. The Federal Energy Regulatory Commission (FERC) (an independent regulatory agency within the DOE) enacts legislation that establishes the regulatory structure for the states. Local governments play a significant role in promoting decarbonisation processes. They are authorised by state governments to address electricity issues within their localities. The Infrastructure Investment and Jobs Act, supported by the federal government, enabled local governments to expand their integration of smart grids. This initiated projects that enhanced electrification, maintained grid infrastructure, and developed local distributed energy resources.[140] This trend is projected to accelerate smart grid projects in counties, cities, and towns.

Figure 22: Key regulators in the US electricity market



Source: Thomson Reuters[141] and KPMG China

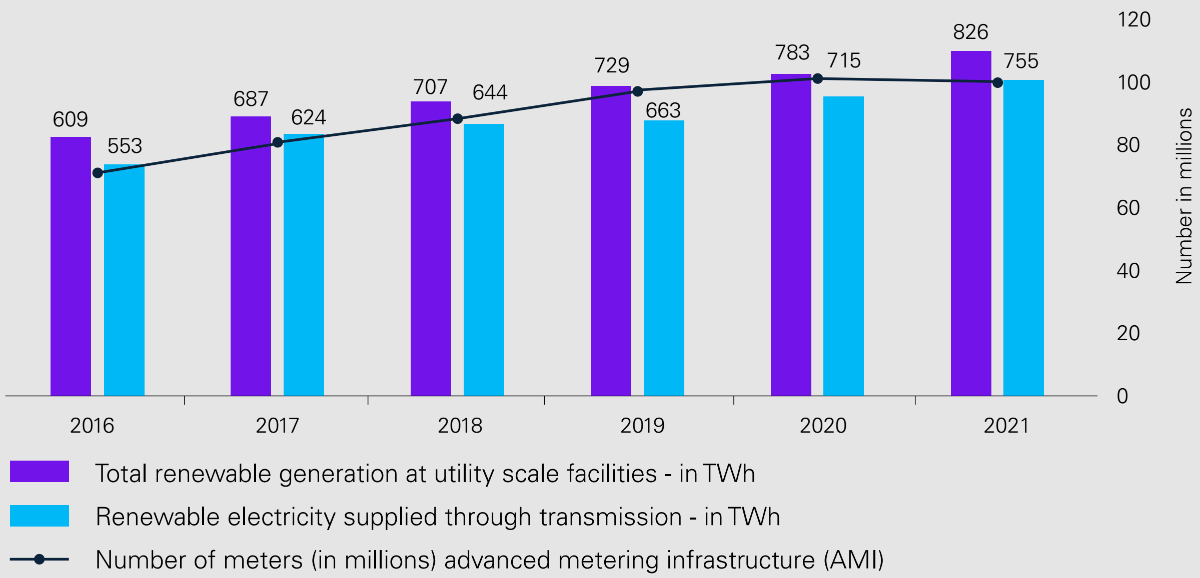
Key players

There are around 3,000 electricity providers in the US, including Investor-Owned Utilities (IOUs), cooperatives, public-owned, and federal electricity utilities, as well as retail and wholesale providers. In 2020, IOUs accounted for a 57% share of electricity sales, with public and deferral entities accounting for 16%, and cooperatives 12%. For transmission, there are five large US transmission project owners, namely American Transmission Company, Pacific Gas & Electric Company (PG&E), American Electric Power (AEP), Xcel Energy and Dominion.[142] Though these transmission projects are usually privately owned, ISOs and RTOs manage the process from electricity generation to consumption, maintaining competition and ensuring the reliability of electricity supply.[143]

AEP, one of the largest power producers in the US, which owns both significant generation capacity (approximately 30,000 megawatts and 5,300 megawatt of renewable energy) and the largest transmission system, plays an important role in enabling the US to achieve its net zero goals. As owners of the largest US transmission system (a 39,000-mile network that includes several 765 kV extra-high voltage transmission lines), its ability to promote RE integration is critical to US climate goals.[144]

Investment, emissions and electricity consumption in the US

Figure 23: US electricity generation and transmission from renewable sources

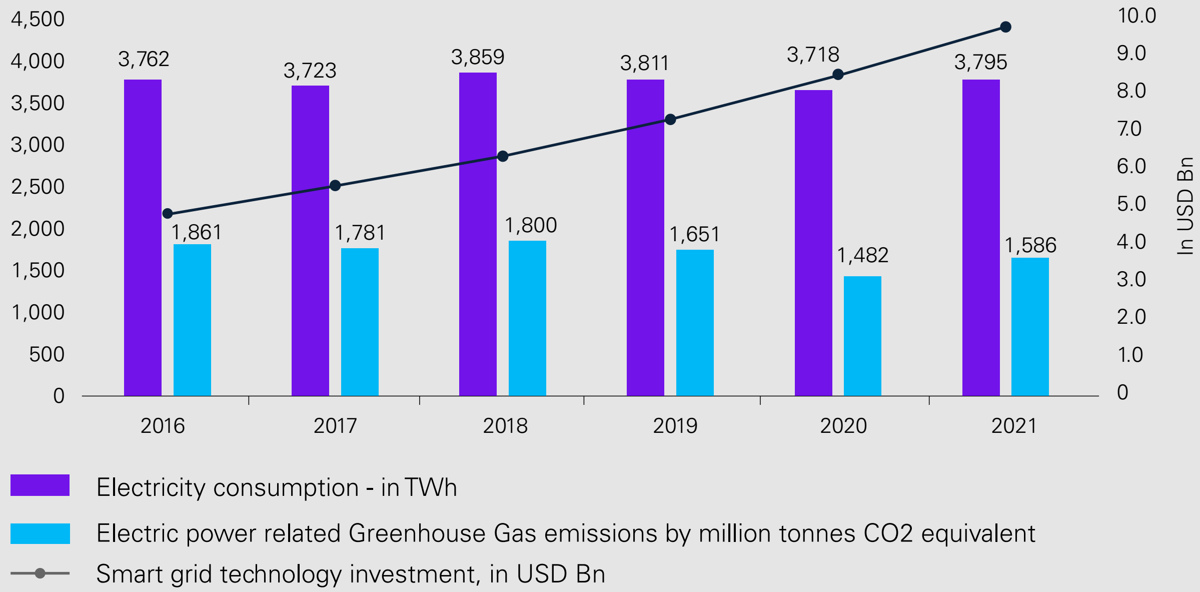


Source: EIA[145]

The US re-joined the Paris Agreement in March 2021 and restated its commitments to net zero goals. As part of its net zero strategy, the US has seen a steady growth in RE generation and transmission, with a 6.3% annual growth rate.

Although the decline in smart meter installation in 2021 could be attributed to the COVID-19 economic downturn, smart meter deployment in the US is expected to pick up as investment in technology and smart grids grows (see Figure 24 in the next page).

Figure 24: Greenhouse gas emissions, electricity consumption and smart grid investment



Source: US Department of Energy[146], United States Environmental Protection Agency and EIA[147]

An increase in smart grid investment in the US has occurred alongside a steady decline in CO2 emissions, creating a path to a less carbon intensive power sector. GHG emissions from the power sector dropped by almost 15% from 2016 to 2021.

This increase in smart grid investment is also happening alongside a reduction in energy consumption. This indicates that energy efficiency properties of smart grids enable better DSM and reduced emissions.

Considering that the slight decline in electricity consumption in 2020 could be attributed to the economic downturn caused by the pandemic, it is unsurprising that in 2021, as the economy recovered, electricity consumption increased. However, this slight increase cannot be compared to the electricity consumption levels seen in 2018. It is yet to be seen how the growth of investment in grid technology could prevent the US from hitting the 2018 consumption levels in the future.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Key considerations for stakeholders

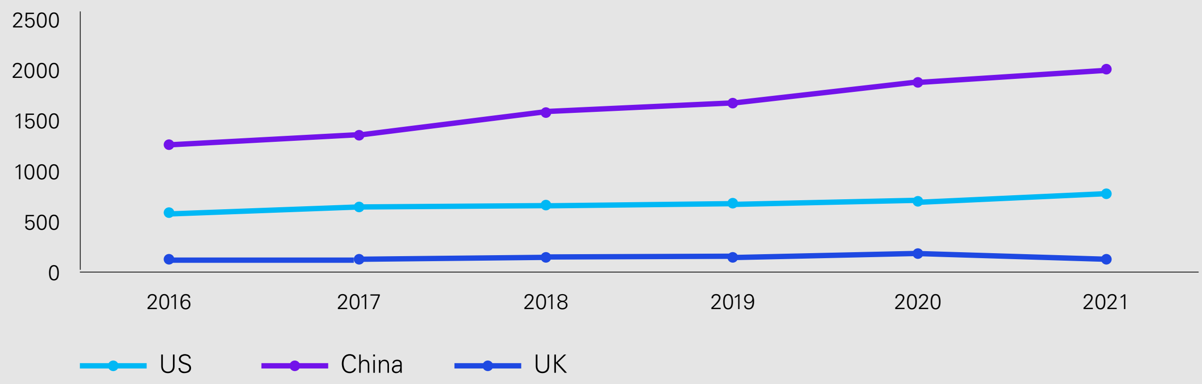
The three case studies illustrated in this report indicate that the cumulative volume of renewable energy supplied through transmission lines increased by 8.5% between 2016-2021. This suggests that integrating smart technology as part of the distributed energy resource management (DERM) is critical to not just utility companies, but also other stakeholders that are increasingly interacting with the grid as "prosumers".

According to KPMG's 2022 CEO Outlook, based on a survey of over 1,300 global CEOs, long term digital transformation and ESG/sustainability make up two of the top four trends impacting businesses globally.[148] Smart grids straddle these two issues in a way that impacts stakeholders across a number of sectors.

Energy transition is going to put a tremendous strain on existing grid infrastructure with significant intermittency and changing load profiles. Advanced grid operation technology coupled with the power of digital technology is the only way for grids to build resilience in the short to medium term.

Deven Chhaya
Partner, Infrastructure Advisory, KPMG Singapore

Figure 25: Renewable energy supplied through transmission lines in the US, UK and China



Source: KPMG China, EIA

Financial institutions foresee two key benefits from driving decarbonisation through technology enabled energy efficiency. Firstly, investing in the development and upscaling of smart grid technology is beneficial to decarbonising their portfolio. Secondly, adapting their premises with energy efficient retrofits and providing their consumers with products such as 'green mortgages' and 'green premiums' can be a practical way of contributing to their net zero targets.

Erik Bleekrode
Head of Insurance, Asia Pacific; Partner and Co-Head of Insurance, KPMG China

Figure 26: Impact of smart grid development on stakeholders across industries

Source: KPMG China

Key action points for stakeholders

Government, policymakers and regulators should create incentives that drive digital integration within the grid and energy efficiency for both individual and corporate consumers. This includes policies that drive partnerships between utility companies and other private and public sectors as well as financial institutions. These policies should take into consideration net zero goals, energy security, and IoT-based urban and rural digitisation ("smart cities"). Regulators for both the electricity sector and finance sector play a pivotal role by creating a regulatory environment that redirects capital into smart grids implementation. Public-Private Partnerships (PPPs), subsidies and a host of incentives are currently being used to drive this agenda across different electricity markets.

In line with clearly defined decarbonisation goals, **C-level executives** (CEOs, CSOs, CIO/CDO, CFOs etc.) should consider opportunities that adapt their core infrastructure and business portfolio to more energy-efficient approaches. This will secure their competitive advantage as first-movers and industry pioneers in the digital energy revolution.

In view of existing and impending regulations as well as investor pressure to divest from carbon intensive investment, **banks, asset managers, private equity and insurance companies** should define strategies to reduce their investment in brown assets and increase investments in advancing digitisation and energy efficiency. Investing in smart grids will fulfil both objectives.

Utility companies should consider ways of integrating smart technology across their entire value chain. Integrating smart grids creates access to multiple streams of sustainable finance, reduces energy costs and improves the sustainability outlook of the company. This level of digitisation should include a change management plan that prepares personnel and customers for the impact of these changes.

Corporates should explore ways of working with utility companies to create opportunities to green their premises and processes. By investing in technology that enables them to better interact with the grid, corporate entities such as manufacturers and real estate developers have significant carbon reduction opportunities. A decarbonisation pathway can include participating in energy production and retrofits that enhance the energy efficiency of their operations and assets.

Conclusion

As the global trend towards more integrated systems continues, connectivity powered by reliable, secure and dynamic electrical systems is critical. Components that make a grid smart include the application of digital, sensory and cyber security infrastructure to enhance the physical system's secured performance of sensory, communication, DER integration, data and energy management functions.

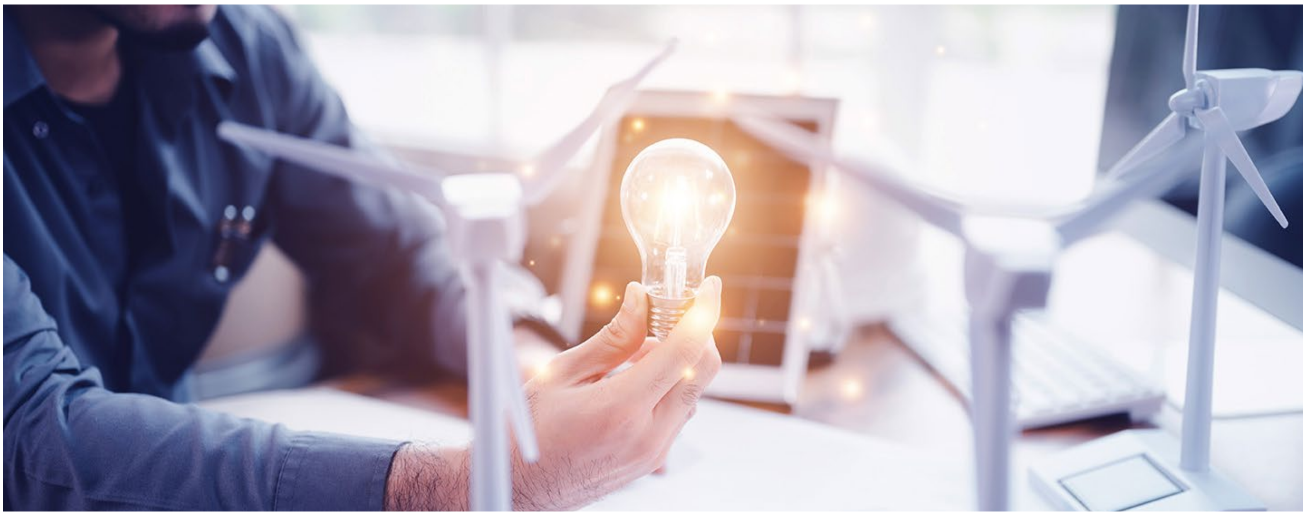
Smart grid investment is essential to decarbonising the electricity sector and achieving net zero goals. In each of the markets studied in this report, factors such as the structure of the electricity market, supporting policies, access to finance, energy security and technological development interact to determine the trajectory of smart grids.

Smart buildings, smart ports and smart cities powered by smart grids are changing not only the investment landscape but the process through which we achieve energy transition through greater energy efficiency. A digitised power grid now enables bi-directional communication, enhanced transparency and more accuracy in managing electricity demand and supply. As a result, considerably less power is required to meet growing electrification demands.

Meanwhile, sustainable finance is increasingly targeting the clean technologies of the future. Banks, asset managers, institutional investors, utilities and corporates are in many ways exploring opportunities for decarbonising their portfolio as well as their processes. Investing in and integrating smart grids technology offers a clear path to substantial carbon reduction critical to energy transition.

Advanced grid technology can now enable transition fuels such as natural gas and clean coal to be utilised more efficiently with substantially less carbon emissions. We expect smart grid investments to continue to grow as they help facilitate this energy transition.

Daisy Shen
Partner, Head of Climate Change and Sustainability, KPMG China



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Guide to abbreviations

AC	Alternative Current
AI	Artificial Intelligence
AMI	Automated Meter Infrastructure
ASG	Asia Super Grid
BEIS	The Department for Business Energy and Industrial Strategy
BESS	Battery Energy Storage Systems
CHD	China Huadian Corporation Limited
CEIC	China Energy investment Group Corporation Limited
CfD	Contracts for Difference
CRP	China Resources Power Holdings and China General Nuclear Power Group
CHNG	China Huaneng Group Limited
CM	Condition Monitoring
CMA	The Competition and Markets Authority
CRPH	China Resources Power Holdings
CSRC	China Securities Regulatory Commission
CSG	China Southern Power Grid
DC	Direct Current
DER	Distributed Energy Resources
DERMS	Distributed Energy Resource Management System
DES	Distributed Energy Storage
DG	Distributed Generation
DMS	Distribution Management System
DNOs	Distribution Network Operators
DOE	Department of Energy
DR	Demand Response
DSM	Demand-Side Management
EEF	Entrepreneur Funds
EHVDC	Extra High-Voltage Direct Current
EMS	Energy Management Systems
EPRI	Electric Power Research Institute
ESS	Energy Storage System
EU	European Union
EV	Electric Vehicles
EVS	Electric Vehicles Storage
FERC	Federal Energy Regulatory Commission
GEMA	Gas and Electricity Markets and Authority

GHGs	Greenhouse Gases
GIS	Geographic Information Systems
G2V	Grid to Vehicle
HC	Human Centric
HVAC	Heating, Ventilation and Air-Conditioning
IDNOs	Independent Distribution Network Operators
IEA	International Energy Agency
IEEE	Institute of Electrical and Electronics Engineers
IHD	In Home Display
IoT	Internet of Things
ISGAN	International Smart Grid Action Network
ISOs	Independent System Operators
LDS	Legacy Distribution Grid
ML	Machine Learning
MMC	Maintenance Monitoring Center
NDRC	National Development and Reform Commission
NEA	National Energy Agency
NHC	Non-Human Centric Approaches
NIST	National institute of Standards and Technology
NPC	National People's Congress
NREL	National Renewable Energy Laboratory
NSL	North Sea Link
Ofgem	Office of Gas and Electricity Markets
PBoC	People's Bank of China
PLCs	Programmable Logic Controllers
PMU	Phasor Measurement Units
PURPA	Public Utilities Regulatory Policy Act
PV	Photovoltaic
RE	Renewable Energy
RES	Renewable Energy Source
RIIO	Revenue using Incentives to deliver Innovation and Outputs
RO	Renewables Obligations
RTOs	Regional Transmission Operators
SASAC	State-owned Assets Supervision and Administration Commission
SDIC Power	State Development & Investment Corporation Power Holdings
SERC	State Electricity Regulatory Commission
SPC	State Power Corporation
SPIC	State Power Investment Corporation Limited
T&D	Transmission and Distribution
UHVDC	Ultra-High-Voltage Direct Current
UK ETS	UK Emissions Trading Scheme
V2G	Vehicle to Grid

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