한·독 에너지 파트너십 팀
Energiepartnerschaft - Team
DEUTSCHLAND – KOREA

Overview Paper

Smart Grids in Korea and Germany

Germany and South Korea (hereafter Korea) have both set ambitious goals: achieving climate neutrality by 2045 and 2050, respectively. However, energy transition places considerable technical demands on infrastructure, particularly on electricity grids. The role of decentralised and variable power generation from solar photovoltaics and wind has been increasing, changing power generation patterns spatially and temporally. At the same time, consumption patterns are shifting due to electric mobility, heat pumps, stationary storage systems, data centres, and electrification of industrial processes. Traditional grid structures are increasingly reaching their technical limits. Smart grids are therefore a prerequisite in both countries to enable the integration of decentralised renewable energy sources while simultaneously managing rising demand.

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Executive Summary

Germany and Korea both view smart grids as essential for integrating variable renewable energy sources, managing shifting electricity demand patterns and maintaining system reliability. Core technologies include smart metering, communications infrastructure, digital grid monitoring, data analytics and cybersecurity, but their deployment follows markedly different pathways.

Germany's liberalised, highly fragmented system with more than 800 DSOs and stringent data protection rules has produced a detailed regulatory framework but a slow rollout — intelligent metering systems cover only 5.5% of metering points. Korea's centralised, KEPCO-led model has enabled near-complete AMI deployment (around 20.05 million units by 2024), nationwide advanced distribution management and rapid digitalisation of substations.

The strongest cooperation potential lies in combining both countries' complementary strengths: Korea's large-scale implementation experience and integrated digital grid operation with Germany's regulatory expertise, flexibility markets and specialised technology providers. Joint work could focus on standards, interoperability, secure data use, Virtual Power Plants (VPPs), microgrids and export-ready smart grid solutions.

1. Overview of Key Technologies

Smart grids are widely regarded as necessary for the transformation of the electricity system. Their significance lies particularly in their ability to facilitate the integration of decentralised renewable energy generation resources into the electricity grid and to coordinate the increasingly dynamic interactions between generation, consumption, and storage. Through the digital capture, near real-time monitoring and control of feed-in and loads, grid stability, and congestion can be better managed. Key overarching technological concepts can be summed up as

- Smart metering / Advanced Metering Infrastructure (AMI),
- Distributed Energy Resources (DER) integration,
- Sector coupling (especially Electric Vehicles (EV) and heat pumps),
- Demand response and flexibility,
- Distribution System Operator (DSO) digitalisation,
- Grid observability and active network management,
- Interoperability and standards, and
- Cyber resilience and privacy.

Smart grids therefore represent a set of concepts which bring together technical, operational, market-based, and regulatory elements. They emerge through the interplay of digital metering, communication, and control technologies; suitable operational management and flexibility options; and the relevant regulatory and market frameworks. These include the mandates of market actors, incentive structures, power tariffs and grid fees, as well as rules on grid operation and congestion management.

This paper examines key technologies and their deployment within the German and Korean electricity grid systems.

1.1 Metering Technologies

A cornerstone of a smart grid is the digital capture and transmission of consumption and generation data in real time. Smart meters, communication modules, and other sensor technologies provide the foundation for tracking consumption, power generation, and grid conditions with greater temporal and spatial resolution.

Smart meters measure electricity consumption and generation in time-stamped intervals, and often also record voltage and current. They replace mechanical meters with digital devices and support time of use tariffs, remote reading, outage visibility, and more detailed consumption feedback.

Smart meter gateways (SMGW) provide secure communication between meters, controllable devices in households and businesses, and authorised external actors. They transmit metering data and tariff signals and support interaction with devices such as heat pumps, EV chargers, storage systems, and rooftop PV.

Data concentrators aggregate data from multiple meters and SMGWs and transmit it onwards through the wider communication network, for example via Powerline Communication (PLC).

1.2 Communications Infrastructure

Metering, sensor and control data must be transmitted between relevant market participants, including end-customers, metering point operators, grid operators, aggregators and energy suppliers. Several transmission pathways have established themselves today to fulfil this function.

Powerline communication (PLC) uses existing power lines as a transmission medium, often for last mile communication between smart meters, concentrators, and local substations. It supports remote meter reading and other basic data exchange functions.

Radio frequency mesh networks are wireless communication systems in which field devices relay messages between one another, creating a local network for reliable data exchange without a separate wired connection to every device.

Cellular networks such as 2G, 3G, 4G/Long-Term Evolution (LTE), and 5G are widely used for smart meters, gateways, EV chargers, battery sites, weather sensors, and distributed energy controllers. They enable rapid rollout and support remote commissioning, near real-time telemetry, and demand response signalling.

Proprietary fixed line connections such as ethernet, fibre and Internet Protocol/Multiprotocol Label Switching (IP/MPLS) backhaul are often used to connect substations, control centres, and data centres. They offer high bandwidth and low latency.

Satellite communication can serve as a fallback option for remote or infrastructure poor regions.

Advanced Metering Infrastructure (AMI) refers to an intelligent power metering infrastructure that collects, stores and analyses various smart metering data and provides (e.g. tariff) data to consumers in order to enable intelligent services and improved customer benefits. Its scope includes metering, communication, and backend data and operations infrastructure but does not cover the entire low voltage power grid.

1.3 Digital grid infrastructure, monitoring and control

Digital technologies for the automation, control, and monitoring of power grids are a central component of smart grids.

Digital local grid substations combine transformers with sensors, digital communication modules, and remote-control functions. Unlike conventional substations, they continuously record key operating data and enable real time monitoring and remote control of medium and low voltage grids.

Digital substations go a step further by digitising the internal architecture of the substation itself, typically on the basis of IEC 61850 standard. This improves interoperability and supports more automated operation, remote switching, and better integration with control centres.

Advanced Distribution Management Systems (ADMS) are central software platforms for monitoring, analysing, and controlling the distribution grid. They build on Supervisory Control and Data Acquisition systems (SCADA) which collect and processes real-time data from sensors, monitors anomalies and failures, and enables remote control of grid components, and Distribution Management Systems (DMS) which apply analytical and optimisation tools to SCADA data to support real-time monitoring of grid parameters, fault location, and switching management. ADMS support real time grid monitoring, load and voltage simulations, outage management, and peak load control.

Fault Location, Isolation and Service Restoration (FLISR) is a control technology for distribution feeders. It helps detect faults, isolate the affected section, and restore power to unaffected customers as quickly as possible.

1.4 Data Analytics

The use of the data generated within the smart grid requires a high-performance infrastructure for analysis and processing. Particularly relevant are the following technologies and functions, often enabled by the use of artificial intelligence and data centres.

Load and net load management tools predict electricity demand and, increasingly, net load after accounting for local renewable generation, storage, and demand response. They support procurement, flexibility dispatch, and peak management.

Tools for low voltage observability and state estimation use AMI data, feeder models, topology, and limited sensors to estimate the actual state of the low voltage network. A more advanced form is the digital twin, a network model updated in real time from operational data.

Flexibility and demand response analytics identify, forecast, and monetise flexible consumption, generation, and storage. They support peak shaving, dynamic tariff response, congestion relief, and aggregation into Virtual Power Plants (VPPs) and local flexibility markets.

Asset health, power quality and anomaly or loss analytics use sensor and meter data to detect equipment degradation, power quality problems, technical losses, and suspicious patterns. They support predictive maintenance, loss reduction, fraud detection, and improved customer power quality.

1.5 Cybersecurity and Data Protection

Cybersecurity is an integrated requirement at every layer of the smart grid, as successful cyberattacks can manipulate load distribution, prevent operators from accessing control functions, cause power outages, misuse consumption data, and at worst, paralyse larger parts of the energy grid (Energy+ Solutions GmbH 2026; safeREACH 2026). Two key concepts are presented below.

Secure smart metering architecture and identity management combine certified components, role-based access, protected interfaces, and controlled gateway administration. Together, these measures help secure communications and data access across the smart grid.

Information Security Management System (ISMS), zero trust, and privacy by design form a cross-cutting governance layer. An ISMS structures risk management, controls, audits, and incident response. Zero trust limits implicit trust between users, devices, and systems, helping to contain breaches. Privacy by design protects personal data from the outset. These principles are reflected in standards such as ISO/IEC 27001, utility guidance, and privacy law.

2. Overview: Germany

In Germany, the need for smart electricity grids arises at both transmission and distribution grid levels, albeit for different reasons. At transmission level, the primary drivers are the massive expansion of variable renewable energies changing generation patterns following the phase-out of nuclear power and the gradual coal phase-out, as well as the emergence of new electricity demand from sectors such as data centres, electric mobility and electrified industry. These developments increase the challenges of load flow management, redispatch requirements, and investment needs. At distribution level, the transformation is driven by decentralised photovoltaic feed-in, the ramp-up of electric mobility, and the growing proliferation of heat pumps and battery storage systems. Together, these trends are making power flows more dynamic and bidirectional, particularly in medium and low voltage grids, requiring greater visibility, more precise forecasting, and improved control capabilities. Against this background, smart grids are becoming increasingly important in Germany to integrate flexibility, maintain grid stability, and enable more efficient use of existing infrastructure.

2.1. Market structure

Germany's smart grid development takes place in the context of a liberalised electricity market, a highly fragmented distribution grid landscape, and a comparatively detailed regulatory framework.

The transmission grid is operated by four Transmission System Operators (TSOs) – Amprion, 50Hertz, TenneT, and TransnetBW – each within geographically defined control zones. Distribution grids are operated by more than 800 operators, a degree of institutional fragmentation that contributes to varying levels of grid digitalisation progress across regions.

The wholesale market is organised through the EEX and EPEX SPOT (European Power Exchange) electricity exchange, where power is traded for shorter time horizons from the day-ahead market to intraday trading. Prices are set using the merit order principle, whereby the price is set by the most expensive production plant still needed to meet demand.

The retail market is fully liberalised, allowing households to choose freely from a wide range of suppliers. There are no government-set retail prices; instead, suppliers set tariffs competitively. A regulated default supply obligation remains in place, requiring the largest local supplier in each area to serve as a fallback option to household customers.

The retail electricity price comprises several components, with wholesale accounting for less than half: procurement and supply (approx. 40%); grid charges (approx. 25%); and taxes, levies, and surcharges (approx. 35%) (E.ON 2026b). In 2025, average household electricity prices in Germany stood at around 40 cents/kWh, while industrial electricity prices were approximately 18 cents/kWh (Statista 2025).

Since the amendment of the Energy Industry Act (EnWG), all electricity suppliers are required to offer dynamic electricity tariffs from the start of 2025 onwards. Dynamic tariffs are based on spot market prices passed on to customers, either directly or with safeguards such as price floor and cap, typically alongside a fixed basic charge. This creates an important precondition for the stronger integration of flexible demand into the electricity system.

2.2 National targets and legal framework

Several legal acts and regulatory provisions shape the deployment of smart grid technologies, concepts, and standards. The most significant are outlined below.

The Metering Point Operation Act establishes the rules for the rollout of intelligent metering systems, including rollout obligations, price caps, and minimum technical requirements. An intelligent metering system in this context is usually understood as the combination of a modern metering device and a smart meter gateway (SMGW). Mandatory installation applies to defined user groups, including owners of generation plants with more than 7 kW of installed capacity (relevant, among other things, for solar PV installations), final consumers with annual electricity consumption above 6,000 kWh, and controllable loads (*steuerbare Verbrauchseinrichtungen*) under Section 14a of the Energy Industry Act such as heat pumps, charging infrastructure, and home battery storage systems. Under § 45, at least 20% of relevant mandatory installation cases should have been equipped with intelligent metering systems by the end of 2025, with 90% coverage is to be reached by 2032.

§ 14a EnWG establishes the regulatory basis for grid-serving control measures for controllable loads, i.e. heat pumps, charging stations, air conditioning units and battery systems with a connected load exceeding 4.2 kW in return for grid tariff reductions. For all relevant devices installed after January 1, 2024, the necessary customer-side requirements must be met to enable remote control, typically achieved with a smart meter and a control unit or inbuilt control functionalities.

Telecommunications Law, the Spectrum Ordinance, and Frequency Plan together establish the 450 MHz band as a key communications layer for resilient, wide-area and blackout-resistant digital grid operations, particularly for critical infrastructure applications. It complements fibre, public mobile networks and other communications technologies, and is key for providing coverage of basements, rural areas and safety critical use cases where ordinary public mobile coverage may be insufficient.

The **General Data Protection Regulation** (*Datenschutz-Grundverordnung; DSGVO*), along with the **Federal Data Protection Act** (*Bundesdatenschutzgesetz; BDSG*), addresses the handling of granular, often person-related data about electricity use, behaviour, occupancy patterns and device operation. It stipulates that any processing of personal data must rest on a lawful basis and follow principles such as purpose limitation, data minimisation, transparency, security, storage limitation and accountability.

Federal Office for Information Security (*Bundesamt für Sicherheit in der Informationstechnik*; ***BSI***) **security** and **certification framework for smart metering and critical infrastructure** includes protection profiles, technical guidelines, certification rules, and critical infrastructure security obligations, ensuring cybersecurity, interoperability and data protection across metering, communications and digital control systems. Its main mechanisms include mandatory certification of smart meter gateways, cryptographic security requirements, secure authentication, standardised interfaces, and compliance processes for critical infrastructure operators. Which operators and facilities fall under the BSI security and certification framework is determined by the KRITIS ordinance.

The Redispatch 2.0 framework, introduced in 2021, establishes a unified congestion management regime extending redispatch obligations to all generation plants at or above 100 kW. TSOs and DSOs must continuously exchange forecasts, schedules, and operational data to enable coordinated congestion relief across voltage levels, creating binding requirements for digital data exchange, forecasting, and near-real-time communication at the distribution level. Implementation has proven challenging given the fragmented DSO landscape and uneven digitalisation across grid areas. Redispatch 2.0 is therefore one of the most significant regulatory drivers for smart grid investment in Germany, translating the need for improved grid visibility into enforceable obligations for both transmission and DSOs.

2.3 Deployment status for key technologies

This section presents qualitative and quantitative information on the deployment of smart grid technologies in Germany, following the categories established in section 1. It aims to provide a representative snapshot rather than an exhaustive overview.

2.3.1 Metering Technologies

Germany follows a distinctive smart metering approach based on the intelligent metering system, or iMSys. This system combines a modern metering device with a separately certified smart meter gateway, which enables secure communication with authorised market participants. The German architecture reflects the country's particularly stringent data security requirements, but it has also contributed to a comparatively slow rollout.

Across all metering points in Germany, the installation rate for iMSys stands at 5.5% (equivalent to 3,094,346 installations), compared to 53.8% (equivalent to 30,393,141 installations) for modern metering devices (Bundesnetzagentur 2026a)[1]. While overall penetration remains comparatively low, deployment has accelerated significantly since the 2023 reform of the Metering Point Operation Act, especially Around two million smart meters were installed in 2025 alone. As a result, Germany reached the first statutory rollout milestone for mandatory installation cases.

Germany increasingly views intelligent metering systems not primarily as metering technology, but as a key enabling infrastructure for smart grids. Through the Smart Meter Gateway architecture, they provide a secure communication platform for grid operators, consumers, distributed energy resources and market actors.

2.3.2 Communications Infrastructure

At transmission level, communication infrastructure has long been well established. The four German TSOs (TenneT, 50Hertz, Amprion, TransnetBW) operate dedicated, proprietary communication networks primarily based on fibre-optic cables, often deployed as Optical Ground Wires (OPGW) integrated into overhead transmission lines.

The most significant recent changes have occurred on the medium-voltage level, driven by the digitalisation of secondary substations. Fibre-optic connections, public LTE/4G, and a dedicated 450 MHz LTE network are being deployed, while legacy narrowband PLC is gradually phased out. The 450 MHz network is primarily intended for resilient grid operation, critical

[1] The regulatory survey covers only primary metering point operators (MSBs). Data from competitive metering point operators (wMSBs) is only partially included in the survey, as not all wMSBs have submitted data. Against this background, it can be assumed that the actual overall rate across all metering points in Germany is higher than the figures shown here.

infrastructure communications and blackout-resilient applications. Smart metering may become one of several application areas.

Germany's smart meter gateways are technology-neutral and support multiple communication options for the Wide Area Network (WAN), including Ethernet, PLC, and cellular technologies like LTE (BSI 2026; Schlegel et al. 2019). In practice, public LTE is the most widely used connection given its immediate availability via existing mobile networks.

2.3.3 Digital grid infrastructure, monitoring and control

The digitalisation of grid infrastructure in Germany is progressing unevenly across voltage levels.

At transmission level, the four TSOs are subject to EU's System Operation Guideline and are required to maintain advanced level of observability for real-time operational data, planning and scheduling data, and asset unavailability data – both for their own assets and those of Significant Grid Users. The regime implies substantial control over switching states, reactive power management, congestion responses, emergency measures, restoration procedures etc. The four TSOs also jointly operate the Grid Control Cooperation platform (*Netzregelverbundplattform*; NRVP).

At distribution level, by contrast, substantial gaps remain in grid visibility and automation, including FLISR capabilities that are not yet widely deployed. Comprehensive national data on FLISR implementation are lacking, though the ongoing digitalisation of substations is laying the groundwork for broader adoption. The digitalisation of distribution grids is increasingly regarded as a prerequisite for unlocking flexibility and reducing future grid expansion requirements.

The digitalisation of substations is also progressing, though no comprehensive national data are available and implementation varies across regions. Regional pilot projects and initiatives suggest growing momentum (BKW Energy Solutions; E.DIS AG 2022). E.ON aims to achieve 100% visibility and 20% control coverage across its entire medium-voltage grid by end of 2026.

Germany has around 500,000 local grid substations, of which around 30,000 were digital by 2025 (E.ON 2026, 2025). This also indicates considerable untapped potential for improving real time monitoring and control in medium and low voltage grids.

Software based grid planning and grid operation tools are gaining traction. One notable example is envelio GmbH's Intelligent Grid Platform, which integrates grid data into a unified computational model and supports processes ranging from grid connection assessment and target grid planning to real-time monitoring, congestion management, and forecasting. According to the company, its platform currently covers around 50% of Germany's medium and low voltage grid (Envelio 2026).

ADMS are also being introduced gradually. In Germany, such systems are currently used mainly by DSOs and are increasingly replacing older combinations of SCADA, DMS, and OMS. One example is Stromnetz Berlin GmbH, which commissioned Schneider Electric to replace existing grid control and fault management systems across the high, medium, and low voltage grid with an ADMS (Stromnetz Berlin 2018).

2.3.4 Data Analytics

The use of advanced analytics and AI in German distribution grids remains largely at the pilot stage, with applications spanning load forecasting, grid state estimation, anomaly detection, and operational optimisation (Bundesnetzagentur 2023). A prominent example is the AI4Grids project (2020–2023), led by HTWG Konstanz in cooperation with Fraunhofer ISE, which explored AI-based planning and operational management of distribution grids and microgrids. In a pilot application at Stadtwerk am See, an AI controller learned to stabilise voltage and frequency using real-time grid data without manual intervention. E.ON, the largest DSO in Germany, has built a digital twin of its 700,000 km distribution network, representing more than a third of Germany's entire distribution grid.

Flexibility and demand response are gaining traction in Germany, driven notably by VPPs. Next Kraftwerke (Shell Energy) aggregates more than 10,000 MW across more than 14,000 decentralised units for spot and balancing markets (Next Kraftwerke 2022; EM-Power 2022). Flexa operates Germany's largest residential VPP, connecting over 40,000 households (Flexa 2025). Nonetheless, broader flexibility markets and large-scale operational deployment of data analytics and AI for grid management remain at an early stage in Germany, despite growing awareness of their potential.

2.3.5 Cybersecurity and Data Protection

Cybersecurity and data protection are central design principles of Germany's smart grid architecture. In particular, the deployment of smart metering systems is shaped by extensive security requirements defined and supervised by the BSI. The BSI framework defines the technical and organisational security requirements such as end-to-end encryption, secure authentication mechanisms, and standardised communication interfaces. KRITIS defines the operators and assets which are subject to the BSI certification. Currently, over 300 operators and 522 assets fall in the scope of KRITIS (BSI 2026).

Germany's strict security regime has two important effects. On the one hand, it strengthens trust, security, and interoperability in digital energy infrastructure. On the other hand, it raises technical and administrative hurdles for market entry and rollout.

Unlike many first-generation smart meter rollouts, the German architecture was designed from the outset to combine metering, cybersecurity and smart-grid functionality within a single certified framework. Through the Smart Meter Gateway architecture, intelligent metering systems provide a secure communication platform for grid operators, consumers, distributed energy resources and market actors. Germany increasingly views intelligent metering systems not primarily as metering technology, but as a key enabling infrastructure for smart grids.

2.4 Industry structure and business models

Germany has a strong industrial base in smart-grid-relevant technology segments, particularly electrical equipment, automation, and digital control systems, with core competitive strengths in grid control software and system integration. Major providers include Siemens (Germany), ABB (Switzerland), and Schneider Electric (France). Siemens develops low-voltage switchgear, measuring and control devices, and distribution systems; its Gridscale X platform illustrates the company's expertise in intelligent grid management (Siemens 2026). ABB offers electrification and automation solutions for industry and energy infrastructure (ABB 2026), while Schneider Electric provides electrical switching and distribution systems as well as grid and energy management technology (Schneider Electric 2026).

Alongside these multinationals, several German-origin companies play important roles in specialised segments. PSI Software SE (Berlin) develops grid control and energy management systems and, in 2025, entered a long-term partnership with E.ON to implement a standardised network control system across its distribution grid (PSI 2025). Envelio (Cologne), an RWTH Aachen spin-off, provides an intelligent grid platform that, according to the company, now covers around 50% of the German distribution network (envelio 2026b). SAE IT-systems (Cologne) supplies remote terminal units and substation automation for distribution grids (PPC 2025). Germany also maintains a specialised domestic smart metering industry. Smart Meter Gateways certified under the German security framework are developed and manufactured primarily by medium-sized German technology companies, including Power Plus Communications (PPC) and Theben Smart Energy. In addition, companies such as Robotron Datenbank-Software provide backend and data management solutions supporting smart metering and digital energy market processes. This ecosystem reflects Germany's emphasis on secure, interoperable and domestically developed smart-grid infrastructure.

Germany is a significant exporter in selected product groups, notably switchgear, where Siemens is a global market leader (Marketsandmarkets 2025), and industrial enclosures and control cabinet systems, where Rittal (Herborn) is a major international supplier (Siemens). PPC AG also exports BSI-certified smart meter gateways, a product category of growing interest to markets developing comparable certification frameworks. At the same time, Germany depends on imports for key components, particularly semiconductors and power electronics used in inverters, meters, and control devices, as fabrication capacity is concentrated in Asia despite domestic designers such as Infineon (Mordor Intelligence 2026). Battery cells for stationary storage are also predominantly imported (GTAIC 2025). Further upstream, critical raw materials such as lithium, cobalt, nickel, gallium, germanium, and rare earths are still sourced largely from China, though efforts are underway to reduce this dependency (McGovan and Wehrmann 2025). These supply dependencies are increasingly recognised as a strategic concern for grid modernisation.

Smart-grid-enabled business models are developing along two main tracks. In the consumer segment, the key drivers are VPPs and dynamic tariffs, which incentivise households with EVs, heat pumps, and storage to shift consumption. Aggregators such as Next Kraftwerke, Ostrom, and Flexa bundle these assets into VPPs for balancing and spot market participation (Flexa 2025; Next Kraftwerke 2022; Ostrom 2024). In the industrial sector, companies leverage flexibility from their own assets, optimise energy procurement against spot market prices, and stack revenues across balancing, intraday, and congestion management markets (Pant and Belz 2026). Neighbourhood-scale microgrids such as Smart Quart demonstrate technical feasibility but remain limited to pilot projects.

3. Overview: Korea

In Korea, the need for smart electricity grids arises from the profound transformation of the power system. Key drivers include the (currently still limited) expansion of variable renewable energies, the continued development of nuclear power, and the gradual decline of coal-fired generation. At the same time, maintaining a reliable and inexpensive power supply for large industrial consumers remains a priority. Smart grids are thus gaining importance to reduce peak demand, optimise load patterns, lower transmission and distribution losses, improve the integration of renewable energy, and shorten outage durations. More broadly, Korea Electric Power Corporation (KEPCO) explicitly links the need for such infrastructure to the decarbonisation, decentralisation, digitalisation, and deregulation of the power sector, as well as to rising demand for load management, more effective use of data, and new market models such as power purchase agreements and virtual power plants.

3.1 Market structure

In Korea, transmission, distribution, and retail supply remain dominated by the state-controlled utility KEPCO. Reform has been largely confined to the generation segment, where KEPCO's former generation assets were split into several Power Generation Public Corporations (GENCOs). At the same time, the generation mix also includes private and independent power producers, which participate alongside the public GENCOs in the wholesale market. Electricity is traded through a central wholesale market operated by the Korea Power Exchange (KPX), in which KEPCO acts as the single buyer (Chambers and Partners 2025). Retail prices are set by regulation rather than competition among suppliers. Households pay regulated tariffs according to an official rate schedule established by the relevant authorities. Regulated KEPCO tariffs also apply to industry; however, large customers may in certain cases have specific contractual arrangements (Institute for Energy Economics & Financial Analysis 2024; KEPCO 2026a). Households in Korea currently pay KRW 161.820 per kWh (9.4 EUR Cent/kWh)[2] for electricity. For businesses, the price is slightly higher, at KRW 173.982 per kWh (10.1 EUR Cent/kWh) (Global Petrol Prices 2026). Market-based, wholesale-price-indexed real-time pricing (RTP) does not exist. Supplier switching is not possible for households or small and medium-sized commercial customers, as no competitive retail market exists. Large industrial consumers, however, have limited options to procure electricity directly through the KPX, bypassing KEPCO (Kim 2025b).

Innovations in pricing are taking place within this regulated framework. Korea already uses differentiated electricity tariffs by time of day and season in parts of the KEPCO tariff system, particularly for industrial and other non-residential customers with relevant metering and tariff arrangements (KEPCO 2026a). From 16 April 2026, Korea will introduce a new time-of-use electricity pricing system that makes electricity cheaper during the day and more expensive in the evening. (Nahum 2026).

3.2 National targets and legal framework

Several legal acts and regulatory provisions shape the deployment of smart grid technologies, concepts, and standards. The most significant are outlined below.

The **Smart Grid Construction and Utilization Promotion Act** provides the core statutory framework for smart grid deployment in Korea. It defines smart grids and smart grid information, requires the government to establish a master plan every five years and annual implementation plans, and provides the basis for conversion plans, registration of smart grid business entities, public support measures, certification, and standardisation. In this sense, the Act functions as the principal enabling framework for the deployment of smart grid infrastructure, services and related digital technologies in Korea. In addition, it establishes the legal basis for the collection and management of smart grid information, prescribes protective measures for personal data, and sets out prohibitions on unauthorised system intrusions, among other requirements (MOLEG).

The **Electricity Business Act** provides the broader regulatory basis for the operation and planning of the electricity sector. Under this framework, a Basic Plan on Electricity Supply and Demand is established every two years, covering the long-term direction of electricity supply and demand, major generation and grid infrastructure needs, and demand management over a 15-year period. In practice, this makes the Electricity Business Act a key framework for grid investment, tariff design, demand response and the integration of distributed and renewable energy resources in Korea (Kim&Chang 2023).

At the policy level, Korea has pursued smart grid deployment through long-term planning instruments since the 2010 **Smart Grid Roadmap**. The roadmap promotes the development of AMI, energy storage

[2] 1 KRW = 0,00058 EUR

systems, and demand response programs, with compliance requirements for utilities to adopt real-time monitoring and control systems (Geetanshi 2025). Korea aimed to achieve full AMI coverage in all newly constructed residential buildings and to equip more than 50% of existing buildings by 2022, with a target of 100% AMI coverage across all sectors by 2025. The rollout of AMI depends on electricity meter ownership: KEPCO is responsible for installing AMI for approximately 22.5 million meters, while private operators install AMI for around 11 million meters.

The current **Third Basic Plan for Smart Grids (2023–2027)** continues this approach and focuses on VPPs, demand response, smart metering, time of use tariffs, grid digitalisation, microgrids, prosumer participation, and standards and certification. These planning instruments therefore translate the general legal framework into concrete implementation priorities for smart grid rollout (MOTIE 2023).

The Basic Guidelines on Protective Measures for Smart Grid Information set out the data protection framework applicable to smart grid environments. The provisions cover general principles governing personal information, rules on data collection, and restrictions on its use, thereby complementing the statutory requirements established in the aforementioned Act (MOLEG).

The Cybersecurity Guidelines for Smart Grids address smart grid interconnection models, security threats including attack scenarios involving AMI and corresponding security measures, among other topics (NCSC 2026).

3.3 Deployment status of key technologies

This section presents qualitative and quantitative information on the deployment of smart grid technologies in Korea, following the categories established in section 1. It aims to provide a representative snapshot rather than an exhaustive overview.

3.3.1 Metering Technologies

In Korea, smart meter deployment is generally discussed as part of the rollout of AMI rather than as a standalone metering category. For the metering points operated by KEPCO (22,5 million of the total 33,5 million), deployment had reached around 20.05 million installed units by 2024, which is approximately 90 % of the 22.5 million targets. According to secondary sources, the coverage rate for the 11 million metering points operated by private operators remains low (Song 2026). The Korean rollout has been characterised by a utility led implementation model under KEPCO, supported by central planning and policy direction, which has contributed to comparatively high penetration rates (Mordor Intelligence 2025; KTC 2024; Son Cha-min).

From a metering technology perspective, Korea's deployment indicates large-scale use of digital interval metering within an integrated AMI architecture. This supports functions such as remote meter reading, automated data collection, and improved visibility of electricity consumption patterns. Overall, Korea's near nationwide smart metering rollout appears highly advanced.

3.3.2 Communications Infrastructure

Korea uses a mix of communication technologies to support smart metering and wider digital grid applications. PLC remains an important component of the Korean AMI, as it enables data transmission through existing electricity infrastructure. Radio frequency mesh technologies are also used in some applications, particularly where wireless communication offers operational advantages for local data exchange (WM Systems LLC 2025).

Cellular networks are becoming increasingly important as Korea links smart grid development with its broader digital communications strategy. In particular 5G (e-Um 5G) is seen to improve data transmission, device connectivity, and communication with DER and other smart grid applications. These newer mobile network capabilities complement rather than replace established utility communication systems (KCA; Park).

This combination of established utility communications technologies and newer digital network capabilities strengthens Korea's ability to support large-scale data transmission and real time grid management.

3.3.3 Digital grid infrastructure, monitoring and control

Korea has developed an advanced digital infrastructure for grid monitoring and operational control, supported by a highly centralised institutional structure.

The digitalisation of substations is also advanced. KEPCO has gradually transformed conventional substations into digital facilities and has shifted from manual local operation towards more centralised management through digitally connected dispatch structures. All 154 kV substations built since 2013 have reportedly been designed as digital installations based on the IEC 61850 standard. As of 2023, around 200 such sites were either in operation or under construction (KEPCO 2024).

A distinctive feature of Korea's smart grid development is the strong role of microgrids. These have been used not only to supply remote areas but also as demonstration spaces for more advanced smart grid applications. Their use has expanded into Smart Town and Smart City concepts and has also been reflected in the legal and policy framework. In this respect, Korea places greater strategic emphasis on microgrids than many other countries (Nautilus 2020).

Advanced distribution management has also progressed significantly. Building on the existing Distribution Automation System, KEPCO developed the Korean Smart Distribution Management System as an integrated platform for monitoring and controlling the distribution grid. Following nationwide deployment across regional headquarters and distribution centres, the system supports real time monitoring and control of a large number of automated switching devices and strengthens outage management and operational responsiveness (Yun et al. 2014). Beyond refining domestic operations, KEPCO is now actively pursuing global technology expansion into international markets, including North America (Kim 2025a).

Supporting platforms further expand Korea's digital grid capabilities. These include xGrids, which combines grid analysis and intelligent application functions, and the Smart Metering Data Platform, which enables the analysis and operational use of large-scale AMI data (KEPCO 2026b; KEPCO KDN 2025). Overall, Korea's approach places strong emphasis on integrated control, digital substations, and distribution automation within a centrally coordinated grid architecture.

3.3.4 Data Analysis

Korea has moved beyond pilot projects to embed data analytics into operational electricity system and market operations, with forecasting, AMI-based data use, and predictive maintenance as the applications particularly in demand.

For load management, KPX operates demand forecasting models as part of its role in electricity market operation, power system operation, and real time dispatch. According to KPX, these models include panel models, time series models, structural break models, and micro models for electricity consumption, as well as macro and time series approaches for peak demand forecasting. This provides an established analytical basis for short- and long-term supply demand planning (KPX 2026).

For data use on the distribution and customer side, KEPCO KDN describes Korea's AMI as a source of meter big data that supports real time billing information and analytic forecasts for demand management. This suggests that AMI data in Korea is used not only for metering, but also as an analytical input for broader power system and retail functions (KEPCO KDN 2026).

Korea has developed notable applications of asset health analytics in the electricity sector. One prominent example is the Intelligent Digital Power Plant platform, which uses large volumes of sensor data for predictive maintenance and operational optimisation in power plants (Power 2024). Recent developments involving KEPCO KDN further indicate growing interest in digital twins and AI-based predictive analytics for wider energy system applications (ABB 2025).

3.3.5 Cybersecurity and Data Protection

Korea has a stringent legal and technical framework for the protection of critical national infrastructure. The Act on the Protection of Critical Information and Communication Infrastructure classifies smart grids as a primary core element within this framework and is subject to the most rigorous administrative requirements. Under this legal framework, the responsible administrative institutions are obliged to conduct annual technical vulnerability analyses and assessments. In addition, they must submit comprehensive protection plans to the central administrative authorities and undergo regular compliance audits to ensure continuous security (KLRI 2024).

In the smart metering context, AMI technologies are also subject to structured conformity procedures. Smart meters must satisfy both metrological accuracy requirements and security related certification requirements before deployment. Testing and certification are carried out by nationally accredited institutions, including KTC, KTL, and KERI. Overall, this links smart meter deployment to a formalised regime of technical verification and security control (KTC 2026).

Data protection is an important additional layer of the Korean framework. The Personal Information Protection Act provides the general legal basis for the processing and protection of personal data, applying where no sector-specific rules take precedence (KLRI 2020). The Smart Grid Construction and Utilization Promotion Act complements this by explicitly embedding the creation and use of smart grids - including the collection, use, and protection of smart grid information within this broader information protection framework (MOLEG).

3.4 Industry structure and business models

Korea has significant industrial strength in grid-related hardware, particularly in high-voltage and extra-high-voltage transformers, power cables, and power converters. In establishing the K-Grid Export Alliance, the Korean Ministry of Trade, Industry and Energy explicitly highlighted these segments, as global competitive strength of the Korean grid industry. Leading companies include Hyosung Heavy Industries, HD Hyundai Electric, LS Electric and LS Cable & System (Yu 2024; Kan).

An important segment is grid software and operational control systems. Korea has developed considerable expertise in digital grid management platforms, including distribution management systems, intelligent data platforms, and power plant analytics. As these technologies mature domestically, Korea is increasingly seeking to commercialise them abroad. According to recent strategy reporting, KEPCO is using the domestic deployment of K ADMS and related digital platforms as a basis for international market expansion (Choi Eun-hwa 2025).

Korea is actively expanding its export position in selected smart grid software and digital operations technologies. Recent examples include the export of an Intelligent Digital Power Plant platform to Vietnam (Sukyee 2026). These developments suggest that Korea's competitive advantage extends beyond hardware manufacturing to encompass software-based grid operation, integrated control systems, and utility oriented digital platforms.

4. Conclusion and Cooperation Potentials

Germany and Korea both regard smart grids as a necessary foundation for integrating more variable renewable power generation, increasing reliability and keeping electricity costs in check. At the same time, they are pursuing this objective from very different institutional settings. Germany is digitalising a liberalised and highly fragmented electricity system with more than 800 DSOs, strong data protection requirements and growing pressure to activate flexibility from households and industry. Korea is modernising a far more centralised system in which KEPCO retains a dominant role in transmission, distribution and retail supply, supported by regulated tariffs, national planning and coordinated utility implementation. These structural differences explain much of the contrast in deployment outcomes. Germany has established a detailed framework for secure and interoperable smart grids, but rollout has been slow. Intelligent metering systems cover only 5.5% of metering points, and only around 30,000 of roughly 500,000 local substations had been digitalised by 2025. Korea, by contrast, had installed around 20.05 million AMI units by 2024, deployed advanced distribution management nationwide and made faster progress on digital substations and microgrid based applications.

The comparison nevertheless shows complementary strengths. Korea's approach allows metering, tariff design, distribution automation and system planning to be embedded in a tightly coordinated institutional framework which has enabled rapid nationwide deployment. The Korean Smart Distribution Management System has been rolled out across regional headquarters and distribution centres, and all 154 kV substations built since 2013 have reportedly been designed as digital installations based on IEC 61850. Germany's approach places greater emphasis on role separation, certified communications, cybersecurity and market participation. This has slowed physical deployment, particularly in smart metering, but it has also supported a broader ecosystem of suppliers, metering operators, aggregators and service providers. Germany has moved further in the development of smart grid-enabled services and business models, especially around VPPs, dynamic tariffs and household flexibility.

One potential area for bilateral cooperation concerns the regulatory use of flexibility. Germany's experience may offer useful reference points for Korea regarding flexibility potentials, the services and business models that have emerged in liberalised electricity markets, and the regulatory conditions under which they became viable. This applies in particular to VPPs, dynamic tariff offers, household aggregation and the market integration of flexible assets such as electric vehicles, heat pumps, battery storage, distributed generation and industrial assets. The introduction of mandatory dynamic tariffs from 2025, together with Redispatch 2.0 and Section 14a EnWG, offers concrete lessons on how digital infrastructure can be linked to active system operation and flexibility procurement. Korea is not able to replicate the German model directly, given its vertically integrated market structure, but bilateral exchange on specific regulatory design questions could be highly valuable, including regarding the role of aggregators, rules for secure third-party data access, incentives for load shifting and the testing of local flexibility services within a regulated environment.

Germany, in turn, could draw practical lessons from Korea's smart meter rollout. The main lesson is not market centralisation, which would not fit the German system, but institutional coordination and harmonisation of technical requirements. Korea's experience suggests that rollout progresses more quickly when responsibilities are clearly assigned and standards are aligned at an early stage. This is particularly relevant in Germany, where high certification requirements and fragmented implementation have created persistent bottlenecks, and where debate continues over simpler and more cost-effective rollout models. Germany could also examine how Korea linked AMI deployment with data platforms and distribution automation, creating operational value earlier in the rollout process.

From a policy perspective, cooperation would be most useful if organised around a limited number of concrete topics. First, ministries, regulators and implementing agencies could establish a **structured exchange on incentive structures, controllable loads, AMI data governance and interoperability rules**. Second, both countries could support **joint pilot projects** involving German DSOs, aggregators and software firms together with KEPCO, KPX and Korean technology providers, for example **on activation of flexibility potentials or low-voltage grid observability**. Third, **cybersecurity and conformity assessment** offer a concrete field for mutual learning. Germany's BSI certification framework for smart metering is among the most demanding internationally, while Korea's treatment of smart grids as critical national infrastructure, including mandatory annual vulnerability assessments, offers a useful model of system-wide security governance.

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Implementing Organization:
adelphi consult GmbH
Address: Alt-Moabit 91, 10559 Berlin
Phone: +49 (30) 8900068-0
Email and website: office@adelphi.de;
https://adelphi.de/de

Author: Beyza Adak, Miha Jensterle

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adelphi uses AI-assisted tools as part of its standard data processing workflow. All data processing occurs within the European Union. The service provider does not retain data beyond the session and does not use input data for model training. Data Processing Agreements are in place with both the platform provider and underlying model providers. Staff receive mandatory training on responsible AI use, and all usage complies with GDPR, the EU AI Act, and applicable client-specific contractual requirement.

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