



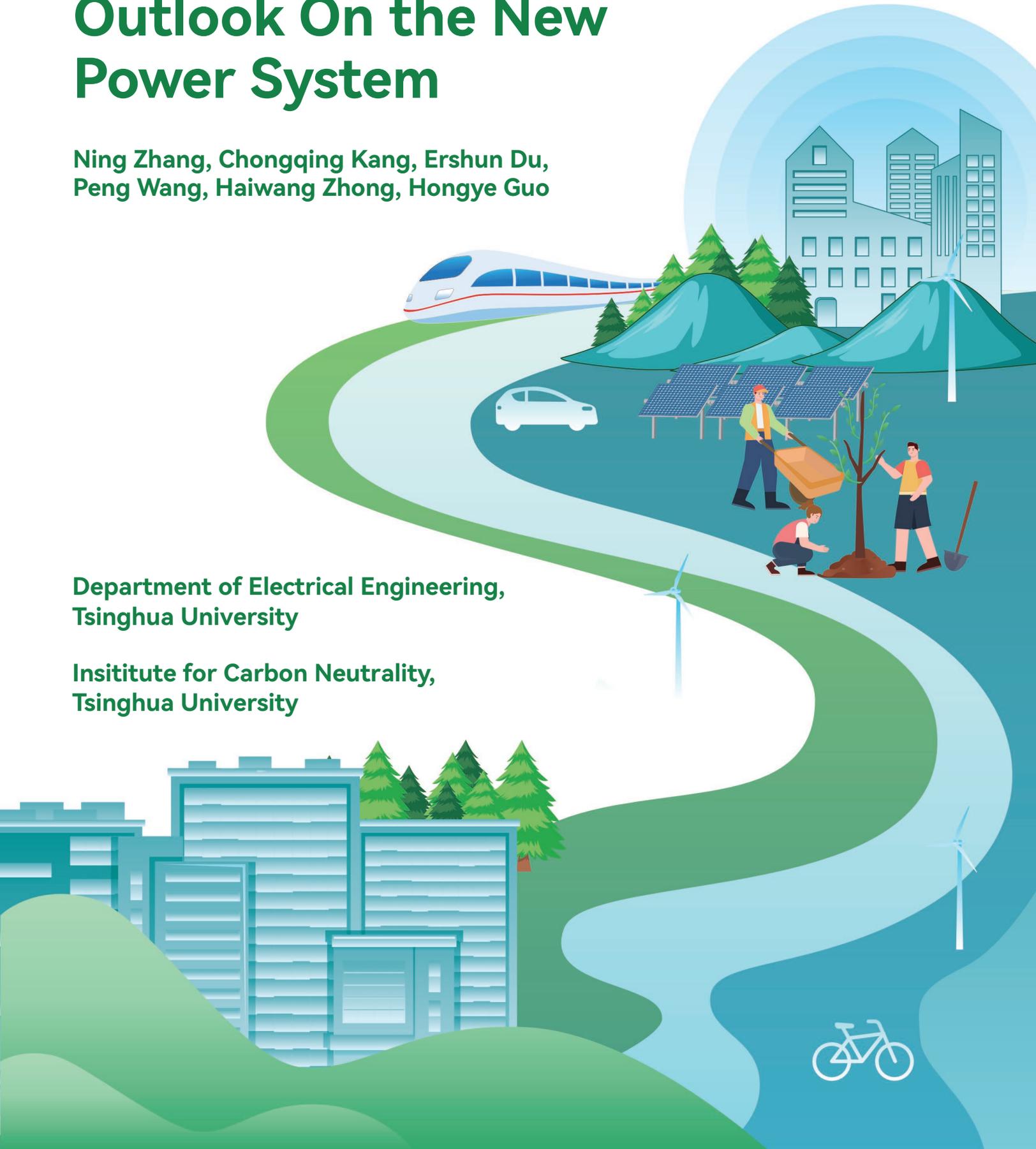
清华大学 碳中和研究院  
Institute for Carbon Neutrality, Tsinghua University

# Technology Roadmap Outlook On the New Power System

Ning Zhang, Chongqing Kang, Ershun Du,  
Peng Wang, Haiwang Zhong, Hongye Guo

Department of Electrical Engineering,  
Tsinghua University

Institute for Carbon Neutrality,  
Tsinghua University





**Abstract:** Power system decarbonizing is crucial for achieving the "carbon peaking and carbon neutrality goals", which has led to the proposal of a new power system. This paper outlines the vision and implications of constructing a new power system, defining its development goals and pathways under carbon neutrality targets. It analyzes eight key technological areas: renewable energy integration, new electricity transmission, flexible distribution networks, smart consumption and supply-demand interaction, energy storage regulation, grid digitalization, operation optimization, and carbon accounting. The paper summarizes critical supporting technologies, evaluates current development levels, introduces existing demonstration projects, identifies technological challenges, and predicts future trends. It presents a road map for future technological advancements and offers policy recommendations from the perspectives of generation, grid, load, storage, digitalization, and carbon. By clarifying the state of power system development and identify key issues, this paper provides decision-making references for the construction of a new power system in China and the establishment of a carbon neutrality road map in the country.

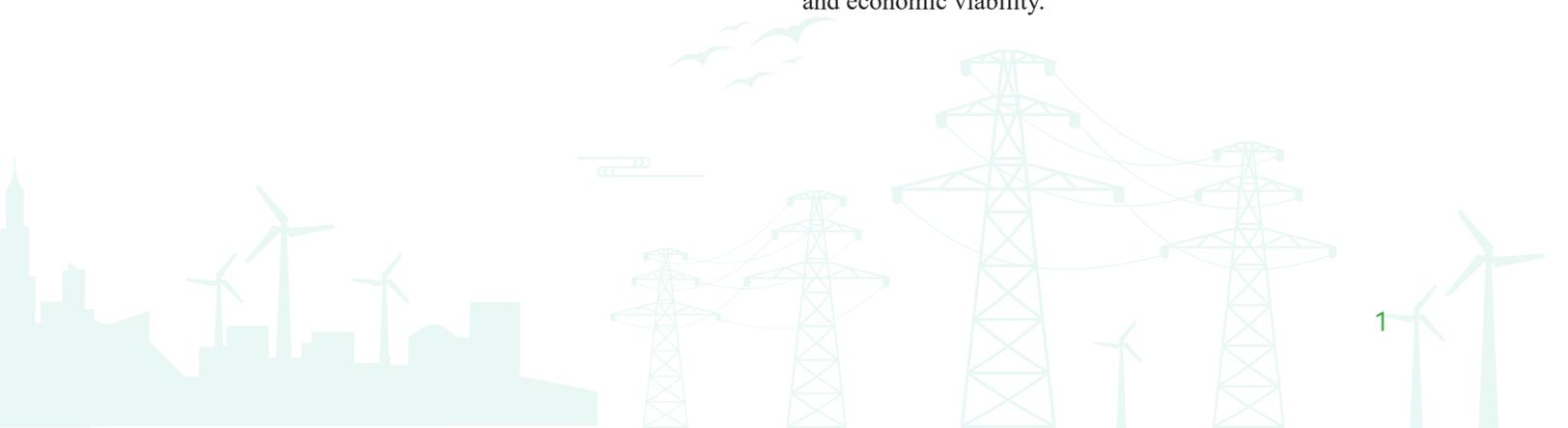
**Key words:** New power system; Carbon peaking and carbon neutrality; Renewable energy; Road map



## Outlook on the Technical Pathways of the New Power System

As traditional fossil energy sources become increasingly scarce, the challenges posed by greenhouse gas emissions and pollution from fossil fuel combustion are intensifying. At the same time, energy security concerns are on the rise. In this context, global consensus is shifting towards green development. This shift accelerates the achievement of "carbon peaking and carbon neutrality goals". To achieve these goals, China must implement electrification across various sectors, including industries, buildings, and transportation. This makes the "decarbonization of the power system" and the "electrification of end-use sectors" essential. In 2021, China proposed the establishment of a new power system dominated by renewable energy. This initiative significantly contributes to its carbon neutrality efforts.

The core essence of this new power system can be summarized as safe, low-carbon, and efficient. Its fundamental premise is to ensure a secure supply of electricity. Renewable energy will serve as the primary source, promoting green electricity consumption. This system centers around the grid and features several significant characteristics, including green, safe, intelligent, open, digitally empowered, and economically efficient. These characteristics are achieved through the complementarity of multiple energy types and the interaction of energy sources, grids, loads, and storage. Digital technologies will be employed to manage resources holistically. They will improve scheduling mechanisms and enhance flexibility, safety, and operational efficiency, aiming to meet the comprehensive goals of secure electricity supply, green consumption, and economic viability.



Compared to traditional power systems, the structure of the new power system will undergo significant changes. On the generation side, renewable energy will become the primary source for electricity generation, while fossil fuels will mainly focus on power balancing. On the grid side, there will be an integration of large power grids and distributed smart grids. On the demand side, there will be increased diversification and flexibility, along with active participation in energy consumption. Regarding storage, a shared system will integrate various temporal and spatial resources.

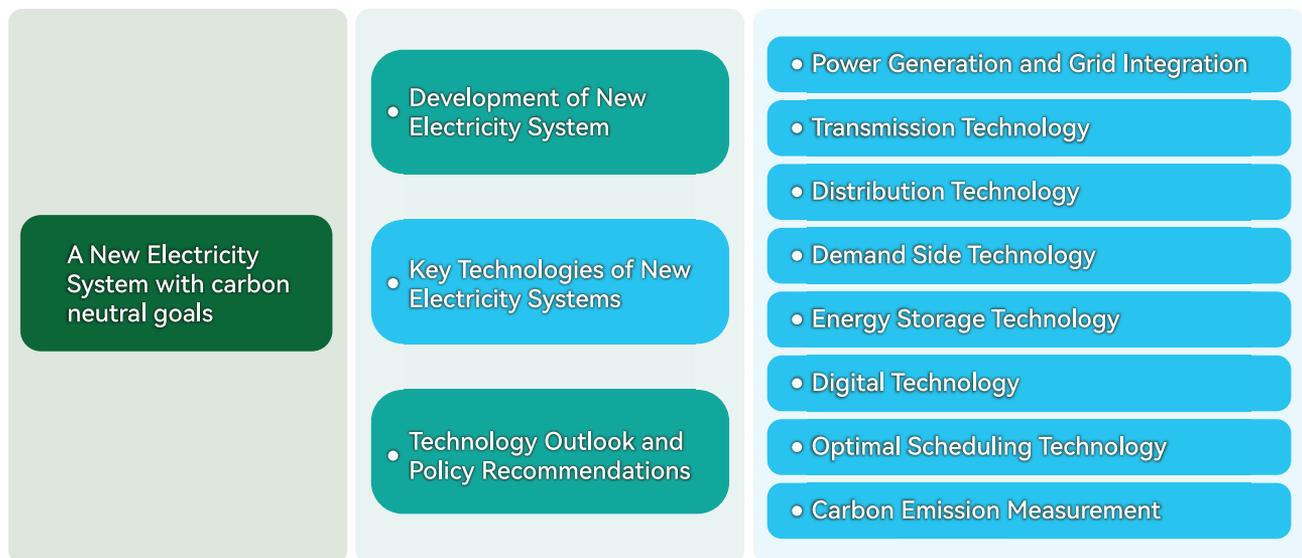


The structure of the new power system will undergo significant changes, shifting from a single energy structure to multi-energy complementarity. It will transition from traditional power systems to cloud-edge interconnections, moving from isolated systems to a peer-to-peer energy system. The system will evolve from deterministic to uncertain frameworks, and from electromechanical dominance to electromechanical-electromagnetic coupling. Additionally, it will transform from traditional power systems to energy internet systems, and from a focus on electricity to a perspective that integrates carbon and electricity.

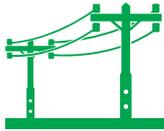
The evolution of the power system can be categorized into three stages. The first is the carbon peaking and platform stage, which is expected by 2030. This stage focuses on utilizing existing technologies and addressing key institutional challenges. The second stage is the rapid reduction phase, which will take place from 2031 to 2050. This phase will emphasize technological innovation and deep transformations in energy sources, grid structures, usage methods, and institutional mechanisms. The final stage is the carbon neutrality stage, which will occur post-2050. At this point, various technologies and applications will have matured.

Throughout the construction of the new power system, several significant strategic needs and scientific challenges remain. On the generation side, there is simultaneous pressure from integrating renewable energy and ensuring power supply stability. This creates substantial regulatory challenges. On the grid side, the high proportion of power electronics due to renewable energy integration poses unprecedented challenges to safe and stable operations. On the demand side, the blurred boundaries between generation and consumption increase controllable elements. This necessitates enhanced regulatory capabilities. On the storage side, existing technologies struggle to meet the strategic demands of high renewable energy integration. Therefore, breakthroughs in new storage technologies that are safe, durable, and cost-effective are required.

This paper is structured as follows: Chapter 1 clarifies the core essence, structural evolution, and development stages of the new power system. Chapters 2 to 8 discuss key technological systems and development needs, as figure 1 shows. Finally, Chapter 9 summarizes the technological development goals and road map for the new power system, offering policy recommendations from multiple perspectives.



**Fig.1 Key Technologies at Various Stages of the New Power System**



## Supporting Technologies for High Penetration of Renewable Energy in New Power System

Renewable energy sources like wind and solar power exhibit significant randomness and volatility. Additionally, the power electronics in renewable energy generation differ markedly from traditional power sources, leading to challenges in forecasting, control, and scheduling.

This chapter introduces supporting technologies for high penetration of renewable energy that enhance the capacity to integrate renewable energy and supports system stability and security. These technologies address the randomness and volatility of renewable generation, enabling it to match the support and adjustment capabilities of primary power sources, which is essential for achieving carbon neutrality in power systems.

High-precision multi-time scale power forecasting technology for renewable energy predicts the output of renewable sources such as wind and solar energy, providing accurate forecasts across different timescales to help the grid manage the volatility and uncertainty of renewable generation. This technology must overcome three technical barriers: 1) develop fine modeling techniques for analyzing the impact of terrain, cloud distribution, meteorological conditions, and wake effects on power output; 2) implement online interactive forecasting technology that allows for dynamic adjustment of models and parameters; 3) create forecasting techniques covering ultra-short, short, medium, and long-term periods.

Grid-connected control technology for renewable power considering generator and grid coordination utilizes various power resources with advanced control and optimization methods to efficiently coordinate renewables and traditional sources, ensuring safe and stable grid operation. This technology needs to address two technical challenges: 1) develop collaborative control techniques to enhance the overall efficiency of wind-solar-thermal systems in China, facilitating refined scheduling and emergency control; 2) improve control capabilities at renewable sites to actively support grid peak-shaving, frequency response, and other critical functions.

System-friendly reliable replacement technology for new energy power plants enhance the friendliness and reliability of renewable plants, ensuring they possess proactive control capabilities similar to synchronous sources to support voltage and frequency stability and provide reserve capacity. This technology must overcome two technical hurdles: 1) optimize large-scale renewable resource storage configurations to improve storage utilization and cost recovery; 2) develop integrated proactive control technologies for renewable plants that enhance system stability, focusing on inertia support, frequency control, and voltage control.



Active support technology for grid-forming renewable power plants aims to enhance the proactive support capabilities of renewable plants, providing ancillary services similar to traditional power plants to improve grid stability and reliability. This technology faces three key challenges: 1) analyze the dynamic behavior and synchronous stability of grid-forming converters over multiple timescales and develop control strategies for high-proportion grid-forming renewable generation applicable under various grid conditions; 2) address protection, control, and fault-ride-through techniques for grid-forming renewable units during symmetrical and asymmetrical faults; 3) develop methods for coordinating a large number of converters under complex dynamic system conditions.





## Power Transmission and Flexible Smart Distribution Network Technologies for New Power Systems

Transmission technology is essential for transferring electrical energy from power plants to users, efficiently and safely delivering renewable energy to load centers. It enhances energy supply, improves grid flexibility and reliability, and better manages the volatility of renewable energy, supporting stable operation and energy transition in power systems.

DC grid transmission technology, based on flexible multi-terminal DC systems, effectively addresses the challenges of integrating and dispatching large-scale renewable energy, serving as a hub for new power systems. Key technical barriers to overcome include: 1) developing converters with self-clearing capabilities for DC faults; 2) creating high-voltage, high-capacity DC circuit breakers and transformers; 3) investigating the integration of DC grids with AC grids, their fault response characteristics, and interaction mechanisms.

New flexible AC transmission technology combines power electronics and modern control techniques for rapid, flexible control of AC transmission system parameters. This technology can quickly adjust grid parameters, optimize power transfer paths, respond swiftly to grid fluctuations, suppress oscillations, and enhance both dynamic and transient stability, alleviating congestion on transmission lines and increasing the utilization of existing networks, thereby reducing reliance on new lines. Key technical barriers include: 1) developing multifunctional FACTS technologies and hybrid FACTS topologies; 2) researching wide-band oscillation and harmonic sensing and monitoring techniques; 3) advancing active support systems for multi-scenario applications and resilient grid-forming equipment; 4) investigating key technologies for voltage regulation and flexible overvoltage suppression.

Flexible low-frequency transmission technology merges low-frequency AC transmission with flexible transmission advantages, aiming to enhance the efficiency and reliability of long-distance power transmission. Key barriers include: researching suitable scenarios and configurations for flexible low-frequency systems; developing flexible control support and protection technologies; creating core equipment like converters; and conducting system and equipment testing.

High-temperature superconducting transmission technology utilizes high-temperature superconducting materials for power transmission, exhibiting zero resistance at liquid nitrogen temperatures for lossless energy transfer. Key technical barriers include: 1) developing low-cost, industrial-grade high-temperature superconducting tape production techniques; 2) creating efficient, economical cryogenic technologies for long-distance applications; 3) developing long-term operation and maintenance techniques for superconducting systems.

UHV transmission technology under extreme conditions addresses key challenges in constructing ultra-high voltage transmission projects in harsh atmospheric environments, high altitudes, and complex terrains. This technology is strategically significant for developing and utilizing renewable energy bases in remote areas. Key technical barriers include: researching external insulation characteristics and configuration techniques for ultra-high voltage systems in high-altitude environments, predicting and controlling electromagnetic and noise issues, and developing critical technologies for ultra-high voltage equipment.

In a new power system, innovative distribution technology plays a crucial role. As the energy structure transforms and electricity demand grows, traditional distribution networks face challenges such as improving supply reliability, optimizing energy efficiency, and integrating distributed renewable energy. To address these challenges, new distribution technologies have emerged, enhancing the intelligence and automation of distribution networks and providing technical support for a more flexible, reliable, and efficient power system.

Flexible AC/DC distribution network technology combines the advantages of both AC and DC systems, allowing for flexible conversion and distribution between them, thereby enhancing grid reliability, flexibility, and stability. Key technical barriers include: 1) leveraging multi-source data integration to extract critical information; 2) developing multi-voltage fault localization and current-limiting technologies based on multi-feature assessment and networked information.

Situational awareness technology for smart distribution networks uses advanced sensors and data analytics for real-time monitoring and assessment of distribution network operations. By analyzing grid data in real time, it can promptly identify anomalies and potential faults, enhancing grid safety and reliability. Key challenges include improving observability through optimized measurement configuration, synchronized phasor measurement optimization, and developing advanced measurement systems.

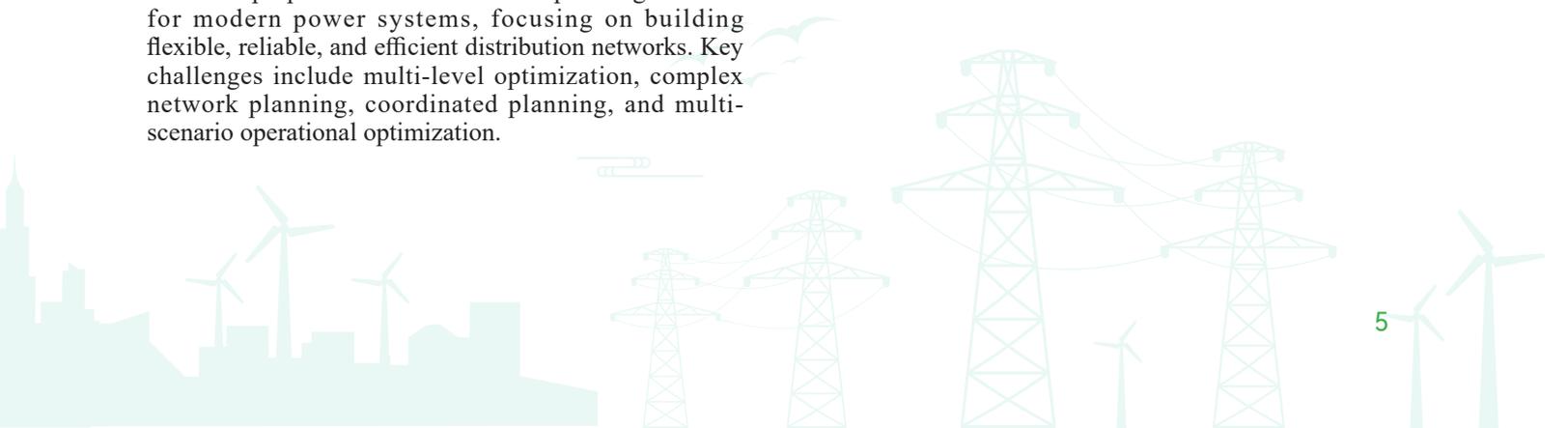
Distribution IoT technology connects and manages distribution network devices through IoT solutions. Utilizing sensors, communication networks, and data analysis platforms, it enables real-time monitoring, remote control, and intelligent maintenance of equipment, improving operational efficiency and reliability while reducing fault rates and maintenance costs.



Integrated energy system technology for distribution networks aims to combine electricity, heat, and gas for efficient resource utilization, enabling multi-energy complementarity and coordinated optimization. Key barriers include addressing the uncertainties and multi-agent dynamics of integrated energy systems.

New forms and planning technologies for distribution networks propose new structures and planning methods for modern power systems, focusing on building flexible, reliable, and efficient distribution networks. Key challenges include multi-level optimization, complex network planning, coordinated planning, and multi-scenario operational optimization.

Distribution network protection technology ensures safe operations by rapidly detecting and isolating faults to prevent escalation. Modern protection systems employ intelligent relay protection devices, circuit breakers, and automatic reclosers, combined with advanced fault detection and localization algorithms, to respond swiftly to incidents. Key technical challenges include analyzing fault characteristics considering the nonlinear responses of power electronic devices.



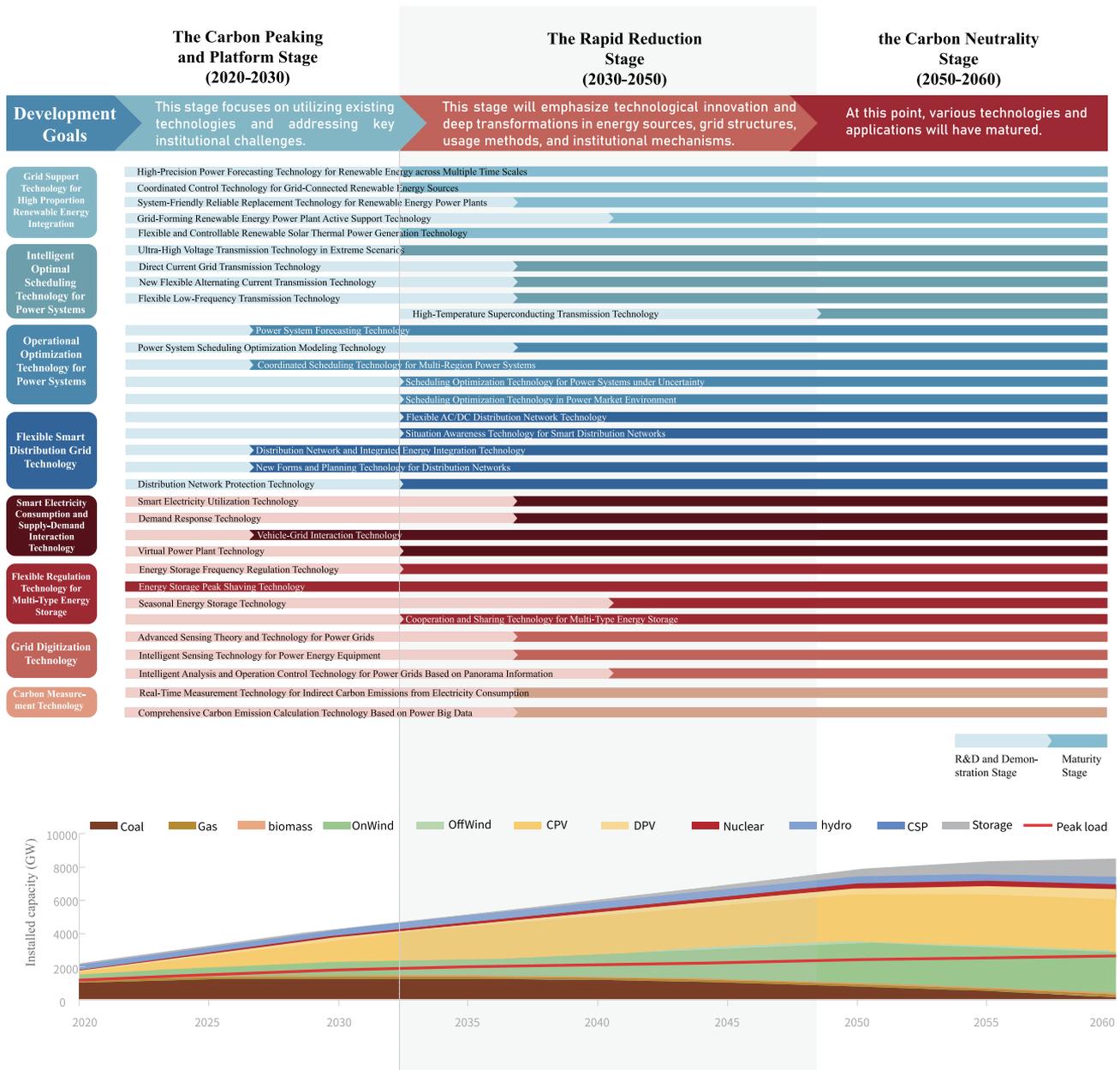


Fig.2 Technology Roadmap for the New Power System



## Smart Consumption and Supply-Demand Interaction Technologies

Smart consumption and supply-demand interaction technology refers to the ability to adjust electricity usage behaviors to meet power system demands. The increasing share of renewable energy and intermittent loads on the user side heightens the requirements for flexible regulation in power systems. The traditional "supply follows demand" operation model urgently needs to transition to "source-load interaction" to address real-time supply-demand balancing challenges. Research indicates that during rapid emission reduction and carbon neutrality phases, responsive system loads should comprise about 25% of the maximum load and contribute over 15% to electricity balance, making them essential for carbon neutrality in power systems. Smart consumption and supply-demand interaction technologies provide technical support for this new operational mode, with key technologies including smart consumption, demand response, vehicle-grid interaction, and virtual power plant technology.



Demand response involves strategies and incentives for electricity users to reduce or shift their consumption during peak demand periods. Utilities or grid operators encourage users to decrease usage during high-demand times through price signals, incentives, or direct load control, alleviating grid pressure and balancing supply and demand. This technology not only enhances grid stability and reliability but also helps users save on energy costs. Key technical challenges in demand response include designing interaction mechanisms that accommodate a growing variety of participants and ensuring timely integration with electricity market mechanisms.

Smart consumption employs advanced measurement, efficient control, high-speed communication, and rapid storage technologies to create real-time interaction between the grid and customers' energy, information, and business flows. Implementing demand response and virtual power plant technologies requires equipping users with smart devices and terminals. Major technical barriers include efficient analysis methods for vast amounts of electricity consumption data. While smart meter technology has advanced, the extensive and complex data collected from smart terminals necessitates the development of techniques for collecting, integrating, mining, and intelligently analyzing user consumption data to uncover interactive potential and support supply-demand interaction.

Vehicle-to-grid connects electric vehicles with the grid through bidirectional charging and discharging systems, facilitating energy exchange that enhances grid stability and flexibility. This technology also offers additional income for electric vehicle users while promoting renewable energy utilization. Key technical challenges include designing mechanisms and control strategies that effectively address the large-scale uncertainties in electric vehicle user decisions, and leveraging transportation network analysis to exploit decision-making patterns.

virtual power plant(VPP) integrates distributed energy resources and adjustable loads using information and communication technology to create a dispatchable comprehensive energy system, providing services similar to traditional power plants, such as peak shaving, frequency regulation, and backup power. VPPs improve the efficiency of distributed energy utilization, enhance the flexibility and reliability of power systems, and promote sustainable energy development. Core technical challenges for virtual power plant technology include efficiently coordinating and controlling diverse resources and managing energy to meet grid operational needs while optimizing internal energy management and enhancing utilization efficiency.



## Flexible Regulation Technologies for Multi-Type Energy Storage in New Power Systems

In the new power system, renewable energy exhibits volatility and intermittency, and energy storage systems play a crucial role in smoothing output fluctuations, enhancing the utilization of renewables, and significantly improving the flexibility and reliability of the grid. Therefore, storage technology is of exceptional importance in new power systems and serves as a core support for achieving smart grids and energy transition.

Frequency regulation with energy storage technology utilizes storage systems to rapidly respond to grid frequency changes, maintaining frequency stability in low-inertia power systems with a high share of renewable energy. Primary frequency regulation employs virtual inertia control and droop control methods to simulate the inertial response of traditional synchronous generators, reducing the initial rate of frequency change and the maximum frequency deviation during disturbances. Secondary frequency regulation leverages the rapid response, precise tracking, and excellent power characteristics of energy storage stations to adjust output and keep frequency deviations within specified limits during power or load shifts. Key technical challenges for frequency regulation include: (1) enhancing the frequency control performance of large-scale physical storage technologies (e.g., variable-speed pumped storage); (2) improving battery management capabilities in electrochemical storage; and (3) advancing the maturity and reducing investment costs of power-type storage (e.g., flywheel storage).

Peak shaving with energy storage technology uses storage systems to store energy during low-demand periods and release it during peak demand, effectively reducing peak load. This technology is vital for alleviating grid load pressure, optimizing power resource allocation, and improving grid operational efficiency, especially during peak loads and emergencies. Key challenges include lowering the costs of large-scale energy storage technologies and establishing a robust market revenue mechanism for storage participation in ancillary services, along with improving policy support to reduce non-technical costs.

Seasonal fluctuation smoothing technology employs long-duration energy storage systems (e.g., compressed air storage, pumped storage) to shift energy across seasons, addressing seasonal supply-demand imbalances. This technology can effectively tackle the seasonal fluctuations of renewable energy and enhance overall energy utilization efficiency. Key challenges include: (1) reducing the investment costs of new seasonal storage technologies (e.g., hydrogen storage); and (2) exploring economically viable, low-loss, and safe solutions for long-term energy storage and large-scale spatial transportation across different energy forms.



Coordination and sharing of multiple energy storage types technology integrates various storage technologies (e.g., electrochemical, mechanical, thermal) for collaborative optimization and resource sharing among different storage systems. This approach maximizes the advantages of diverse storage systems, providing more efficient energy management and dispatch services, thus improving overall performance and economic benefits. Key challenges include: (1) constructing a cloud storage operation platform to support safe and efficient interactions and collaboration among multiple storage types and users, ensuring flexible supply-demand matching and safeguarding storage and user information; and (2) developing replicable business models that ensure long-term stable profitability for multiple types of energy storage.



## Digital Technologies for Power Grids

Digital technologies in power systems encompass a range of tools and methods that enhance monitoring, management, optimization, and control capabilities through digitization. By utilizing real-time monitoring, intelligent analysis, and optimized scheduling, these technologies improve grid flexibility and adaptability, as well as power quality and supply reliability. Additionally, they facilitate user interaction with the grid, effectively addressing the limitations of traditional grids in managing the volatility of renewable energy and distributed energy resources.

Advanced sensing theory and technology for power grid utilize cutting-edge sensors to achieve precise monitoring and data collection of grid operating conditions. This enhances monitoring accuracy, enables rapid fault detection, and improves grid safety and stability, thereby supporting efficient management and operation of smart grids. Key technical challenges include: (1) in-depth research on the sensing mechanisms of weak signals for feature parameters, improving multi-parameter fusion sensing technology to meet diagnostic needs for electrical equipment defects; (2) enhancing sensor interference resistance, reliability, and lifespan in complex electromagnetic environments; and (3) developing low-power, chip-based miniature sensors.

Intelligent sensing technology for power equipment involves installing intelligent sensors on power devices to monitor operational states and environmental

parameters in real time. Combined with big data analysis and artificial intelligence, this technology evaluates and predicts the operational state of electrical equipment, allowing for timely detection of potential faults and anomalies. It improves equipment efficiency and reliability, extends lifespan, reduces maintenance costs, and ensures the safe and stable operation of power systems. Major technical challenges include: (1) in-depth research on multi-physical field information regarding defect occurrence and development, along with their spatiotemporal evolution; (2) establishing a distributed panoramic information sensing network within equipment; and (3) developing comprehensive theories and methods for multi-source data fusion in health diagnostics and lifespan predictions.

Smart grid operation and control technology based on panoramic information integrates comprehensive data about the grid for in-depth analysis and forecasting. This facilitates intelligent scheduling, optimized operation, and fault prediction, enhancing the operational efficiency and stability of the grid. Key challenges include: (1) improving data quality in complex wide-area systems and addressing data security issues; (2) developing theories and methods for user information perception and modeling in complex wide-area systems; (3) enhancing the credibility, interpretability, and transferability of AI-based power system analysis and control methods; and (4) improving analysis and control technologies for large-scale heterogeneous power devices.





## Intelligent Optimization Scheduling Technologies and Market Decision-Making in Power Systems

Optimization scheduling technology refers to the use of advanced mathematical algorithms and computational tools to monitor, manage, and optimize generation, transmission, and distribution resources in power systems in real time. Its core task is to arrange the operational status of generation and transmission equipment according to changes in electricity demand, coordinating the supply and demand of various power resources. In traditional power systems, it primarily aims to enhance generation and transmission efficiency, stabilize grid operation, and respond to faults. In modern power systems, it focuses more on supporting the integration of renewable energy, improving grid flexibility, facilitating smart demand response, and managing integrated energy.

Power system scheduling optimization technology for uncertainty handling addresses challenges arising from uncertainties such as renewable energy generation, load fluctuations, and equipment failures. It effectively reduces the impact of uncertainty on power system operation, improving system stability and reliability. The main technical bottleneck is to lower operational costs while ensuring system reliability, requiring precise modeling of renewable energy uncertainty to avoid overly conservative solutions while minimizing computational pressure.



Power system scheduling optimization modeling and solution technology develops mathematical models and optimization algorithms to enhance the economics and safety of power system scheduling. The main technical challenge is solving large-scale, non-convex, nonlinear power system scheduling models.

Multi-area power system coordinated scheduling technology optimizes the coordinated scheduling of interconnected power system regions, effectively utilizing cross-regional power resources to balance supply and demand differences between regions, thereby enhancing reliability and economic efficiency. Key challenges include: (1) industrial application of interactive coordination technology based on feasible regions of interactive power; and (2) industrial application of interactive coordination technology based on decomposed operations.

Scheduling optimization technology in power market environment optimizes generation plans and electricity trading strategies to achieve economically efficient operation of the power system. This technology considers factors such as market prices, generation costs, transmission constraints, and market rules, using optimization algorithms to develop optimal strategies for market participation. It promotes market competition, improves operational efficiency, and fosters the healthy development of the electricity market.



## Carbon Emission Accounting and Measurement Technologies in Power Systems

Carbon emission measurement technology in power systems aims to accurately measure and manage carbon emissions during the processes of generation, transmission, distribution, and consumption. These technologies utilize advanced sensors, data analysis, and real-time monitoring to provide detailed carbon emission data, helping power companies and users understand their carbon footprints. By achieving precise carbon emission measurement, power systems can more effectively formulate and implement reduction measures, facilitating low-carbon transitions and supporting global carbon neutrality goals. Here are several key carbon emission measurement technologies:

Real-time measurement technology for indirect carbon emissions in electricity consumption monitors users' electricity consumption in real time to calculate their indirect carbon emissions. Utilizing smart meters and carbon emission factors, it provides real-time carbon emission data for electricity use. This real-time measurement technology enables users to adjust their consumption behaviors promptly, reducing carbon emissions and optimizing energy efficiency, thus supporting smart grid initiatives and sustainable development. The main technical challenge lies in accounting for the impact of market trading behavior on real-time measurement, separating this carbon emission responsibility from the tracking and transfer of physical flows.

Comprehensive carbon emission calculation technology based on electricity big data collects and analyzes large datasets from the power system to comprehensively calculate carbon emissions across all stages. It integrates carbon emission data from the entire lifecycle of generation, transmission, distribution, and consumption, employing big data analysis and machine learning algorithms to deliver precise carbon emission calculations. This measurement technology supports governments and businesses in managing carbon emissions and making informed decisions, advancing green energy transitions and achieving carbon neutrality goals. The bottlenecks to overcome include improving the accessibility and accuracy of historical data, as well as enhancing the rationality and effectiveness of the calculation models.





## Conclusion

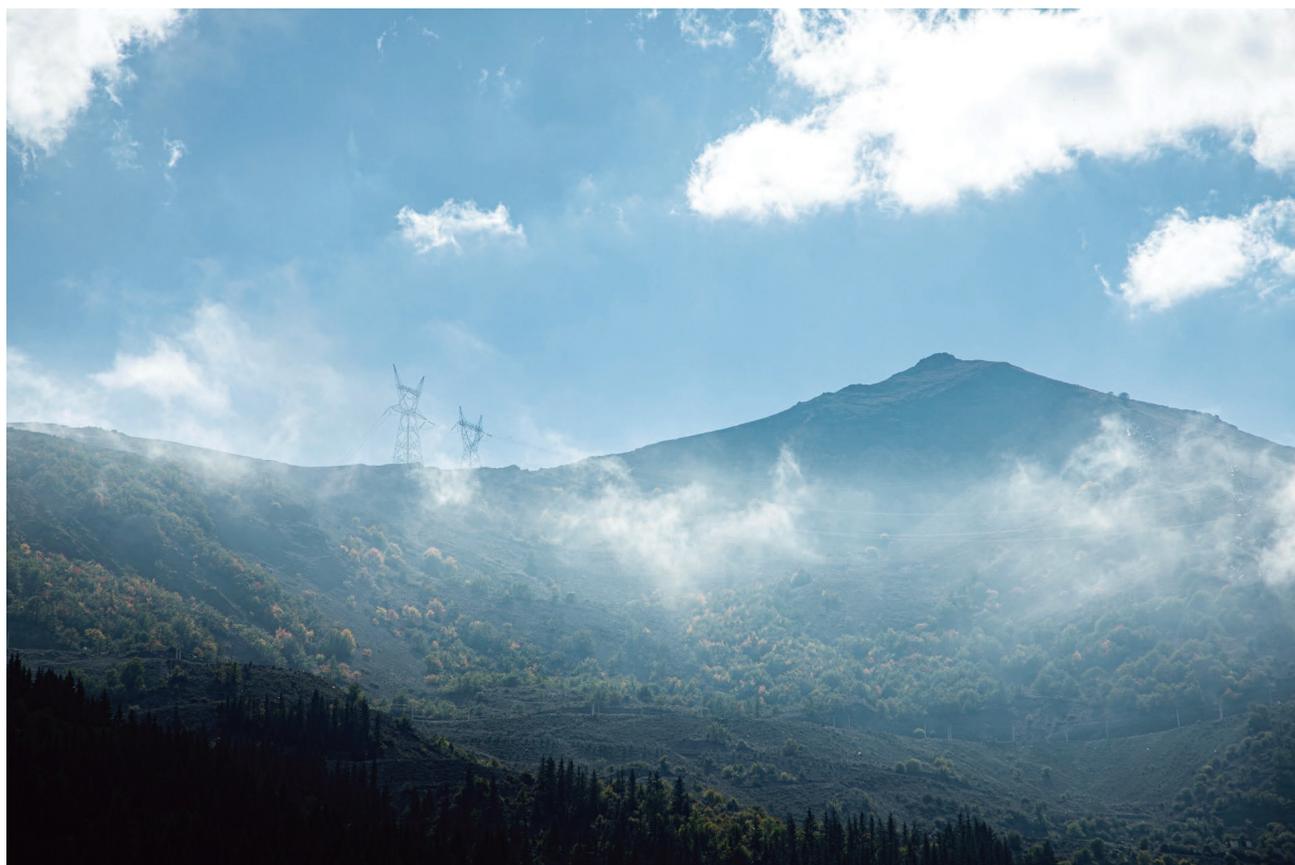
China's power system aims to peak carbon emissions between 2025 and 2030 and achieve carbon neutrality by 2060. The development of technologies for the new power system must align with this carbon peak and neutrality pathway. As the carbon peak and neutrality processes evolve, related technologies need to continuously progress to meet the development needs of the electricity and energy systems at different stages.

During the carbon peaking and platform stage, technologies in the new power system must support several macro goals. First, renewable energy should become the main installed capacity. Second, there should be a coexistence of large grids and distributed generation. Third, the development of electricity substitution and flexible loads must be accelerated. Additionally, rapid advancements in energy storage technologies are essential. Finally, further improvements in the electricity market system are necessary.

In the rapid reduction stage, technologies should facilitate the gradual dominance of renewable energy in electricity generation. They should also diversify grid forms and deepen integration with end-use sectors. Moreover, forming multi-scale and multi-technology energy storage systems is crucial. Lastly, the establishment of a unified national electricity and carbon market should be promoted.

In the carbon neutrality stage, technologies must support the retention of some coal-fired power plants. There should be coexistence among multiple grid forms, and the establishment of a clean and intelligent energy internet is essential. Furthermore, energy storage capacity must grow with shared utilization models. Lastly, the electricity-carbon coupling market should mature.

Figure 2 illustrates the technological road map for the development of the new power system, highlighting the power generation capacity and overall carbon emissions at different periods, along with the development routes for key supporting technologies.



For the development of the new power system, this article proposes policy recommendations from six perspectives: generation, grid, load, storage, digitalization, and carbon.

On the generation side, it is necessary to establish a collaborative mechanism for large-scale renewable energy development and grid integration, as well as a benefits coordination mechanism. This includes strengthening the synergy of renewable energy development policies and creating long-term mechanisms. Tailored renovation and capacity reduction plans for coal-fired power units should be proposed based on local conditions, and efforts should be made to significantly enhance the flexibility and regulation capacity on the generation side.

On the grid side, it is essential to promote the grid as a secure platform for the low-carbon transformation of the power system and as a resource optimization platform. This will ensure the safety and stability of the power system during its low-carbon transition, enhance the resilience of urban power systems, and fully utilize the grid's role as a resource allocation platform.

On the load side, integrating flexible loads as dispatchable resources is key. This can be achieved by establishing demand-side response mechanisms and platforms, while actively exploring the flexibility potential across different systems.

On the storage side, efforts should focus on reducing energy storage costs and promoting the large-scale, integrated application of various storage technologies. Supportive policies are necessary to lower storage usage costs, alongside the development of seasonal energy storage resources.

Digitalization requires the application of digital twin technology to promote the informatization and intelligence of the power system. It aims to advance the comprehensive use of digital twin technologies, facilitate the cloud-based and information-driven transformation of the entire power system, and enhance energy conversion efficiency and safety, thereby accelerating the intelligent development of the power system.

From the carbon perspective, it is necessary to promote the planning, operation, and market mechanisms for electricity-carbon coupling. This includes advancing high spatiotemporal resolution carbon measurement across all aspects of the power system, facilitating low-carbon planning and dispatching in the electricity system, and designing new market trading mechanisms for electricity-carbon coupling.

