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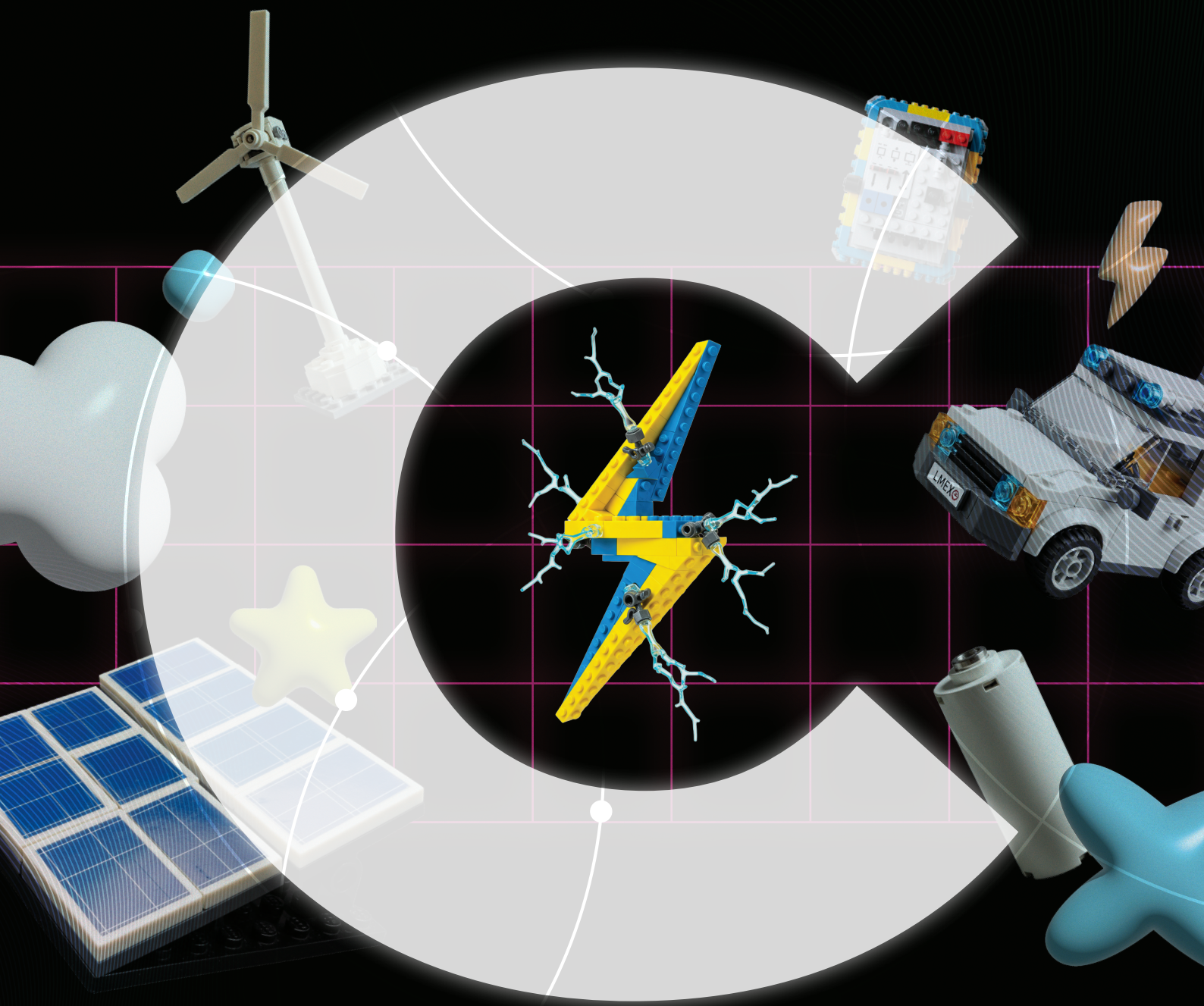

VPPs: The Key to Korea's Transition to a Renewable Energy-Based Power System

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Solutions for Our Climate(SFOC) is an independent policy research and advocacy group that aims to make emissions trajectories across Asia compatible with the Paris Agreement 1.5°C warming target.

Published August 2025

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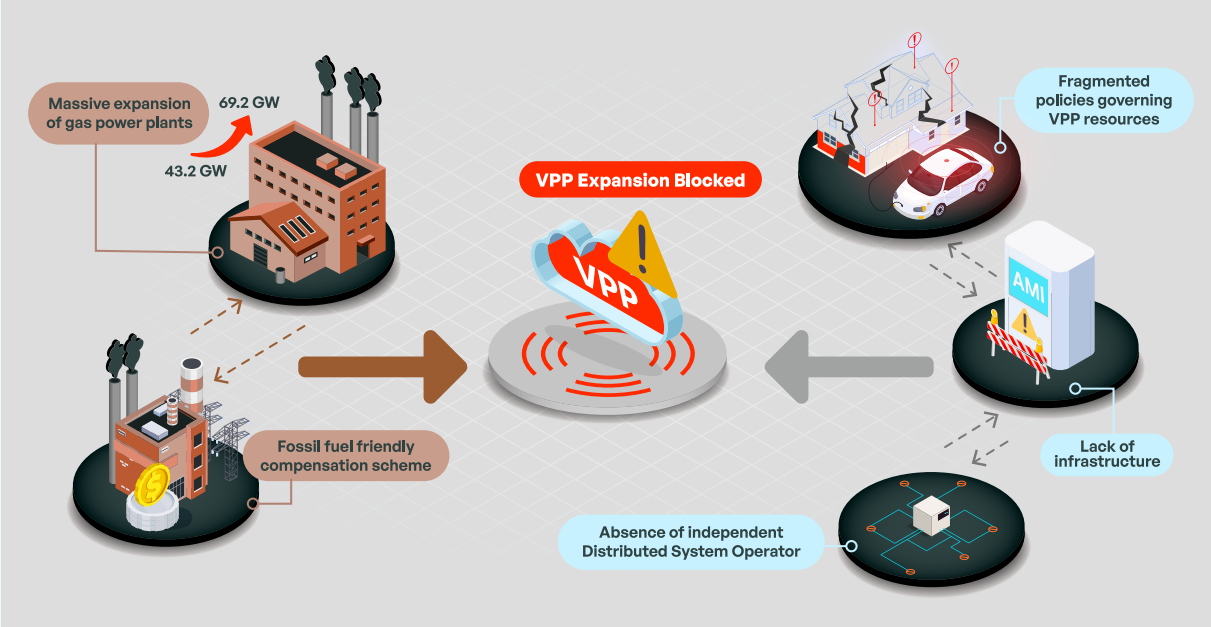
Contents

Summary

Building a power system centered on renewable energy requires a paradigm shift from Korea's existing centralized model, which relies on large-scale fossil fuel power plants, to a distributed structure. At the heart of this paradigm shift is the Virtual Power Plant (VPP), which integrates Distributed Energy Resources (DERs)—such as solar power, wind energy, Energy Storage Systems (ESS), and Demand Response (DR) to operate and participate in the wholesale power market.

Nevertheless, the Korean government has not established adequate policy measures to incentivize the transition to a distributed power system. The existing wholesale power market continues to prioritize the operation and compensation of large-scale fossil fuel power plants, while lacking the market structure and the infrastructure required to support the expansion of DERs. This report examines the key challenges to the expansion of VPPs as an essential component of Korea's renewable energy transition and suggests possible solutions.

◦ Barriers



▪ Massive Gas Power Expansion

- Due to the 10th and 11th Basic Plan on Electricity Supply and Demand ("Basic Plan"), introduced in 2023 and 2025, domestic gas power capacity would increase from 43.2GW in 2023 to 69.2GW in 2038, locking-in centralized power system based on fossil fuel generation for many years to come.

- **Power Market Compensation Scheme**
  - Current power market is run as Cost Based Pool (CBP) market in which KEPCO, the sole retailer, absorbs all the risks surrounding possible fuel cost increase. On the other hand, it fails to properly value renewable energy and flexibility resources without fuel costs—there is lack of value stacking to compensate for their capacity, environmental contribution, and ancillary services.

- **Policies on Flexibility Resources**
  - Demand Response (DR) resources are currently blocked from participating in the wholesale market, while KEPCO recently introduced a new scheme (Customer Participation Load Shedding Scheme) that directly competes with DR scheme. Worse, KEPCO's scheme promises much higher compensation for their customers than the DR scheme, preventing growth of DR industry in Korea.

- **Infrastructure building**
  - KEPCO's Advanced Metering Infrasturcture (AMI) falls well below minimum performance standards as a smart meter, while Ministry of Environment's EV charging infrastructure projects excluded chargers with bi-directional capabilities, which blocked Vehicle to Grid (V2G) technologies from being adopted.

- **Lack of Independent Distribution System Operator**
  - KEPCO officially launched as the Distribution System Operator in Nov 2024 and is expanding its role, but its heavy exposure to fossil fuel assets means it lacks the incentive to expedite Korea's transition into renewable energy-based power system. This creates inherent conflict of interest.

◦ Solutions

1	Cancel the gas power expansion plan
2	Reform the current power market to ensure adequate compensation of VPPs
3	Support infrastructure investments for VPPs
4	Improve power market governance to create independent DSOs

I. Challenge #1 to VPP Expansion: Massive Expansion of Gas Power Generation

The power market, grid, and associated policies remain anchored in a centralized system, despite the imperative for a paradigm shift toward a renewable energy-centered power system. Furthermore, funding continues to be directed toward the expansion of fossil fuel power plants, which reinforces the centralized framework.

Under the 10th Basic Plan on Electricity Supply and Demand ("10th Basic Plan"), introduced in 2023, the government outlined the conversion of 28 aging coal-fired plants (14.1 GW) into gas power plants. The 11th Basic Plan, introduced in 2025, includes plans to build additional Combined Heat and Power (CHP) gas power plants, expanding gas power capacity from 43.2 GW in 2023 to 69.2 GW by 2038.

[Table 1] 10th Basic Plan: Conversion of Coal-Fired Plants to Gas Power Plants

Year	Unit Name	# of Units	Capacity (MW)
2025-2036		28	14,120
2025	Taean #1	1	500
2026	Taean #2, Hadong #1, Boryeong #5	3	1,500
2027	Samcheonpo #3, 4, Boryeong #6, Hadong #2, 3	5	2,620
2028	Samcheonpo #5, Taean #3, Hadong #4	3	1,500
2029	Donghae #1, 2, Samcheonpo #6, Taean #4, Dangjin #1, 2	6	2,400
2030	Dangjin #3, 4	2	1,000
2031	Hadong #5, 6	2	1,000
2032	Taean #5, 6	2	1,000
2034	Yeongheung #1, 2	2	1,600
2036	Dangjin #5, 6	2	1,000

Source: The 10th Basic Plan on Electricity Supply and Demand

Although the government intends to leverage the new combined cycle power plants as backup and flexible resources, the plan is economically unsound. Building and operating 28 new gas power plants is expected to cost approximately KRW 55 trillion and their utilization rate is projected to decline to just 12% by 2038. As a result of this reduced utilization, the Levelized Cost of Electricity (LCOE) for the new gas power plants is forecast to rise from KRW 261 in 2025 to KRW 331 per kWh by 2036.

The construction of large-scale gas power plants represents a significant obstacle to the transition toward a distributed energy system, and consequently to the expansion of renewable energy. Jeju Island illustrates this challenge: although renewable energy accounts for 18% of the power grid, large combined cycle power plants are designated as "must-run" facilities or guaranteed a high minimum generation level, while

renewable energy remains subject to curtailments. With construction underway for new gas power plants with a combined capacity of 300 MW, the renewable energy curtailment rate is expected to increase further.

[Table 2] Number of Curtailment Cases in Jeju (2016-2023)

Year	2016	2017	2018	2019	2020	2021	2022	2023
# of Cases	6	14	15	46	77	64	132	181

Source: Data adapted by Solution for Our Climate

[Table 3] '23~'36 Jeju RE Curtailment Prediction (Unit: %)

Crtieria	2023	2024	2025	2026	2027	2028	2029
Curtailment rate	1.08	0.00	0.07	0.77	2.20	4.42	8.12
Crtieria	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
Curtailment rate	18.98	25.54	25.06	24.99	24.83	24.65	24.57

Source: Jeju Special Self-Governing Provincial Council, Jeju Energy Policies and Tasks (2024)

The government should rethink its policy of maintaining a power system that guarantees the construction and operation of fossil fuel power plants while restricting renewable energy generation at a time when renewable generation should instead be expanded.

II. Challenge #2 to VPP Expansion: Flawed Compensation Mechanism in the Power Market

The Korean wholesale power market continues to operate under the Cost-Based Pool (CBP) and capacity payment scheme, both of which are designed to compensate fossil fuel power plants for fuel and fixed costs, thereby guaranteeing long-term revenue stability for large-scale fossil fuel power plants. In contrast, the value of Virtual Power Plants (VPPs)—distributed energy resources that incur no fuel costs—has yet to be properly assessed, resulting in a lack of incentives to expand the VPP industry.

1. Problems with the Capacity Payment Scheme

In the renewable energy bidding market launched in Jeju in 2024, Virtual Power Plant (VPP) companies receive capacity payments based on their bid capacity and are obligated to comply with dispatch instructions. However, because the capacity payment is determined by the lowest of Effective Load Carrying Capacity (ELCC), actual bid capacity, or generation output, companies face a double penalty[1] that undermines their profitability.

[Table 4] Capacity Payment Calculation in Jeju's Renewable Energy Bidding Market

Without Curtailment	With Curtailment
min(generation output, bid capacity, ELCC) × Reference Capacity Price (RCP)	min(bid capacity, ELCC) × Reference Capacity Price (RCP)

Source: Korea Power Exchange (KPX)

In addition, the capacity payment mechanism fails to create a level playing field by applying the Reference Capacity Price (RCP)—calculated based on the fixed costs of gas power plants—to renewable and VPP resources such as Energy Storage Systems (ESS), which operate under fundamentally different cost structures, technological maturity, and facility lifespans.

[Table 5]

Criteria	Gas-Fired Generation	ESS
Facility Lifespan	30+ years	10-15 years
Tech Maturity	Very high	Intermediate
Variable Cost	High (high fuel cost volatility)	Low
Fixed Cost	Low	High

1 They already face imbalance penalties for failing to meet minimum forecast threshold of 8%

More importantly, the cost of carbon should be fully incorporated into the compensation mechanism for carbon-free energy sources in order to enhance their relative competitiveness against fossil fuel power generation. Under Korea's Emissions Trading Scheme, the current price of CO2eq per ton is less than KRW 10,000, which is approximately one-tenth of the price in Europe. Moreover, with the government's revision of capacity payment regulations that had previously factored in environmental contributions, the compensation scheme has become even more advantageous to fossil fuel power generation.

2. Establishment and Operation of the Ancillary Service Market

With the launch of an ancillary service market on Jeju Island, it was expected that Energy Storage Systems (ESS) and Virtual Power Plant (VPP) resources would actively participate in the market for compensation. However, VPP resources participating in the spot market are not permitted to enter the ancillary service market.

In the mainland, compensation is determined by the ancillary service framework rather than through market mechanisms, but flaws exist in the framework's calculation of the settlement price. Market principles suggest that greater demand for ancillary services should drive higher prices in order to incentivize the participation of ESS and VPP resources. Under the existing system, however, the settlement price declines as demand for ancillary services increases.

(Example)	Primary 2025 settlement price for Frequency Control Ancillary Services (FCAS) = Total compensation allocation for primary FCAS in 2025 / primary FCAS volume in 2024

Source: Korea Power Exchange (KPX)

In addition, the Fast Frequency Response (FFR) capabilities of VPP resources including ESS that help mitigate renewable energy volatility are not given any compensation.

III. Challenge #3 to VPP Expansion: Absence of a Dedicated Distribution System Operator (DSO)

System operation in Korea has been focused on the transmission network with the Korea Power Exchange (KPX) serving as the Independent System Operator (ISO). However, in the absence of a dedicated Distribution System Operator (DSO), critical functions such as data sharing required for the operation of distribution-level VPPs and the standardization of grid codes have not been achieved. As a result, VPPs' essential role in providing Non-Wired Alternatives (NWAs) has not been utilized, nor has the compensation mechanism for their services been developed.

Under the Special Act on Activation of Distributed Energy enacted in 2024, distribution network management responsibilities were delegated to the distribution companies, making Korea Electric Power Corporation (KEPCO) the official DSO. Since then, KEPCO has established the DSO-MD Jeju Centre and has been collaborating with LG Energy Solution's VPP platform to operate ESS while reviewing its effectiveness in reducing peak loads at the distribution level.

The role of a DSO is integral to the scaling of VPPs. However, a conflict of interest arises from KEPCO holding dual responsibilities: maintaining the current wholesale power market structure while also serving as the DSO. KEPCO owns six power generation subsidiaries that are either fossil-fuel- or nuclear-based, which means as the de-facto monopoly in Korea's wholesale power market, it has little incentive to expand renewable energy resources that could undermine its market share and profitability. This underscores the need for fundamental reforms in the governance structure of the wholesale power market.

IV. Challenge #4 to VPP Expansion: Systemic Barrier to Demand Resource (DR) Integration

1. Fragmented DR-related Mechanisms

VPP companies submit bids for renewable energy resources either on a standalone basis or in combination with ESS through Jeju's market bidding framework and receive payments in the spot market. However, DR—a key component of VPPs—cannot enter the market jointly with VPP resources as it is confined to a separate DR trading market.

Moreover, on April 5, 2024, KEPCO introduced the Customer Participation Load Shedding Scheme in addition to the existing DR program operated by the Korea Power Exchange for the same customers, thereby stifling the expansion of DR, one of the most critical resources for VPPs. Unlike the existing DR program that is grounded in a network-based control system, KEPCO's scheme physically disconnects power supply at the facility level. This approach makes sustained DR activation difficult and prevents its integration and joint operation within VPPs.

[Table 6]

Criteria	고객참여 부하차단 제도
Activation standard	59.55Hz
Operation period	24/7
Operator	Directly operated by KEPCO
Load shedding method	Load unilaterally shedded by KEPCO
Compensation	Fixed compensation Activation compensation

Source: Korea Electric Power Corporation (KEPCO)

KEPCO's Customer Participation Load Shedding Scheme offers payments that are 15 times higher than those of the Fast DR program for load reduction performance, creating a substantial barrier to the expansion of the DR industry. In effect, KEPCO is exploiting its dominant position in the market as the sole power supplier to suppress the scaling of VPPs.

2. Public Notice Restricting the Utilization of Electric Vehicles

With the Ministry of Trade, Industry and Energy (MOTIE) excluding Electric Vehicles (EVs) from the category of small-scale power resources in its public notice, it is uncertain whether power exchange will be permitted for Vehicle-to-Grid (V2G) technology that enables EVs to function as ESS. Given the rapid adoption of EVs in Korea, MOTIE's public notice must be revised to ensure that EVs can be utilized as ESS resources.

V. Challenge #5 to VPP Expansion: Insufficient Infrastructure

In 2011, the government enacted the Smart Grid Construction and Utilization Promotion Act to build a smart grid that serves as the foundation for VPP operations. However, the initiative failed to establish adequate infrastructure to support VPP operations, as its sole focus was on cost reduction.

1. Lack of AMI Infrastructure

The success of facilitating VPPs and transitioning to a distributed energy system depends on enabling data sharing through IoT technology. Since 2010, KEPCO has led seven rounds of Advanced Metering Infrastructure (AMI) distribution projects.

However, Model E of AMI cannot be regarded as smart equipment as its firmware cannot be updated online. Without built-in IoT functionality, new features cannot be incorporated into AMI, despite such capabilities being essential for supporting VPP projects and upgrading the power system. Furthermore, all AMI equipment deployed by KEPCO lacks real-time measurement capability, creating another significant barrier to advancing VPP operations.

To enable the active market participation of distributed resources, the existing AMI must be replaced, and metering standards for distributed resources should be relaxed for the time being.

2. Lack of Bidirectional Charging Infrastructure

The EV charging stations deployed by Korea's Ministry of Environment lack bidirectional charging capabilities essential for enabling V2G, a constraint that prevents EVs from contributing as VPP resources.

As of May 2025, Korea has approximately 750,000 EVs and 417,000 charging stations. Despite the substantial cost-saving potential of smart EV charging systems, nearly all charging station projects led by the Ministry of Environment have focused on unidirectional charging units.

Policy Recommendations

1. Gas Power Generation Policies

▪ Rollback plans to convert coal-fired power plants into gas power plants

- The plan to repurpose 28 coal-fired power plants into gas power plants should be withdrawn as it is economically unjustifiable, undermines carbon neutrality goals, and obstructs the transition to a distributed power system.

2. Reform of Market Mechanisms

▪ Enhance the capacity payment system

- The capacity calculation standard should be revised to properly reflect the value of VPP resources and eliminate the double penalty currently imposed on participants in Jeju's renewable energy bidding market.

- Because the low carbon price under Korea's Emissions Trading Scheme fails to encourage fossil fuel phase-out, environmental contribution should be strengthened and reintegrated into the capacity payment calculation process to accelerate the energy transition.

- The value of flexibility resources should be established in accordance with market principles by transitioning to a capacity market design that incorporates flexibility.

▪ Establish and strengthen the ancillary service market

- VPP resources should be granted access to the ancillary market, enabling them to contribute to grid operations while receiving appropriate compensation.

- The ancillary service market should be improved and expanded to mainland systems, and compensation for Fast Frequency Response (FFR) should be enhanced to accelerate the expansion of VPPs.

▪ Integrate fragmented frameworks for flexible resources

- The government should enable the wholesale bidding of Demand Resources (DRs) and allow the power trading of EVs in order to establish an institutional foundation for the expansion of VPPs.

- Market mechanisms should be strengthened by abolishing the outdated Customer Participation Load Shedding Scheme, maximizing the utilization of DR resources, and enacting other supportive measures.

3. Infrastructure Development for VPP Expansion

- Programs for deploying EV charging stations should transition toward bidirectional units.

- Substandard AMI units should be replaced and the metering standards for VPP resources should be eased to lower entry barriers.

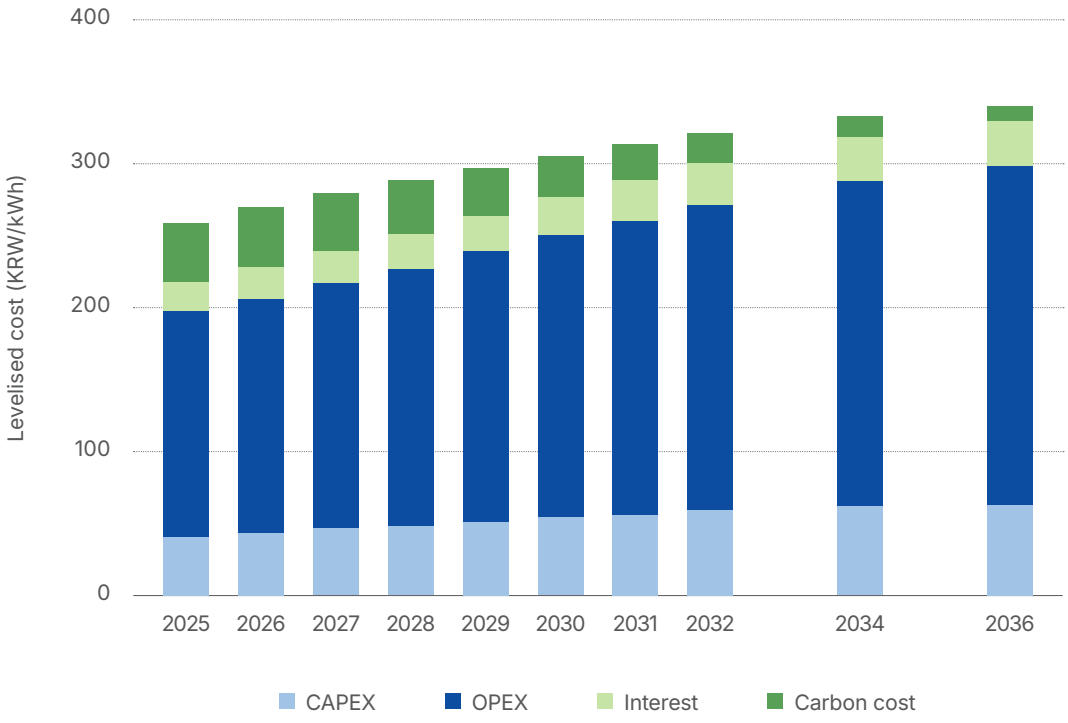
4. Establishment of a Dedicated DSO

- The governance structure of the wholesale power market must be reformed by measures such as financially separating KEPCO's transmission and distribution division from its generation and sales unit, thereby enabling KEPCO to fulfill the role of an independent DSO and contribute to the expansion of VPPs and renewable energy.

- An independent and dedicated DSO should be established with clearly defined responsibilities and authority to ensure the timely deployment of VPPs and other technologies that enhance grid flexibility.

Appendix

1-1. Projected LCOE of gas power plants repurposed from coal-fired plants under the 11th Basic Plan on Electricity Supply and Demand



Source: Solution for Our Climate (SFOC) Analysis

1-2. Technical characteristics of gas power generation

Property	Open cycle gas turbines (OCGT)	Combined cycle gas turbines (CCGT)
Most commonly used power plant		
Minimum load (% P_{Nom})	40-50 %	40-50 %
Average ramp rate (% P_{Nom} per min)	8-12 %	2-4 %
Hot start-up time (min) or (h)	5-11 min	60-90 min
Cold start-up time (min) or (h)	5-11 min	3-4 h
State-of-the-art power plant		
Minimum load (% P_{Nom})	20-50 %	30-40 %(20% with SC)
Average ramp rate (% P_{Nom} per min)	10-15 %	4-8 %
Hot start-up time (min) or (h)	5-10 min	30-40 min
Cold start-up time (min) or (h)	5-10 min	2-3 h

Source: International Renewable Energy Agency

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