Agrivoltaic, the Baseload for Decarbonised Distributed Power System in Korea

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Summary

Structural issues in current power policy: The present national power supply plan remains heavily focused on short-term supply stability, maintaining a fossil-fuel-centered, centralized generation structure. This structural bias makes it fundamentally impossible to comply with or respond to international decarbonization frameworks such as RE100 (Renewable Energy 100%) and CBAM (Carbon Border Adjustment Mechanism), and serves as a root cause of declining international competitiveness for Korean industries.

Spatial imbalance of power supply and renewable potential: Over 55% of Korea's total electricity demand is concentrated in the Seoul Metropolitan Area, while renewable energy potential is predominantly located in non-metropolitan regions such as Jeolla-do and Gyeongsang-do. This severe spatial mismatch has entrenched an inefficient system in which electricity generated in "high-potential but low-demand" regions must be transmitted long distances to "high-demand but low-potential" areas.

Transformative potential of agrovoltaics: Agrovoltaics goes far beyond being a supplementary income source for farmers—it represents a strategic use of national land as a distributed baseload energy resource. Based on realistically available farmland, more than 200 GW of agrovoltaic capacity could be deployed nationwide, enough to supply over half of Korea's total electricity consumption as of 2024. Regional potential analysis shows that not only Jeolla-do and Gyeongsang-do but

also Gyeonggi-do—close to major demand centers—possess substantial capacity, making agrovoltaics a key tool to mitigate regional supply-demand imbalances.

Policy recommendations: The primary constraint today arises from grid congestion caused by transmission overload. Therefore, instead of further transmission expansion, a fundamental shift toward distributed power systems that produce and consume electricity locally is urgently needed. Agrovoltaics can enhance regional energy self-sufficiency, alleviate grid bottlenecks, reposition agriculture as an active producer of power, and ultimately serve as a strategic pillar enabling Korea to achieve both carbon neutrality and balanced national development simultaneously.

목차

The 11th Basic Power Supply Plan: Limits and Inefficiencies of the Centralized Structure

South Korea's 11th Basic Plan for Power Supply Plan[1] outwardly proclaims goals of carbon neutrality and renewable energy expansion, yet in practice remains focused on supply stability built upon fossil fuels. While the plan nominally outlines a phased reduction of coal power and designates LNG as a transitional energy source, in reality it includes numerous new LNG power plant projects—structurally at odds with a genuine carbon neutrality pathway and effectively an extension of the centralized power system.

This framework may support short-term reliability but fundamentally obstructs the establishment of a mid- to long-term decarbonization system aligned with the 1.5°C target. The government's energy policy, rather than facilitating industrial sustainability, has reinforced dependence on legacy infrastructure—slowing the national transition to renewables. In particular, power-intensive sectors such as semiconductors and batteries are already bound by RE100 compliance as a practical condition for participation in global supply chains. Despite this, the government has failed to provide sufficient institutional mechanisms for companies to procure renewable energy directly. Moreover, a fiscal structure heavily concentrated on transmission expansion and gas power investment has become a policy bottleneck that impedes voluntary RE100 implementation by the private sector.

[1] The 11th Basic Power Supply Plan

The energy supply plan for the Yongin Semiconductor Cluster epitomizes these systemic flaws. To meet initial demand, the government intends to construct six LNG power units totaling 3 GW, yet renewable energy procurement within the project remains marginal—effectively rendering it a fossil-fuel-dependent industrial complex. This reinforces Seoul Metropolitan Area's demand concentration and long-distance transmission reliance, while neglecting the gigawatt-scale agrovoltaic potential of southern Gyeonggi-do.

By contrast, Taiwan has incorporated TSMC's decarbonization strategy into national policy, advancing its RE100 target by a decade to 2040[2]. While the Taiwanese government has restructured its power market and infrastructure to directly support industrial renewable procurement, South Korea continues to uphold a centralized framework that constrains corporate decarbonization efforts. Consequently, Korean industries risk failing to meet international supply chain standards. As global ICT firms move toward 100% renewable energy across their supply chains by 2030–2040, the erosion of Korea's export competitiveness and potential exclusion from global networks are becoming tangible threats.

Ultimately, while the current plan may achieve short-term supply security, it fails to deliver long-term sustainability and delays the structural transformation essential for meeting national carbon neutrality goals.

[2] TSMC Accelerates Renewable Energy Adoption and Moves RE100 Target Forward to 2040

Korea's Power Policy Fails to Meet RE100

Global corporations' RE100 commitments are not mere declarations of environmental intent—they have become tangible entry requirements for participation in global supply chains. Achieving RE100 requires companies to source 100% of their electricity from renewable energy and to ensure additionality, meaning their procurement contributes to the development of new renewable projects. However, South Korea's current power policy structurally fails to meet these conditions.

As long as the Basic Plan continues to rely on coal and LNG as its foundational generation sources, the renewable transition will remain insufficient in both scale and accessibility. In major demand centers such as the Seoul Metropolitan Area, where industrial clusters and data centers are concentrated, securing new renewable generation is highly constrained by space limitations and permitting barriers. This has entrenched an inefficient system in which renewable power generated in remote regions must be transmitted long distances to reach the Seoul Metropolitan Area—resulting in compounded transmission losses, rising grid costs, and mounting public resistance. Collectively, these factors make it increasingly difficult for Korean industries to meet RE100 requirements.

Such limitations directly translate into a risk to national industrial competitiveness. Global ICT companies have already committed to using 100% renewable electricity across their supply chains by 2030, and leading semiconductor firms such as TSMC and Intel have established large-scale Power Purchase Agreement (PPA) systems with government support to meet these goals. In contrast, South Korea continues to

concentrate public investment on gas-fired generation and transmission expansion, undermining the institutional foundations that would enable companies to voluntarily achieve RE100.

As a result, large industrial clusters—such as the Yongin Semiconductor Complex—face growing risks of failing to meet international supply chain standards, leading to potential losses in contracts, supply chain participation, and export competitiveness. Thus, while the country's fossil fuel–centered power plan may offer short-term supply stability, it stands in direct conflict with global decarbonization norms and serves as a structural constraint that fundamentally weakens the long-term sustainability of South Korea's industrial base.

Structural Inertia of the Centralized System Delaying Energy Transition

South Korea's current power supply structure remains centralized and fossil fuel–based, justified under the pretext of ensuring short-term supply stability. While this framework can provide a degree of reliability in the near term, it fundamentally constrains the country's capacity to achieve RE100 in the long run. As long as fossil fuels continue to dominate the generation mix, expanding renewable energy faces both physical and institutional barriers.

In particular, persistent investment in gas-fired power plants and transmission expansion has created a self-reinforcing trajectory that locks the system into its existing structure, making a shift toward a new, decentralized energy model increasingly difficult. This institutional inertia allows short-term stability to take

precedence over long-term transformation, effectively delaying structural transition. Ultimately, the current power planning approach serves as a policy lock-in mechanism that slows the renewable transition and, over time, undermines industrial competitiveness and the achievement of national carbon neutrality goals.

Deepening Spatial Imbalance in Power Supply

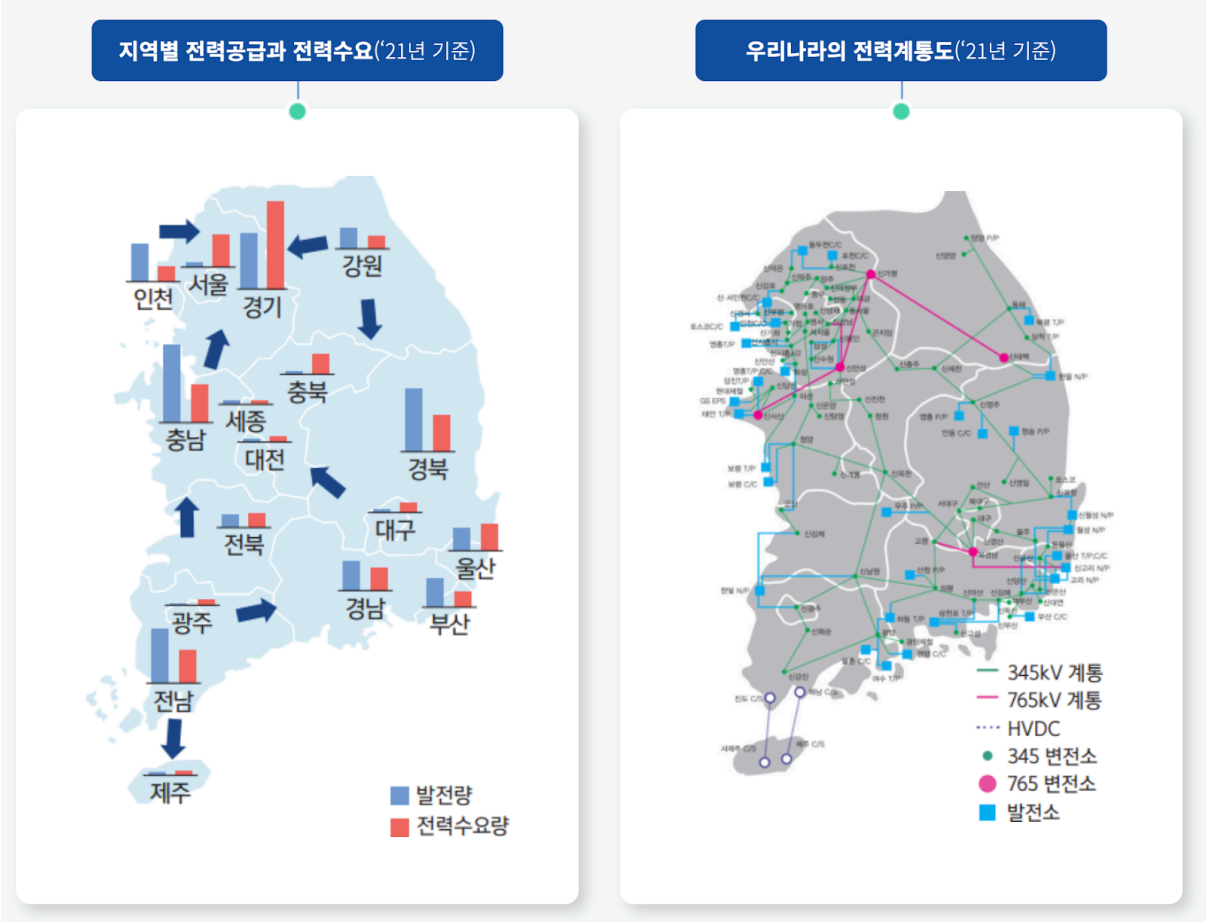
South Korea's electricity demand shows an extreme regional imbalance. The Seoul Metropolitan Area consumes about 55% of the nation's total power, while Chungcheong-do accounts for around 15%, Gyeongsang-do 20%, Jeolla-do 7%, and Gangwon-do only 3%. Despite consuming more than half of the country's electricity, the Seoul Metropolitan Area's self-generation capacity meets less than 30% of its demand, relying heavily on long-distance transmission from other regions.

Currently, the Seoul Metropolitan Area's power supply depends primarily on 765 kV transmission lines delivering electricity from the East Coast, supplemented by 345 kV networks from Jeolla-do and Chungcheong-do. Transmission losses along these routes average 3–8%, amounting to several terawatt-hours annually. This dependence on long-distance transmission not only wastes energy but also requires tens of trillions of won in grid infrastructure investment, fuels public opposition and project delays, and heightens system stability risks—a single line failure could trigger large-scale blackouts.

Crucially, this spatial mismatch also extends to renewable energy potential. Provinces such as Jeolla-do and Gyeongsang-do possess vast renewable resources thanks to abundant farmland and offshore areas, yet their industrial demand is

limited. Conversely, the Seoul Metropolitan Area—dense with industries, data centers, and logistics hubs—faces severe constraints on renewable deployment due to high population density and land costs. The result is a persistent structural disparity between regions that have abundant renewable potential but low demand and those that have high demand but scarce renewable resources, reinforcing the inefficiencies of South Korea's centralized energy system.

Figure 1. Power supply and demand by region, and the power grid map[3]



This imbalance generates systemic inefficiencies across the entire power network. The concentration of electricity demand in the Seoul Metropolitan Area increases

[3] Korea Energy Agency

dependence on long-distance transmission and amplifies the need for continuous grid expansion. This, in turn, imposes enormous social and financial costs, fuels regional conflict over new infrastructure, and delays the integration of renewable energy projects. As a result, the pursuit of RE100 compliance grows increasingly distant, while industrial competitiveness steadily erodes—a self-reinforcing cycle of inefficiency.

To break this cycle, the solution lies not in merely adding more generation capacity but in restructuring the spatial alignment of power demand and supply. Transitioning toward a distributed energy system, where electricity is both produced and consumed within the same region, is essential. Only through such local generation and consumption can South Korea reduce its reliance on long-distance transmission and unlock the full potential of renewable resources distributed across its territory.

Agrovoltaics as a Baseload for Distributed Power Network

Agrovoltaics is far more than a supplementary income source for farmers—it represents a strategic energy resource that supports the transition to a carbon-neutral society through baseload for distributed generation. Unlike large-scale solar farms or offshore wind projects that face growing geographical and social acceptance constraints, agrovoltaics leverages Korea’s vast and evenly distributed farmland network to enable widespread renewable deployment across the entire territory. Given that farmland accounts for roughly 15% of the national land

area, this approach is not merely an energy technology but a land-use restructuring strategy that redefines how energy and geography intersect.

South Korea's total arable land—including both designated agricultural promotion zones and other farmland—is estimated at 15,046 km². Although farmland is largely exempt from higher land-use restrictions, municipal setback regulations significantly limit where agrovoltaic systems can actually be installed. When both legal and local constraints are factored in, the realistically available land area for agrovoltaics shrinks to about 4,988 km², or roughly 5% of the nation's territory, of which 2,833 km² lies outside promotion zones. By land type, paddy fields account for approximately 65% of feasible sites, dry fields for 32%, and orchards for the remainder.

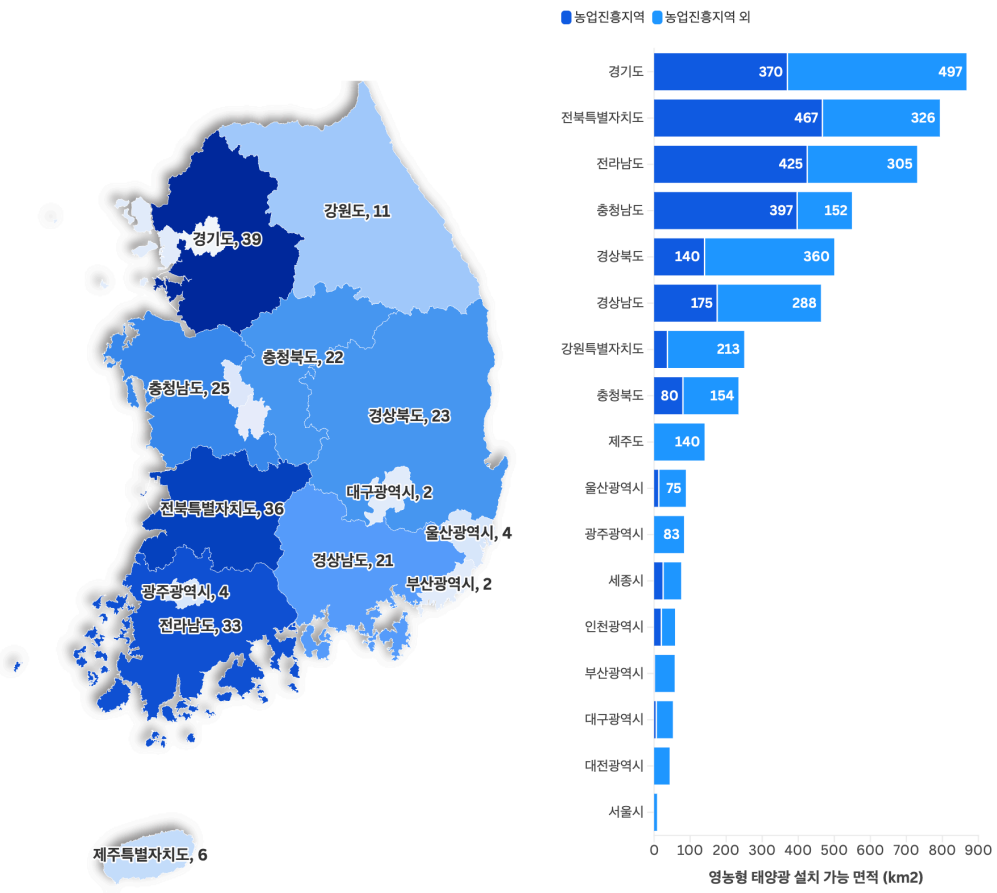
Applying an average installation density of 150 W/m² yields a potential agrovoltaic capacity of around 224 GW nationwide. Assuming a 15% average capacity factor, this corresponds to an annual output of approximately 295 TWh, equivalent to 53% of Korea's total electricity consumption in 2024 (about 550 TWh). In other words, utilizing just 5% of the country's farmland could supply over half of national electricity demand through land-based renewable generation. This underscores agrovoltaics not as an auxiliary source but as a viable backbone of Korea's future energy system—transforming the agricultural sector into an active producer of clean power.

Regional analysis further reveals that Jeolla-do holds the highest potential at about 69 GW, followed by Gyeongsang-do (43 GW) and the Seoul Metropolitan Region (42 GW) including Gyeonggi-do. At the municipal level, Gyeonggi-do ranks first nationwide with 39 GW of feasible capacity, trailed by Jeollabuk-do (36 GW) and Jeollanam-do (33 GW). Chungcheongnam-do (25 GW), Gyeongsangbuk-do (23

GW), and Gyeongsangnam-do (21 GW) also show significant potential—reflecting their extensive farmland, gentle terrain, and abundant solar irradiation. By contrast, dense urban areas such as Seoul (0.4 GW), Daejeon (2 GW), and Busan (2 GW) possess extremely limited capacity due to land-use constraints and high development density.

Agrovoltaics thus represents a strategic cornerstone for Korea's distributed renewable transition—an energy-land nexus solution capable of simultaneously strengthening rural economies, stabilizing the grid, and advancing the nation's carbon-neutral trajectory.

Figure 2. Agrivoltaic potential by region in South Korea



Transmission Limitation is the Critical Constraint

This regional disparity demonstrates that agrovoltaics could serve as a structural tool to mitigate the Seoul Metropolitan Area's energy imbalance while strengthening energy self-sufficiency in non-metropolitan areas. However, despite this significant potential, both Jeollabuk-do and Jeollanam-do are already experiencing generation curtailment due to transmission and distribution network constraints—preventing additional solar capacity from being connected. Currently, Jeollanam-do hosts around 6.0 GW and Jeollabuk-di 4.6 GW of cumulative solar installations, accounting for roughly 37% of the national total (28.6 GW). Their success reflects favorable solar irradiance, ample land availability, and low land costs, yet further expansion is now severely constrained by grid saturation.

Comprehensive analysis of national substation data reveals that these transmission constraints stem not merely from substation capacity saturation but from bottlenecks in transmission corridors. Although some substations in Jeolla-do still retain marginal capacity, grid connectivity is effectively blocked due to overloaded transmission lines. As of 2025, the total estimated available substation capacity nationwide is about 180 GW, with the Seoul Metropolitan Area and Chungcheong-do regions maintaining relatively ample headroom. In contrast, 15 out of 34 counties in Jeolla-do have less than 0.1 GW of spare capacity, rendering new grid connections effectively impossible. In regions such as Gangjin, Jangheung, Jindo, and Haenam (Jeollanam-do) or Gochang, Namwon, Muju, and Jangsu (Jeollabuk-do), substations are already operating at full capacity.

Nonetheless, within these same provinces, areas such as Naju (338 MW), Yeosu (743 MW), Damyang (424 MW), and Jangseong (538 MW) still retain significant substation headroom. This indicates that the constraint lies less in substation limits and more in the transmission paths available to export generated power—revealing localized grid congestion as the real bottleneck. In mountainous inland areas such as Namwon, Muju, and Jangsu, transmission line utilization already exceeds 95%, while coastal and industrial zones like Gunsan (702 MW), Iksan (382 MW), and Wanju (582 MW) still have measurable capacity available.

Due to the constraints, the additional renewable permits are restricted in the Jeolla-do region until 2031 (excluding pre-approved capacity). To address this, KEPCO has announced plans to invest KRW 73 trillion in expanding the national transmission network, including the deployment of HVDC (high-voltage direct current) infrastructure. However, these are long-term projects that will take years to deliver tangible results.

Yet simply building more long-distance transmission lines will not solve the underlying issue; as demand continues to rise, new lines will require continual replication, perpetuating the same structural inefficiency. The fundamental solution lies in transitioning toward a distributed grid system, where power is generated and consumed within the same region. In this model, agrovoltaics and other local distributed generation resources can effectively utilize existing substation headroom, and enhance regional energy self-reliance—providing a practical, scalable pathway for Korea’s renewable transition.

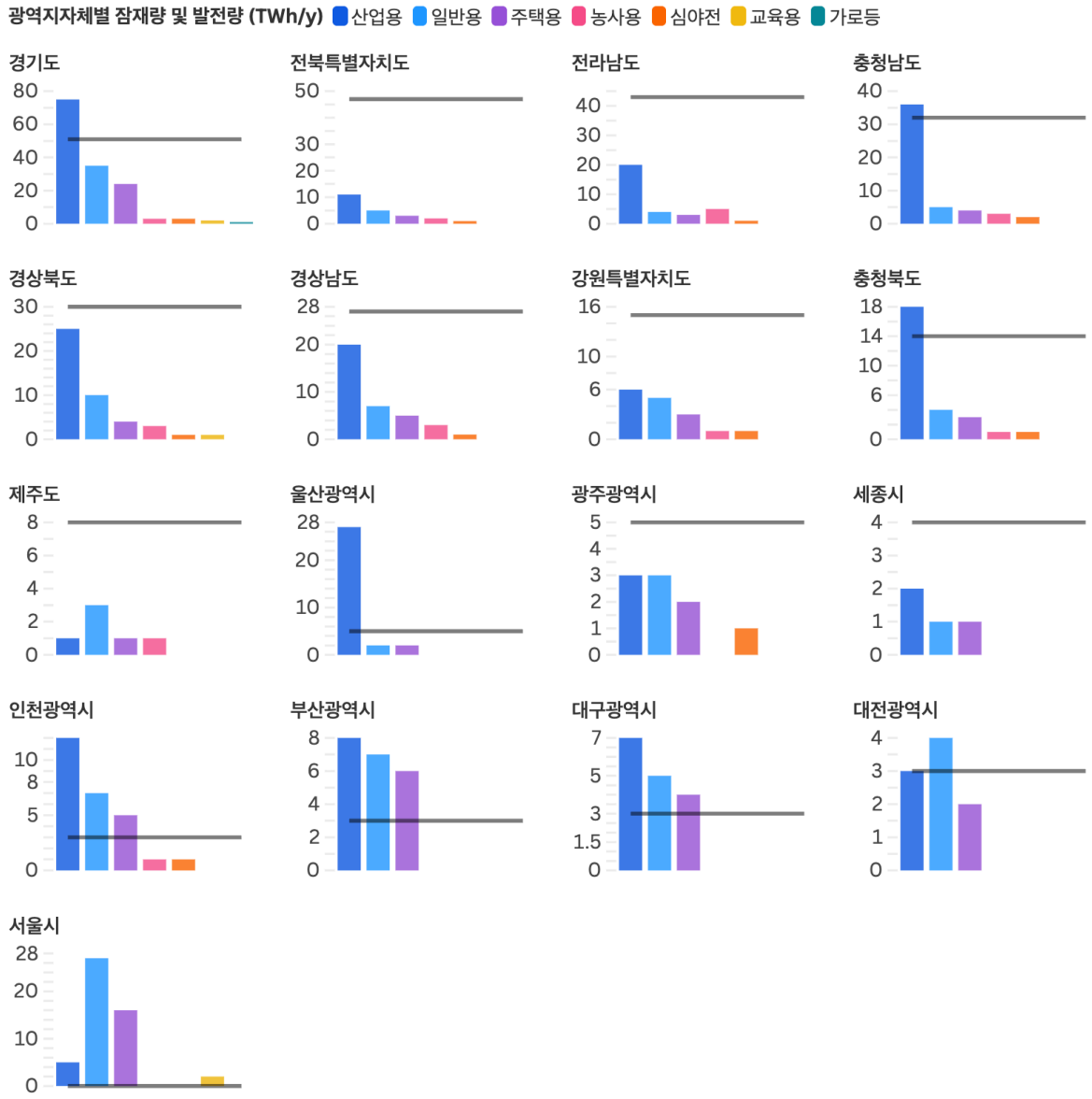
Regional Potential vs. Power Demand: Is Local Energy Self-Sufficiency Achievable?

Despite its vast potential, agrovoltaics alone cannot fully meet regional electricity demand without addressing the inherent intermittency of solar generation. However, unlike large-scale transmission expansion, reinforcing local substation capacity and linking renewable output directly to regional demand can substantially increase local renewable utilization.

When comparing provincial agrovoltaic potential with total electricity demand, most non-metropolitan regions possess sufficient renewable capacity to cover a large share of their consumption. Jeollabuk-do holds potential generation exceeding twice its total demand, while Jeollanam-do could supply roughly 130% of its needs. In contrast, Gyeonggi-do—the largest demand center outside Seoul—could only meet about 35% of its total demand, underscoring a structural supply deficit driven by dense industrial and urban activity.

Both Gyeongsangbuk-do and Gyeongsangnam-do have the potential to replace 60–70% of total regional demand through agrovoltaics alone, and could fully meet their industrial electricity needs under sector-specific conditions. On the other hand, metropolitan areas such as Seoul, Busan, Daegu, and Incheon face severe land-use constraints, making local renewable self-sufficiency virtually impossible. These disparities clearly indicate that expanding transmission lines cannot resolve the problem; instead, a structural transition toward distributed generation and regional balancing is required.

Figure 3. Agrovoltaic potential (horizontal line), and the power demand by type (column) by region.



When assessed by industrial power demand, the gap in renewable self-sufficiency becomes even more pronounced. Jeolla-do and Gyeongsang-do possess enough agrovoltaic potential to supply a substantial portion—or even exceed—the electricity required by their industrial sectors. Jeollabuk-do's potential generation is estimated

to be four times its industrial demand, while Jeollanam-do holds nearly double. Gyeongsangbuk-do and Gyeongsangnam-do could respectively meet almost all or the entirety of their industrial requirements through agrovoltaics. Agrivoltaics can supply 90% of Chungcheongnam-do's industrial demand locally, and >200% for Gangwon-do, reflecting abundant land and solar potential relative to demand. Gyeonggi-do, which has the nation's largest industrial consumer of electricity, could meet about 70% of its industrial demand via agrovoltaics. Seoul, Incheon, Busan, Daegu, and Ulsan possess such limited available land that their potential falls well below half of local industrial consumption.

These findings reinforce that Korea's energy transition must move beyond centralized generation and long-distance transmission. Instead, it requires a distributed, regionally balanced grid system—where renewable generation is spatially aligned with demand and local resources are leveraged to strengthen both energy autonomy and industrial resilience.

National Transition Toward an Agrovoltaic-Based Distributed Power System

While this report analyzes the potential of agrovoltaics and regional electricity balance across Korea, several limitations must be acknowledged. Institutional and permitting constraints, as well as varying levels of social acceptance across regions, could not be fully reflected. Likewise, temporal variations in substation and transmission data introduce uncertainty, and economic feasibility and policy

implementation were beyond the quantitative scope of this analysis. Nevertheless, the direction of implication is clear.

South Korea's power policy must now move beyond the limits of a centralized supply structure. The essence of the energy transition lies not in building more power plants but in establishing a system where electricity production and consumption occur within the same region. Such a distributed framework is not a mere technical adjustment but a philosophical transformation in how the nation governs its energy system. Korea must shift away from a model where electricity is generated in a few centralized locations and transmitted nationwide, toward one where all regions can produce and consume energy autonomously.

The analysis shows that agrovoltaics can play a pivotal role in strengthening regional energy self-sufficiency and industrial power resilience outside the Seoul Metropolitan Area. Regions such as Jeolla-do and Gyeongsang-do possess the structural foundation to become major renewable power hubs, while the Seoul Metropolitan Area and other large cities risk becoming permanently dependent on imported electricity. Future power policy must therefore focus not only on transmission expansion but also on redesigning the circulation of power between production and consumption centers through a distributed architecture.

From this perspective, agrovoltaics offers a practical foundation for national transition. By reinterpreting agricultural land as a strategic energy infrastructure, Korea can alleviate spatial imbalances and build self-sufficient local grids. This would transform rural areas from passive power consumers into active components of the

national energy system. The localization of energy is inherently tied to balanced national development and stands as a prerequisite for achieving carbon neutrality.

Hence, the policy focus should shift from the expansion of total generation or transmission capacity to the construction of regionally centered distributed systems. When each region can produce and consume energy using its own resources, the nation’s energy ecosystem will evolve into a more resilient and balanced structure. Ultimately, agrovoltaics is not merely a renewable energy technology—it is the strategic core connecting carbon neutrality, balanced territorial development, and industrial competitiveness.

Energy transition is both a technological and structural challenge, demanding that energy policy be reframed as a spatial and national strategy. Agrovoltaics marks the beginning of that transformation—through it, Korea can simultaneously achieve energy self-reliance and carbon neutrality.

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