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Design and Operational Structure of the Co-optimized Market in Japan

～Aiming at Institutional Optimization While Maintaining a Decentralized Dispatch System～

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In recent years, against the backdrop of the expanded introduction of variable renewable energy (hereinafter "VRE") and the increasing prominence of fossil fuel procurement risks, a range of challenges has emerged within Japan's power system. These include insufficient sell-side bids and price spikes in the wholesale electricity market and the balancing market, growing difficulty in maintaining the supply–demand balance, and an increase in transmission congestion. Looking ahead, as the large-scale deployment of VRE progresses further, these issues are expected to become even more pronounced.

To address these challenges, comprehensive measures that take a holistic view of the entire power system are indispensable. One promising approach is the introduction of a "Co-optimized Market" (i.e., a co-optimization mechanism), which optimizes the operation of generation resources at a point in time close to real-time supply and demand.

This paper organizes the institutional design and operational structure of the Co-optimized Market under the premise of Japan's decentralized dispatch system. It also clarifies key considerations and challenges for future market design through a comparison with centralized dispatch systems, as exemplified by PJM in the United States.

1. Background to the Introduction of the Co-optimized Market

In Japan, the consideration of introducing a Co-optimized Market is driven by the recognition that, amid significant changes in the environment surrounding the power system, it is becoming increasingly difficult to ensure both stability and efficiency under the conventional market structure and supply–demand operation framework. With the expansion of renewable energy, the variability of generation output has increased, and, coupled with rising fuel prices and growing procurement uncertainty, various challenges have become evident in the wholesale electricity market and the balancing market, including insufficient sell-side bids, sharp price spikes, and shortages of balancing capacity.

These challenges are considered to stem from structural distortions inherent in the institutional framework, in which energy (kWh) and balancing capacity (ΔkW) have been traded in separate markets. For generation companies, the decision of whether to supply capacity as energy (kWh) or to reserve it as balancing capacity (ΔkW) has been left to their discretion. Under tight supply–demand conditions, this tends to result in competition for available supply capacity. Consequently, it has become difficult to achieve an optimal allocation of generation resources across the system as a whole.

In response to these issues, there has been a growing recognition of the need for a mechanism that can secure both energy (kWh) and balancing capacity (ΔkW) in an integrated manner and allocate them optimally at a point close to real-time supply and demand. The Co-optimized Market is positioned as a means to eliminate the competition for supply capacity that existed between the wholesale electricity market and the balancing market, and to form a generation mix that reflects supply–demand balance and network constraints at the market stage. In addition, a key objective of introducing the Co-optimized Market is to review the conventional market design, which has not fully reflected generator-specific cost characteristics—such as start-up costs and minimum output constraints of thermal power plants—and to achieve system-wide cost minimization through optimization based on Security-Constrained Unit Commitment (SCUC) and Security-Constrained Economic Dispatch (SCED), both of which explicitly consider network constraints.

Furthermore, given that the introduction of renewable energy is expected to continue in the future, forecast errors in supply and demand, as well as the required volume of balancing capacity, are anticipated to increase further. Accordingly, it is considered important to establish an integrated market and operational framework that enables stepwise and iterative optimization from the day-ahead stage toward real-time, thereby allowing flexible responses to supply–demand fluctuations and network constraints.

2. Overview of the Co-optimized Market

The Co-optimized Market is a new market framework designed to simultaneously clear energy (kWh) and balancing capacity (ΔkW), which have traditionally been traded separately, with the objective of optimizing generation operations at a point close to real-time supply and demand. Generation companies submit, on a unit-by-unit basis, three-part offers consisting of start-up costs, minimum output costs, and incremental cost curves. In addition, they register operational parameters necessary for unit control, such as upper and lower output limits, start-up times, and ramp rates[1]. Based on this information, the market operator performs Security-Constrained Unit Commitment (SCUC) and Security-Constrained Economic Dispatch (SCED), and determines in an integrated manner the commitment status of each generating unit, as well as the allocation of output and balancing reserves for each time period.

The Co-optimized Market is operated over a time horizon from 1 week prior to real-time up to just before the gate closure, 1 hour ahead of delivery, and consists of multiple market stages, including

[1] Agency for Natural Resources and Energy (2025). Second Interim Report of the Study Group on the Design of the Co-optimized Market. Retrieved January 20, 2026, from https://www.meti.go.jp/shingikai/energy_environment/doji_shijo_kento/pdf/20251015_1.pdf

weekly operation, the day-ahead market, the intraday market, and the final intraday market (just before gate closure). In the weekly operation stage, conducted from 1 week to two days prior to delivery, operational planning for pumped-storage hydro and commitment decisions for units requiring long start-up times are carried out. In the day-ahead and intraday markets, unit commitment plans and dispatch schedules are revised in accordance with updated supply–demand forecasts. Furthermore, immediately prior to gate closure, a final intraday market is conducted in which only dispatch adjustments are made, assuming that committed units have already been started.

Price formation for energy (kWh) in the Co-optimized Market is based on the results of optimization in which both energy and balancing capacity are procured simultaneously, and generation output and unit commitment are determined so as to minimize total system costs while taking network constraints into account. Specifically, the market price reflects the marginal cost of supplying an additional 1 kWh of electricity to the system. Fixed costs that cannot be recovered through this market price alone—such as start-up costs and costs associated with minimum output levels—are compensated through an uplift mechanism, thereby ensuring that generation companies can appropriately recover their costs under the market design.

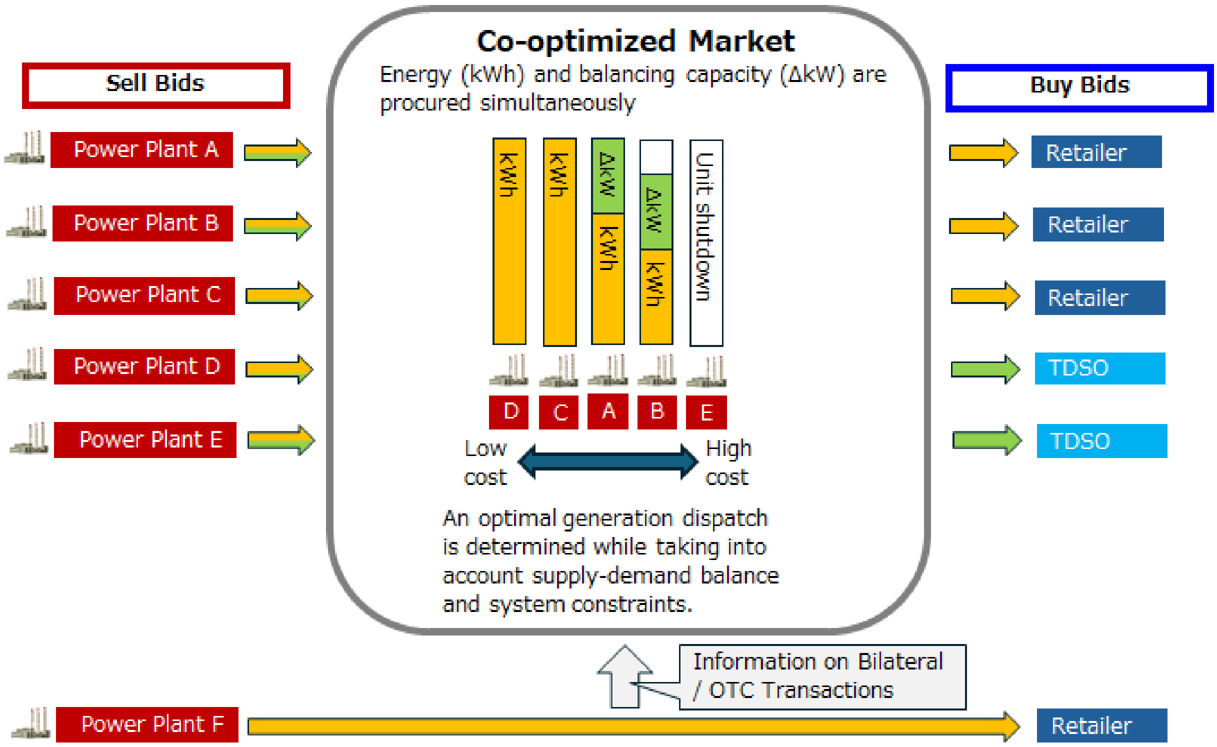

Figure 1: Overview of the Co-optimized Market

Source: Prepared by The Institute of Energy Economics, Japan, based on materials from the Agency for Natural Resources and Energy.

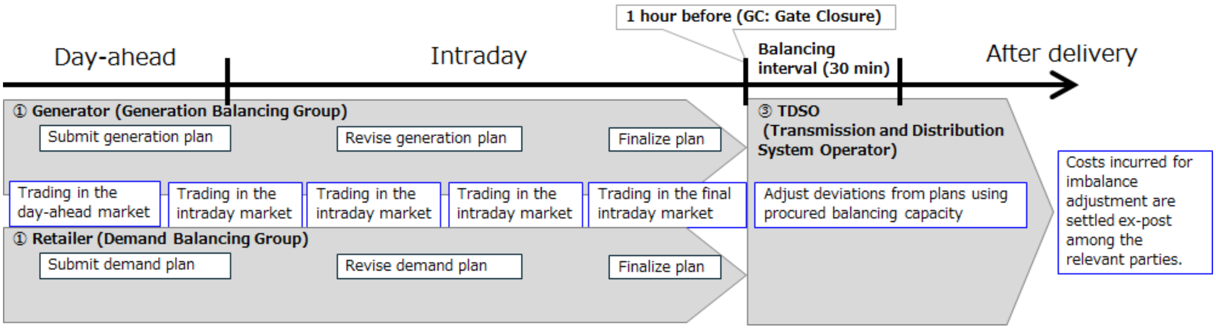

Figure 2: Flow of Market Transactions and Schedule Submissions after the Introduction of the Co-optimized Market

Source: Agency for Natural Resources and Energy (2025). Second Interim Report of the Study Group on the Design of the Co-optimized Market. Retrieved January 20, 2026, from https://www.meti.go.jp/shingikai/energy_environment/doji_shijo_kento/pdf/20251015_1.pdf

Table 1. Comparison between the Current Supply–Demand Balancing Framework in Japan and the Framework after the Introduction of the Co-optimized Market

Item	Current Framework	After the introduction of the Co-optimized Market
Basic Concept	Energy (kWh) and balancing capacity (ΔkW) are traded in separate markets	Energy (kWh) and balancing capacity (ΔkW) are simultaneously cleared in a single market
Main Markets	Wholesale electricity market (spot and intraday) + balancing market	Co-optimized Market (weekly operation, day-ahead market, intraday market, and final intraday market)
Market Objective	Electricity trading and procurement of balancing capacity are conducted separately	Optimization of resource procurement from the day-ahead stage to a point close to real-time
Bidding Method for Generation Resources	Bids in the wholesale market based on kWh prices; bids in the balancing market based on ΔkW prices	Three-part offers, including start-up costs, minimum output costs, and incremental cost curves
Treatment of Start-up and Minimum Output Costs	Recovered by generators through mechanisms such as block bids	Considered in SCUC/SCED; unrecovered costs are compensated through uplift
Consideration of Network Constraints	In the wholesale market, intra-area constraints are not considered (only interconnector constraints are reflected); redispatch is conducted by system operators after gate closure	Constraints of the bulk power system (upper two voltage levels) are explicitly considered; lower-level network constraints are addressed by system operators through redispatch after gate closure
Supply–Demand Balancing after Gate Closure	General Transmission and Distribution Utilities (TDSOs) perform balancing, frequency control, and system operation	Same as current (the Co-optimized Market concludes at gate closure)
Entity Responsible for Balancing	Before gate closure: generators and retailers (balancing groups), with imbalance charges providing incentives for balancing; after gate closure: General Transmission and Distribution Utilities (TDSOs)	Basic structure remains the same (decentralized dispatch system is maintained)
Procurement of Balancing Capacity	Through the balancing market and reserve-sharing contracts	Secured through the Co-optimized Market (reserve-sharing acts as a supplementary measure)
Concept of kWh Pricing	Area prices based on a simple merit order	Marginal incremental cost of supplying 1 kWh under the optimal generation dispatch

Source: Prepared by the Institute of Energy Economics, Japan, based on various sources.

3. Introduction of the Co-optimized Market under a Decentralized Dispatch System

Even if a Co-optimized Market is introduced in Japan, the fundamental structure of supply–demand balancing will continue to be based on a decentralized dispatch system. A key feature of this framework is the clear allocation of responsibilities for balancing according to the time horizon. Prior to gate closure—set at 1 hour before real-time—balancing groups (BGs), consisting of generation companies or retail companies, take the lead in formulating supply–demand plans under their own responsibility and ensure balance through market transactions and other measures. In contrast, in the real-time stage after gate closure, General Transmission and Distribution Utilities (TDSOs) assume responsibility for supply–demand balancing and frequency control, issuing dispatch instructions with priority given to maintaining system reliability.

By contrast, PJM, a Regional Transmission Organization (RTO) in the eastern United States, adopts a centralized dispatch system in which market operation and system operation are integrated. In PJM, supply–demand balance, network constraints, and frequency control are managed in a unified manner from the day-ahead market through to the real-time market, during which Locational Marginal Prices (LMPs) are calculated. Accordingly, the institutional framework observed in Japan—where the entity responsible for balancing shifts at the point of gate closure—is not adopted.

In other words, in Japan, the institutional design is based on a division of roles in which balancing groups autonomously formulate supply–demand plans, and General Transmission and Distribution Utilities (TDSOs) perform adjustments at the real-time stage to address deviations between planned and actual supply and demand. In contrast, in PJM, balancing functions are centralized within the RTO. Generation companies and demand-side participants engage in the market and system operation by submitting operational information and bids and by complying with dispatch instructions, while the operational responsibility for balancing is consistently vested in PJM.

It should be noted that, even in PJM's centralized framework, bilateral contracts exist to a certain extent, often accompanied by self-scheduling for their fulfillment, primarily serving as a means to hedge price fluctuation risks between generators and retailers. However, since balancing operations are centralized in PJM, the institutional structure does not require the generator parties to such bilateral contracts to adjust output in accordance with the demand of specific retailers. In contrast, under Japan's decentralized dispatch system, bilateral contracts provide strong incentives for generators (generation BGs) to perform supply–demand balancing up to the point of gate closure.

4. Key Considerations for the Introduction of the Co-optimized Market in Japan

Finally, this section presents the author's views on key considerations for introducing a Co-optimized Market in Japan.

First, in PJM in the United States, the day-ahead market is positioned as a venue for financial risk hedging, and virtual bidding is permitted. Through this mechanism, price differences between the day-ahead market and the real-time market tend to converge via arbitrage, thereby ensuring market liquidity and rational price formation even under a locational pricing framework. In contrast, Japan's day-ahead market does not adopt a financial bidding scheme. If zonal pricing or nodal pricing were to be introduced in the future under the current framework, there is a possibility that significant price divergences could arise between day-ahead market prices and imbalance charges, either on a zonal or locational basis.

Second, if, in Japan, the Co-optimized Market system were to operate prior to gate closure and the dispatching system of General Transmission and Distribution Utilities (TDSOs) were to take over after gate closure, it is necessary to recognize that, compared with PJM's centralized dispatch system—where supply–demand balancing and price formation are conducted in an integrated manner from the day-ahead stage through to real time—certain constraints may remain in terms of information continuity and operational efficiency between the two systems.

Third, in Japan, the institutional design assumes that balancing responsibility prior to gate closure is borne by balancing groups. Accordingly, it is envisaged that multiple intraday market sessions will be held following the day-ahead market, with an additional market session immediately prior to gate closure. At each stage, balancing groups are required to revise bids and adjust their positions, and optimization based on SCUC and SCED is performed repeatedly. As a result, depending on system conditions, market outcomes may fluctuate significantly across these stages. Careful consideration is therefore required as to whether this could lead to increased operational burdens on balancing groups (e.g., frequent plan revisions), disruptions in generation operations (e.g., changes in unit commitment schedules), and increased system load on the market operator. In this regard, it should also be noted that PJM, which adopts a centralized dispatch system, employs a two-settlement structure consisting of a day-ahead market and a real-time market, resulting in a comparatively simpler market design than that of a Co-optimized Market under a decentralized dispatch system.

In light of the above, if Japan intends to maintain its decentralized dispatch system over the long term, it is unlikely that it can easily evolve toward a system similar to PJM's centralized dispatch system, given the fundamental differences in institutional design. Therefore, it is also useful to examine institutional developments in Europe, where decentralized dispatch systems are likewise adopted. For example, there may be scope to consider reforms such as shortening the trading interval (currently 30 minutes in Japan) and moving gate closure closer to real time (currently 1 hour ahead of delivery), on the premise of placing greater responsibility for balancing on balancing groups (generators / retailers).

It is essential to avoid excessive rigidity in institutional and system design and instead ensure sufficient flexibility to adapt to changing conditions in order to secure long-term stability of the market framework.

(1) Two Options for the Efficient Utilization of ΔkW and kWh

- Option 1: Introduction of a Co-optimized Market (Simultaneous procurement of ΔkW and kWh) ※ Implemented by RTOs/ISOs in the U.S.
- Option 2: Enhancement of the Balancing Framework (Without changing the current day-ahead spot market framework, gate closure is moved closer to real-time, and the balancing interval is shortened) ※ Implemented in Europe

	Introduction of a Co-optimized Market	Enhancement of the Balancing Framework
Advantages	• The T&D operator can efficiently utilize both ΔkW and kWh.(Unused ΔkW can also be utilized as kWh) • The T&D operator can develop efficient operational plans by taking into account marginal costs, start-up costs, and minimum output costs.	• Limited burden on generators and retailers, as it involves improvements to the existing framework.(Japan's power system is based on a European-style design, ensuring high compatibility) • Each generator can conduct long-term operation planning based on its own fuel procurement conditions and constraints.
Challenges	• Increased burden on generators and retailers due to system modifications, redesign of operational workflows, and staff training. • Difficulty in considering information such as fuel constraints of individual generators, raising concerns about achieving efficient long-term system operation.	• Concerns over whether generators and retailers can appropriately perform balancing. • Inefficient utilization of ΔkW and kWh may remain.(A portion of ΔkW may remain unused)

Figure 3: Advantages and Challenges of Introducing Co-optimized Markets and Improving the Balancing Framework

Source: Prepared by the Institute of Energy Economics, Japan, based on "Electricity and Gas Policy Subcommittee, Material 5". Retrieved January 20, 2026, from https://www.meti.go.jp/shingikai/enecho/denryoku_gas/denryoku_gas/pdf/070_05_00.pdf

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