Regulatory Foundations for Cross-Border Electricity Trading: India

David J. Hurlbut and Sam Koebrich

National Renewable Energy Laboratory

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Preface

This report was developed by the National Renewable Energy Laboratory (NREL) for the U.S. Department of State's Bureau of South and Central Asian Affairs Regional Connectivity Program. The report is part of a project providing technical assistance to support increased cross-border electricity trade (CBET) and cooperation in the South Asian region (including India, Nepal, Bhutan, Bangladesh, and Sri Lanka). The project aims to identify opportunities for, and the associated value of, increased power trade through peer-to-peer collaborations, power system modeling, regulatory roadmaps, and improved data. The technical assistance involves four critical stakeholder groups: power system engineers, power system planners, regulators, and electricity developers. This technical assistance will contribute to the future development of a more robust regional energy market, bolster the potential for cross-border connectivity in South Asia, and enable growth of renewable energy in the region.

Through the Greening the Grid program, NREL has been developing national and subnational grid integration studies in India that analyze strategies to integrate high levels of renewable energy into the South Asia grid. These renewable energy grid integration studies provide a solid foundation for understanding regional energy resources and needs, and thus inform the creation of a South Asian regional energy coordination strategy.

Other activities in this project build from the data collection, modeling, and analysis supported by the U.S. government under other interagency partnerships in the South Asian region, including the Partnership to Advance Clean Energy, a new Millennium Challenge Corporation program for South Asia renewable market integration, Enhancing Capacity for Low Emission Development Strategies, the Sustainable Growth Working Group under the U.S.-India Energy Dialogue, the Clean Energy Ministerial, and other Indio-Pacific Economic Corridor activities through U.S. Department of Commerce's Commercial Law Development Program. NREL will build from the knowledge, examples, and institutional relationships that have emerged from these initiatives and will provide concrete improvements for U.S. government investment in the South Asian region.

Acknowledgments

The authors are grateful to S.K. Soonee, senior advisor to Power System Operation Corp. Ltd., for his invaluable feedback on this report series. We are also grateful to our NREL colleagues Dan Bilello, Kristen Ardani, David Palchak, Amy Rose, Mohit Chandra Joshi, and Rasel Mahmud for their review and comments. Isabel McCan and Liz Breazeale provided editorial support.

List of Acronyms

CBET	cross-border electricity trading
CERC	Central Electricity Regulatory Commission (India)
FERC	Federal Energy Regulatory Commission (United States)
GtG	government-to-government
ISGS	interstate generating station
MBED	market-based economic dispatch
MCP	market clearing price
NREL	National Renewable Energy Laboratory
PPA	power purchase agreement
RLDC	regional load dispatch center
RTO	regional transmission organization
SAMAST	scheduling, accounting, metering, and settlement of transactions
SCED	security-constrained economic dispatch

Executive Summary

Cross-border electricity trading (CBET) can reduce costs, improve reliability, and reduce emissions for all participating countries. Regulatory coordination is essential to making CBET successful. For India, expanding CBET mechanisms could increase access to Nepal's large hydroelectric potential, especially if it were done through a comprehensive CBET framework. This report maps the regulatory issues India might address if it elects to expand its national strategy for CBET with its neighbors in South Asia.

CBET can take one of three general forms. Each form raises different sets of regulatory issues and involves different levels of cross-border coordination. CBET types include:

- Tenant generation, in which a generator exports power to another country over a dedicated cross-border transmission line with little or no connection to the host country's system;
- A bilateral contract, where power moves through both national networks and across transmission interfaces linking the two grids; and
- An integrated market exchange where cross-border trades and all other power flows are optimized simultaneously over multiple networks.

These three models vary with respect to new transmission and operational coordination between the two countries. Improvements to dispatch and ancillary service procurement can also differ. Table ES- 1 contrasts the three CBET models.

Table ES-1. Characteristics of CBET Models

	Tenant Generation	Bilateral Contracts	Integrated Markets
Need for coordinated scheduling between countries	○	◗	●
Need for transmission expansion	●	◗	◗
Fixed pricing*	●	●	◗
Improved dispatch—exporting country	○	◗	●
Improved dispatch—importing country	◗	◗	●
Improved reliability	○	◗	●
Improved ancillary services (less cost, more flexibility)	○	◗	●

○: low ◗: moderate ●: high

*In contrast with market clearing prices, which can vary by hour or more frequently depending on market design and system conditions. See chapter 3 for a discussion of market clearing prices.

India is evaluating major market reforms that could accelerate CBET. Regulators proposed these reforms in 2018 to address inefficiencies in India's wholesale power markets, but, if ultimately adopted, they could accommodate CBET with India's neighbors. The development of a South Asian wholesale power market based on security-constrained economic dispatch (SCED) could significantly enhance opportunities for CBET, including power transfers between Nepal and Bangladesh.

India's opportunities for successful CBET depend on strategic coordination across national policy, regulation, and power system planning. A key question for national policy will be how neighboring countries might participate in Indian wholesale market reforms, if and when India permanently enacts them. More generally, national policy provides authoritative guidance on how India balances CBET goals with other national goals. One area that might benefit from policy clarity is guidance on how regulators should balance energy independence with the economic benefits of regional interdependence. This could include identifying critical thresholds for measures such as import/export volumes and domestic service disruptions due to insufficient power supplies.

National policy, in turn, affects the creation of rules and other regulatory decisions. Regulatory issues for all types of CBET might include:

- Accounting for CBET in standards for approving new transmission
- Guidelines for allocating the cost of new transmission intended to enable CBET
- Reporting requirements (sales, purchases, curtailments, cost of energy paid for but not taken, and other metrics).

For bilateral agreements and integrated markets, rules might additionally include:

- Whether to allow large customers to switch service from a traditional distribution utility to an alternative provider, and how it may be done
- Methods for assessing whether wholesale power prices are reasonable and competitive.

For integrated markets, rules might include:

- Registration of market participants
- Application of standards for scheduling, accounting, metering, and settlement
- Dispute resolution processes for parties in different countries.

Governance, which is different from jurisdictional authority, could be important in making India's market reforms work across all of South Asia. A well-crafted governance structure would provide the governments of Nepal, Bangladesh, and other participating countries with an avenue of regular, formal input on matters affecting the shared market, even if ultimate regulatory authority remains with India's Central Electricity Regulatory Commission (CERC). Most regional transmission organizations (RTOs) in the United States have a comparable governance structure. The Federal Energy Regulatory Commission (FERC) has jurisdiction over the RTO tariff, but the RTO itself has several stakeholder committees organized under a governing board. In most cases, state regulators are members of a special committee that provides executive-level policy input to the RTO board.

Wholesale power markets evolve over time, and India's success in achieving beneficial CBET could be aided by tracking indicators of market outcomes. Monitoring prices and trading activity can provide public accountability for CBET policies. It can also provide early signs of the need for mid-course corrections in specific regulations.

Technical analysis can show the theoretical benefits of integrated markets and CBET, but implementation depends on each country's utility laws and regulatory institutions. Building an integrated power market is complex and often requires regulators to enforce transparency, patience, and careful attention to detail. Because institutional evolution does not necessarily proceed at the same pace in all countries, cooperation among regulators is key to managing the process and ensuring that each country enjoys the full benefits of CBET.

Table of Contents

List of Figures

List of Tables

1 Introduction

Greater cross-border electricity trading (CBET) can benefit customers throughout South Asia. Limited trading already takes place, but India, Bangladesh, and Nepal have signaled interest in increasing the commercial flow of electricity among them. Harmonizing policies on both sides of the border is crucial, however, because poor or uncoordinated regulations can suppress CBET and jeopardize the potential public benefits. For India, expanding CBET mechanisms could help in integrating wind and solar, in addition to accelerating its beneficial use of Nepal's large hydroelectric potential. The purpose of this report is to provide an overview of CBET options and the different regulatory decisions they entail, with a focus on India.

Ideally, CBET strikes a balance between two public interest goals: energy independence and cost savings through foreign trade. The early stages of national electrification normally favor energy independence and have little exchange with neighboring countries. As the country's economic development expands to include a larger cross section of the population, however, keeping the price of electricity as low as possible becomes increasingly important to sustainable growth. Low electricity costs might depend on strategies enabled by CBET, such as:

- Greater access to low-cost generation resources
- Development of high-voltage transmission corridors to reduce line losses
- Pooling operating reserves across borders
- Regional resilience plans for speedy recovery from earthquakes, flooding, or other natural disruptions to the grid
- Better integration of high volumes of wind and solar power with less curtailment.

CBET is a feature of the evolving electricity sector around the world, but it does not happen on its own. Economically beneficial trading relies on strategic policies and effective regulation that aim for the right public interest balances. It also involves cooperation among sovereign nations, and agreement on matters, such as the allocation of costs, mechanisms for resolving commercial disputes, technical standards, and the governance of institutions charged with operating joint markets on a shared grid.

Major electricity reforms in India could accelerate CBET in South Asia significantly. While these proposed reforms are not certain as of this report's writing, they would involve considerable preparation if they are implemented and neighboring countries choose to participate. India's aim is to eliminate waste and inefficiency by establishing geographically integrated market-based mechanisms for scheduling, energy dispatch, and procurement of ancillary services. In this report, we pay special attention to these reforms and their status as of this writing. While the key driver of these reforms is India's domestic need to increase the efficiency of its own power sector, current and proposed policies appear to contain no inherent barrier to neighboring countries' participation.

CBET can take place through bilateral contracts, an integrated market with joint dispatch, or a combination of both. Under a bilateral contract, a specific supplier in one country delivers electricity to a specific customer in another country. Deals are negotiated directly between two counterparties who agree on prices, quantities, and schedules for energy delivery. In contrast, an integrated market combines many suppliers offering electricity to many customers through a power pooling arrangement. Integrated trading takes place through an automated auction platform that sets prices and determines dispatch quantities for each plant at hourly or subhourly operating intervals. The result is cost-optimized dispatch across the entire grid.

After defining CBET types, this report examines integrated market exchanges with joint dispatch as contemplated in India's proposed wholesale power market reforms. These markets are generally more complicated, but they are also more transparent. If extended to include CBET, these reforms could represent a new framework for South Asian utilities and CBET.

The fundamentals of integrated markets and differences in CBET types suggest foundational questions India might consider answering as it develops its national CBET policies. The aim of this report is not to recommend answers to these questions. Rather, it is to lay out a roadmap of major decision points that can guide the country's policy development. How India answers these questions would guide how it shapes the regulatory issues described in Section 5.

The report finishes with several suggestions for how India could monitor CBET outcomes. Markets often take years to reach a point of consistent efficiency, and this could include mid-course adjustments to regulations. Monitoring would enable the government to track CBET progress and ensure regulatory policies are up to date.

2 Types of CBET Arrangements

CBET transaction models can differ significantly in their commercial and political characteristics. This section defines three categories, which, in order of regulatory complexity, include: tenant generation; bilateral commercial agreements; and integrated market exchanges.

Addressing each of these CBET categories on its own merits can make government policy and regulation more effective. Important factors that can differ include ownership of generation, coordination with power system operations on either side of the border, risk management, the ability of the generator to recover costs, and impacts on domestic customer electricity bills.

2.1 Tenant Generation

This type of project is built in one country for the primary purpose of serving demand in another country. Dedicated long-distance transmission lines connect the generator to the grid of the importing country with minimal connection to the grid of the host country.

From the viewpoint of the importing country's utility and grid operator, a tenant generator on the other side of the border is operationally the same as a domestic generator. The plant is subject to the importing utility's rules for scheduling, commitment, dispatch, and settlement. Congested transmission flows between the two countries have little or no effect on the delivery of power to the importing country, due to the dedicated transmission line through the host country.

The role of the host government is largely limited to site permitting and terms of tenancy (annual lease payments and other remuneration). Neither the host country nor its grid operator has any role in the plant's scheduling, dispatch, or financial settlement. Financially, energy and capacity revenues for a tenant generator are independent of anything that happens on the host country's grid.

A tenant generator can sign bilateral agreements, participate in an integrated market, or transfer ownership to the purchasing utility. In any case, the country hosting the plant generally does not benefit from greater economic or operational efficiency for its grid. The benefits are mostly limited to the terms of tenancy, taxes, and local employment. A tenant project generally does little for the ability of other generators in the host country to access the market of the importing country.

The proposed 900-MW Arun 3 project, for example, would be built and operated in eastern Nepal by SJVN Ltd., a joint enterprise of the Government of India and the state government of Himachal Pradesh (Investment Board of Nepal 2014). The project includes a dedicated 400-kV transmission line from the dam's powerhouse in Nepal's mountainous Sankhuwashabha District to the Muzaffarpur substation in the Indian state of Bihar. Terms of the agreement with Nepal include providing a portion of the output to the Nepal Electric Authority grid at a substation near the border, as well as annual royalties and tax revenues.

2.2 Bilateral Contracts

Bilateral CBET transactions involve electricity that is scheduled and wheeled across an interconnection between two countries' power systems. The generator is connected to the grid of the exporting country, while the entity purchasing the power is connected to the grid of the importing country.

Unlike tenant generation, bilateral CBET transactions involve a moderate level of operational coordination between the two countries. Balancing—that is, the continuous task of keeping total generation equal to the sum of load and net transfers to neighboring grids—is one example. Each country's grid operator has to ensure that actual generation matches actual metered electricity demand at every moment throughout the day. Imports and exports are part of the balancing equation, as Figure 1 illustrates. The importing country and the exporting country need to have the same information about the volume and timing of electricity flows between their two systems for each to maintain balance. After accounting for net imports and exports, each country maintains its system balance with incremental increases or decreases to its active generation and with load management (demand response, interruptible load, and, in extreme cases, load shedding).

Bilateral exchanges are commercially independent of one another. The agreement between one buyer and one seller does not directly affect the price, quantity, or timing of another agreement between two other counterparties. Only when transmission congestion restricts the total flow of power on the system does the grid operator have a role in changing the amount of electricity moving under a bilateral agreement.

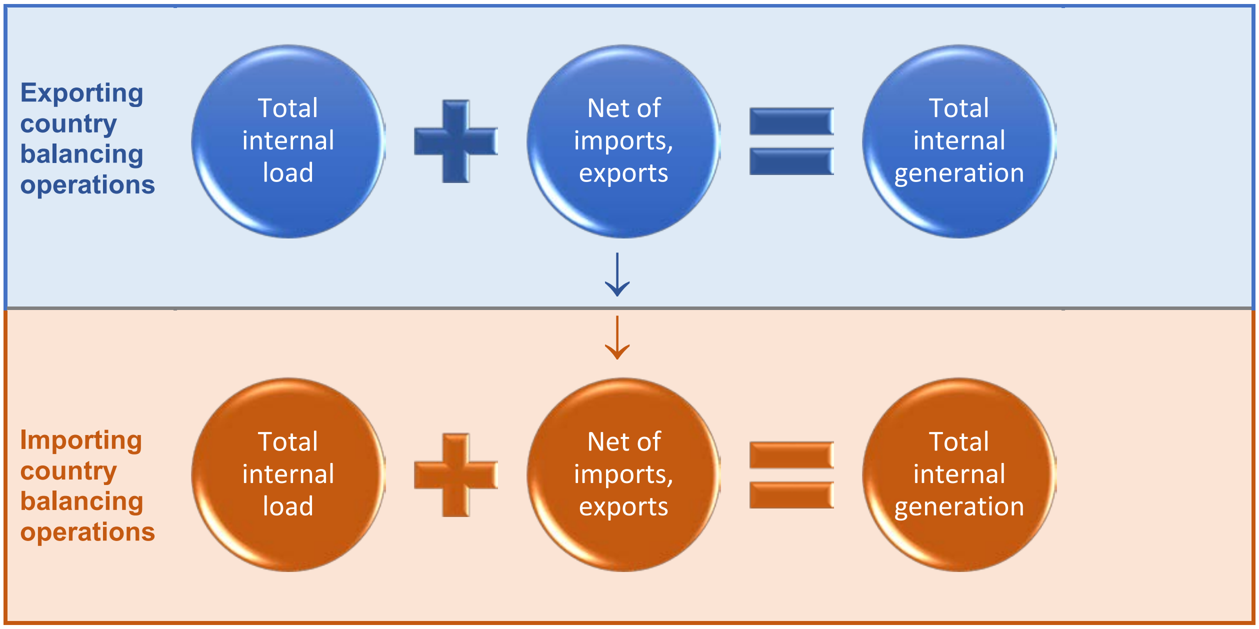
Government policies, such as import tariffs, taxes, and regulations, can create additional costs that counterparties account for when they enter into a bilateral agreement. Such policies tend to be nondiscriminatory, in that they are universally applicable to any deal between two eligible counterparties. Policies might weigh favorably or unfavorably, but it is nevertheless up to the counterparties to decide whether the agreement ultimately benefits both sides.

Barriers to bilateral CBET can include ownership requirements, import tariffs, government requirements for generation to come from domestic resources, or a lack of harmonization in regulations governing grid operations.

2.3 Integrated Market Exchanges

An integrated market optimizes unit dispatch and pricing across the region, so that load is met by the least-cost resources all the time. Energy offers from generators, updated load forecasts, and information on the current state of the grid feed into software that computes market outcomes many times throughout the day.

Bilateral CBET deals are independent of one another and can be as numerous as the market will bear; an integrated market is the opposite. Unit dispatch and pricing are determined simultaneously for all load and all generation within the market footprint. A generator can submit an offer to provide a certain quantity of power at a certain price, but neither the dispatch quantity nor the price will be known to the generator until the market actually clears (i.e., until all offers are processed by the market software to produce a least-cost solution).

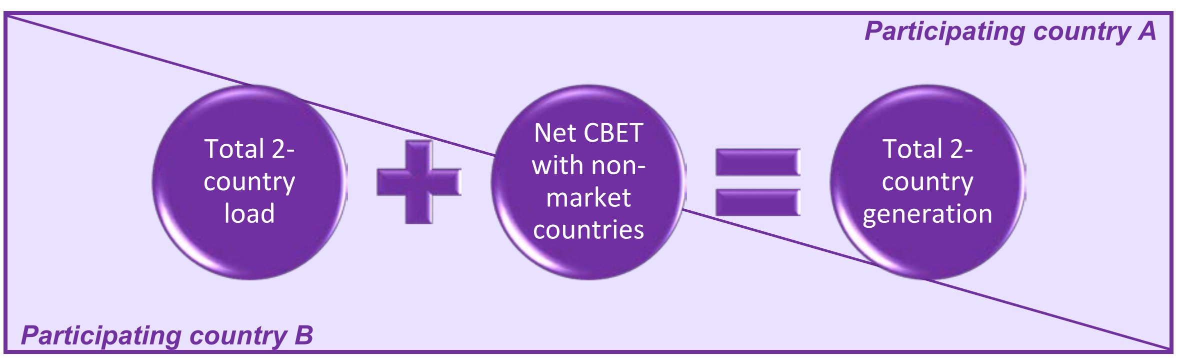


Total load managed separately in each country (demand response, interruptible service, load shedding)

Total generation managed separately in each country (increases and decreases from balancing reserves)

Figure 1. Moderate coordination: Bilateral CBET with separate balancing in each country

NREL illustration



Combining load, bilateral exchanges, and generation across both countries results in a smaller net imbalance that is easier and cheaper to resolve

Figure 2. High coordination: Integrated market combining CBET and energy balancing

NREL illustration

Many integrated markets use security-constrained economic dispatch (SCED) to clear the market every hour or, in some cases, every 5 minutes. SCED is a computerized generator selection process that exactly matches the least-cost portfolio of generators to the amount of load expected for an operating interval without violating the thermal limits of any transmission line in the network. In many markets, SCED run for every hour of the next operating day to determine which generators are started and what their set points (operating levels) will be each hour. SCED can also run in real time to resolve imbalances between actual generation and actual load.

An international border running through an integrated market area has virtually no impact on how the market clears. What distinguishes one generator from another is the marginal cost of generation, the quantity of power available, transmission limits from the generator to the grid, and operational qualities such as ramp rate.

Figure 2 illustrates how balancing is more efficient in an integrated market. First, combining imbalances across several countries (or control areas within a country) often results in a smaller aggregated imbalance: negative and positive imbalances offset one another when combined. Second, this smaller imbalance can be resolved by drawing on a larger number of generators from which the least-cost option can be selected.

Integrated markets and bilateral trading are both driven by the market fundamentals of supply and demand. In bilateral deals, visibility into these fundamentals is a function of knowledge held by the counterparties. In an integrated market, on the other hand, prices form with fuller information about supply, demand, and value across the region.

No government has a hand in determining the quantity or price of electricity traded. A government may, however, approve participation by utilities, generators, and other entities under their jurisdictions. In addition, participating governments may discuss market rules to ensure they are nondiscriminatory, transparent, and promote economically efficient price formation.

Participating in an integrated market involves more regulatory steps by the government and more coordination between governments. Integration significantly changes many of the assumptions behind regulating the power sector. The public interest is less concerned with setting prices that are just and reasonable; it is more concerned with ensuring that pricing, dispatch, and other decisions are based on processes that are fair, transparent, economically efficient, and consistent.

2.4 Key Differences Between the Three CBET Types

With respect to policy and regulation, the major types of CBET involve different levels of coordination among the neighboring countries. Operational issues include generation scheduling, dispatch, and procurement of ancillary services. The types can also differ with respect to the need for new transmission investment and how it is evaluated.

Table 1 summarizes some of the key characteristics of integrated markets in comparison to tenant generation and bilateral contracts.

Table 1. Characteristics of CBET Models

	Tenant Generation	Bilateral Contracts	Integrated Markets
Need for coordinated scheduling between countries	○	◗	●
Need for transmission expansion	●	◗	◗
Fixed pricing*	●	●	◗
Improved dispatch—exporting country	○	◗	●
Improved dispatch—importing country	◗	◗	●
Improved reliability	○	◗	●
Improved ancillary services (less cost, more flexibility)	○	◗	●

○: low ◗: moderate ●: high

*In contrast with market clearing prices, which can vary by hour or more frequently depending on market design and system conditions. See chapter 3 for a discussion of market clearing prices.

2.5 Government-To-Government Transactions

Government-to-Government (GtG) exchanges are driven by diplomatic goals. They differ from tenant generation, bilateral commercial agreements, and integrated markets, in that the governments themselves are the counterparties.

One significant characteristic of GtG agreements is that they are outside the market. They do not necessarily follow fundamental power sector economics of supply, demand, and price formation (otherwise the transaction would not require government initiation). In the case of hydropower, government objectives that are important but outside power sector economics might include irrigation and flood control.

GtG agreements may involve government-financed infrastructure. In the Mahakali Treaty of 1996, for example, the governments of Nepal and India agreed in principle to build a multipurpose water project on the portion of the Mahakali/Sharda River forming part of the border between the two countries (Ministry of Water Resources 1996). Power generation would be divided equally between Nepal and India, similar to how the United States and Mexico share the production of two hydropower projects the countries built on the Rio Grande/Rio Bravo (International Boundary and Water Commission 1944). Nepal and India resumed talks in 2018 and started work on a new detailed project report that envisions a generating capacity of 6,480 MW (*Hindustan Times* 2018).

This report sets aside GtG transactions as a model for CBET. Each agreement is guided by a unique set of government objectives and does not necessarily form a precedent for future CBET policy. Public interest goals outside the bounds of other types of CBET transactions would make comparisons inapplicable.

3 Indian Market Reforms and Opportunities for CBET

Market reforms in India could open new opportunities for CBET across South Asia. The reforms, proposed in 2018 in a series of discussion papers issued by India's CERC, aim to address major inefficiencies that India has with its own system. While they are not aimed specifically at creating a CBET platform, the reforms represent a movement toward integrated markets that could, as a byproduct, enhance CBET.

3.1 Drivers for Reform in India

India's power grid began as a collection of separate state systems with limited connections among them. Consequently, India's electricity procurement and planning practices were largely uncoordinated across states and regions. Individual state-owned distribution companies were responsible for their own power scheduling, and many of these practices continue today. States may schedule their generation between an assortment of long-term electricity contracts with generators within the state, bilateral short-term contracts with generators in other states, and purchases from regional bulk power markets on a day-ahead basis.

The creation of central and state electricity regulatory commissions from the 1990s onward and the formation of the Power Grid Corporation of India (a national transmission company) in the late 1980s were major milestones in the development of India's interstate transmission system. Over the next decade, the all-India network continued to evolve with open access and other tariff reforms, power exchanges, point-of-connection transmission pricing, and (in 2013) operation of the state and regional grids as a synchronous system (Forum of Regulators 2016). Today, most state distribution companies can negotiate power purchases from anywhere in India. The national transmission network can deliver power into regional markets or to individual states.

Interstate generating stations (ISGSs) are generators with ownership shares from two or more states. An ISGS declares its available generation for the next day to its regional load dispatch center (RLDC), which then allocates the available capacity to states within the region based on shares and contracts. State distribution companies may purchase their allocation from the ISGS, sell it to someone else through bilateral contracts or on power market, or release the allocation and allow the ISGS to sell it on a power market (CERC 2018c). Some ISGS have as many 15 beneficiaries in various Indian states, while some states receive power from more than 40 ISGSs (CERC 2019a). In addition to this, each state schedule its own resources along with these ISGSs to meet its demand. While this system allows for some level of state and regional optimization, lack of coordination between the states, the large number of long-term bilateral contracts, and the uncertainty of when capacity is released all prevent economically optimal dispatch.

3.2 Market-Based Economic Dispatch

The new Indian electricity market would operate on the principles of market-based economic dispatch (MBED). The proposed reforms envision a new regime in which energy dispatch and ancillary service procurement would both be done across all of India simultaneously on a least-cost basis. A day-ahead market and a real-time market would determine which generators are dispatched and what they are paid. In each time interval of the market, all dispatched generators would receive a uniform market clearing price (MCP).

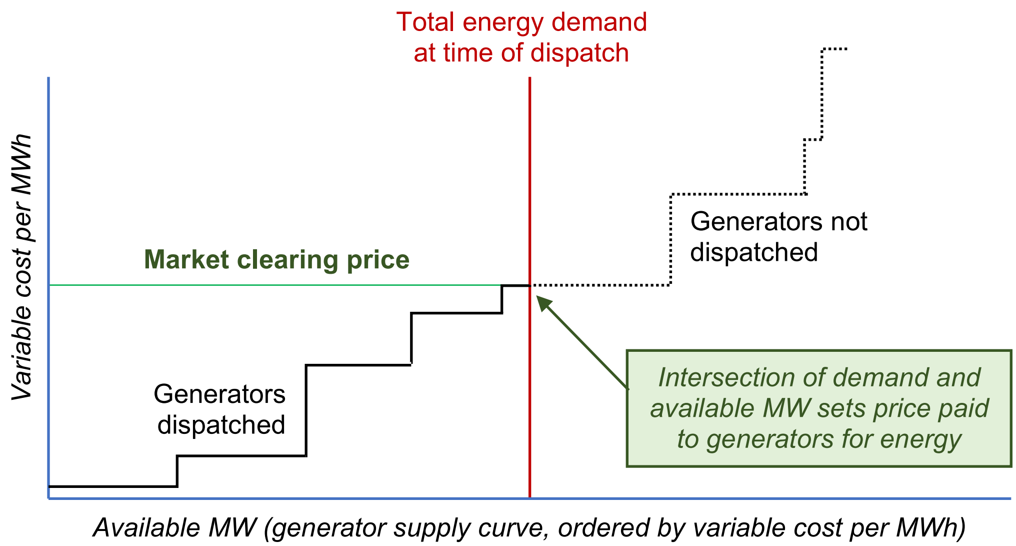


Figure 3. Simple illustration of uniform MCP for energy

NREL illustration

The MCP is the lowest price that will provide exactly enough energy to meet demand for a specific market period, based on the energy offers submitted for the period; this is called clearing the market. It represents the intersection of available supply and demand as illustrated in Figure 3.[1] All generators offering energy at or below the MCP would be selected for dispatch and would receive the MCP as compensation. Offers priced higher than the MCP would not be dispatched and would not be paid.

Under MBED, generators with capacity not already obliged through long-term contracts would offer their power into a single, national day-ahead market. Similar to power markets in the United States and Europe, generators would be able to select the price of their bid for various time blocks at different quantities.[2] Generation is scheduled and dispatched in merit order of bid prices and subject to technical restrictions, such as the unit's ramp rate and thermal limits on transmission lines.

The market operator would also simultaneously run energy and ancillary service markets and would utilize co-optimization to ensure the most economic suite of resources for each market is selected. Additionally, the market operator is proposing a national real-time market to coordinate and optimize energy purchases at the time of delivery before falling back upon ancillary services for procurement shortfalls.

3.3 SCED Pilot Project

In early 2019, CERC authorized India's Power System Operation Corporation (POSOCO) to launch a pilot project on SCED (CERC 2019a). The pilot project includes government-owned thermal power ISGSs that have been participating in the national Reserve Regulation Ancillary

[1] The figure illustrates how MCPs form if there is no transmission congestion. The market would separate into different MCPs if transmission congestion limited the flow of power between high-volume points on the grid.

[2] CERC might establish price mitigation rules if any generation entity has market power.

Services mechanism since 2016. The pilot project will include 57 thermal plants with a cumulative capacity of 55 GW (POSOCO 2018).

While SCED governs the physical dispatch of the participating federally owned ISGSs, the plants' long-term bilateral contracts or power purchase agreements (PPAs) are still in force. The contracted prices on these PPAs are often different from the MCPs that clear through SCED. To grandfather these plants into the new framework, government regulators suggest that distribution companies and generators negotiate new bilateral arrangements to hedge against the variability in MCPs and to share the potential cost savings. Scheduling and dispatching of power would still be decided through SCED, but differences between MCPs and the contracted price should be shared among state utilities and ISGSs (CERC 2019c).

International experience shows that healthy markets often have several forms of hedging mechanisms to balance the potential volatility and savings of day-ahead markets. As such, additional hedging instruments might appear in the Indian context.

3.4 CBET Implications

India's primary objective for reform is to move away from its current patchwork of contracts, markets, and operational norms, to a model that is economically and electrically efficient. An efficient all-India wholesale power market could create significant savings across the entire Indian economy, so the stakes are high.

For India's neighbors, the implications of market reforms could include the ability of Nepal to sell surplus hydropower to India, which would improve the economics of having more hydropower capacity on hand during the dry season when capacity factors are lower. Integration would also facilitate the transfer of hydropower from Nepal to Bangladesh. For Bangladesh, participation in a dynamic wholesale power market could provide cost-effective alternatives at a time when its natural gas reserves are diminishing.

Efficient markets operate on the principle of nondiscriminatory access; therefore, market participants located in neighboring countries might well expect the same treatment as market participants located in any Indian state. Indeed, India's Ministry of Power generally affirmed the principle of nondiscriminatory access in its 2018 guidelines on foreign participation (Government of India 2018).

The market reforms would not preclude tenant generation or bilateral CBET contracts, but they would provide more supply alternatives that would potentially be more cost-effective. Moving Nepal hydropower to Bangladesh illustrates some of the choices.

- Under the tenant generator model, a dedicated transmission line running 500 kilometers from eastern Nepal to central Bangladesh might add billions of dollars to the cost of a hydropower project, assuming no major siting problems in Nepal, India, or Bangladesh.[3] The Bangladesh grid would continue to schedule and balance using its existing resources.

[3] Using indicative cost estimates from the United States, a 500-kV high voltage DC line capable of providing 3 GW of transfer capacity for 500 kilometers might cost around $3 billion. (Estimates obtained using the Western Electricity Coordinating Council's transmission capital cost calculator updated in 2019, which is available at https://www.wecc.org/Administrative/TEPPC_TransCapCostCalculator_E3_2019_Update.xlsx). The transmission

- Under a traditional bilateral contract using Indian state grid systems, power delivery would incur four sets of transmission charges: Nepal, Bangladesh, and the Indian states of Bihar and West Bengal. Delivery would also be subject to the system transmission losses on each network.
- Connecting to India's interstate grid and participating in an integrated market would result in a single transmission charge. It would also allow more supply options, as the hydropower generator supplying Bangladesh would not necessarily have to be in eastern Nepal if it is connected to the Indian interstate grid. The transmission loss factor applicable to India's interstate grid would apply, but this loss would be less than the aggregate losses on lower-voltage state grids. Nepal and Bangladesh would also be able to use India's MBED markets to reduce the cost of balancing and ancillary services.

An analysis of South Asia CBET scenarios conducted by NREL found that increasing market integration among India, Nepal, and Bangladesh would tend to reduce the overall cost of generation and potentially provide savings benefits to ratepayers (McBennett et al. 2019). One scenario tested a fully integrated market comprising Nepal, Bangladesh, and the Indian states of Bihar, West Bengal, Jharkand, and Odisha; cost per MWh fell by more than 6% inside the integrated market, and costs for the rest of India fell slightly as net transfers from Bangladesh, Bhutan, India, and Nepal to the rest of India increased more than 4%.

As India's reforms evolve on its interstate system, CBET with other countries connecting to that system will likely become more liquid and more cost-effective. Additionally, economically efficient transactions from Nepal to Bangladesh, for example, would be pooled on the interstate transmission system using India's integrated market.[4]

But participating in an integrated market would involve other transaction costs that would not be present with a simple tenant generator or a bilateral contract approach. Market readiness would require time and money, as explained in Section 3.5. Market participants would need to dedicate personnel to take part in stakeholder committees involved in market development.

3.5 Stages of Market Integration

Participating in an integrated market requires advance preparation by regulatory authorities, grid operator, and the market entities themselves. An integrated electricity market is the most complicated, but many of the steps also apply to bilateral trading. Figure 5 illustrates the three main stages of transitioning to an integrated market. The first stage is readiness, or the technical capacity to buy or sell power via the market platform. Second is the development and acceptance of common rules applicable to all participants. Third is actual participation in the market with offers to provide and bids to take electricity.

cost could add $10 to $20 per MWh to the delivered cost of energy, depending on the line's financing costs and utilization rate.

[4] This would be consistent with India's Neighborhood-First regional policy (Kaura 2018).

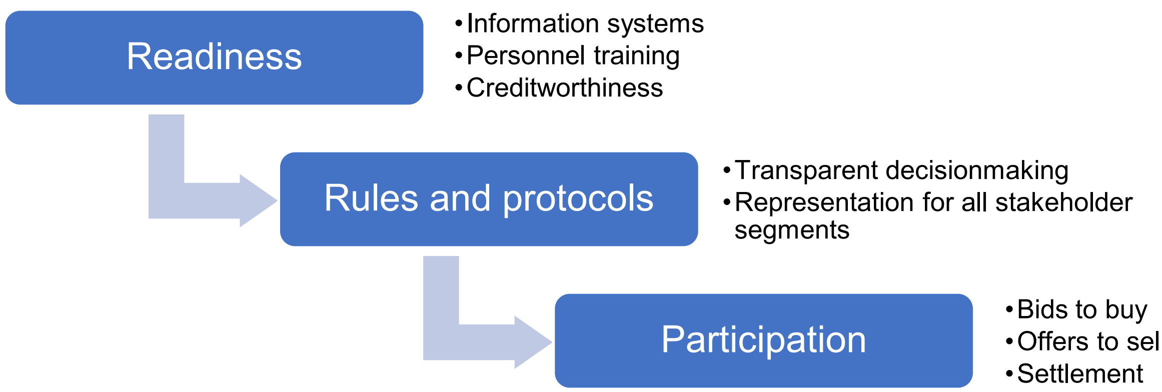


Figure 4. The main steps toward market integration

3.5.1 Readiness

Market readiness is the advance preparation that each participant needs to complete to ensure the accurate and timely flow of information. Each market participant—generator, load-serving entity, or power trader—is responsible for accurately translating its intent into the language of the market.

Among the items included in market readiness are:

- Validation of metering, accounting, and settlement standards (hardware, software, and procedures)
- The ability to comply with daily schedules, including gate closures (deadlines for submitting final bids to buy and offers to sell)
- Application of the interconnection standards used by the system operator
- Telemetry protocols for communications with generators
- Minimum technical qualifications for various ancillary services, such as response times, ramp rate, and sustained delivery
- For bid-based integrated markets, adoption of data formats used for submitting generation offers, commitment schedules, and next-day load forecasts.

India's Forum of Regulators published a report in 2016 listing best practices for scheduling, accounting, metering, and settlement of transactions (SAMAST) that aimed to standardize procedures across all Indian states. The group developed these guidelines in anticipation of market reforms within India. Among the 25 points in the Forum's readiness checklist are assessments of metering, load forecasting, interchange scheduling, power pool accounting, adequacy of human resources, computation of transmission losses, and procedures for clearing debits and credits within the pool (Forum of Regulators 2016). The Forum's recommended timeline for market readiness is about one year.

Major market-wide changes can take longer, however. In the United States, the market in Texas took about 7 years to transition from a zonal market to a full nodal market. This included a "test flight" period, during which both the old and the new systems operated in parallel, with actual market settlement shifting to the new system once all validations were complete.[5]

3.5.2 Common Rules and Protocols

An important aspect of market readiness is compliance with rules that all other market participants follow. These rules evolve over time, however. This means that even after completing the readiness stage, a market participant needs to remain informed about how the market is performing overall and about new rules and protocols to improve that performance.

Common rules can include procedures for reporting unit outages, formulas for determining ancillary service obligations, assignment of transmission costs, timelines for providing unit operating schedules to the grid operator, penalties for uninstructed deviations from schedules, payment formulas for operator-instructed changes from scheduled generation, and financial settlement schedules. While the price of energy is a matter of negotiation (in the case of bilateral deals) or SCED optimization (in the case of integrated markets), items like a unit's capacity value involve a formula applied across the market. In many cases, the rules are not controversial and can be set without the need for regulatory approval.

For a market to operate efficiently, rules need to have the following characteristics.

- **Nondiscriminatory:** Any market participant can expect to be treated as any other market participant in the application of any rule governing market operation.
- **Nonarbitrary:** Often, specific procedures and responses are expressed as equations that use market data or other performance measures as inputs. The aim is to reduce to a minimum the need for discretionary decisions by the grid operator.
- **Transparent:** The means by which any rule takes effect, regardless of how detailed it may be, are known to all market participants. This includes open access to stakeholder decision processes and accountability for outcomes.

Most integrated markets have two levels of governance. At the top is the governmental entity with legal jurisdiction over the market, its system operator, and its participants. The jurisdictional authority authorizes the initial formation of the market and its guiding principles of operation; however, regulatory decision-making processes are often too cumbersome for operational details. These fine-tuning protocols are often delegated to a structured stakeholder process. Market participants engage directly in the review of existing rules and the formulation of new ones. If stakeholders cannot reach agreement on an operational rule, the jurisdictional entity makes the ultimate determination.

In the United States, for example, most RTOs are under the jurisdiction of the FERC, which reviews and approves the RTO's master tariff governing market operations. The FERC-approved tariff includes provisions for creating an RTO governing board and stakeholder processes, which constitute a second level of governance.

Most RTOs have stakeholder groups that serve as working forums for problems and market improvements. With RTO staff support, these stakeholder groups propose modifications to

[5] Texas began its restructured wholesale market in 2001 with a zonal design similar to India's market reforms described in Section 3.2.

protocols for grid operations, market operations, and other rules that eventually go to the governing board for approval. Board decisions involving major policy changes then go to FERC for final review and approval. Changes to technical rules can be implemented by the governing board, with FERC acting as appeal body if there are any challenges to the technical change.

Therefore, an ongoing aspect of market participation is the ability to participate in stakeholder processes. Generally, each segment of participants—generation owners, load-serving entities, transmission utilities, power marketers, consumer representatives, and, in some cases, even environmental interests—will have its own caucus for discussion of the group's common interests. Each stakeholder group will then have one representative to working groups, committees, and the organization's governing board.

3.5.3 Participation

Only after they are market-ready and rule-compliant can a buyer or seller engage in energy transactions.

Settlement is the process of paying generators and billing load based on valid market prices. A market uses one of two approaches for pricing: pay-as-bid or MCP. Both approaches select the lowest-cost portfolio of generation resources. Under pay-as-bid, each selected resource receives its offer price for the energy it provides. Procurements through a request for proposals and periodic auctions are typically paid as bid.

The selection of pay-as-bid or MCP is a market design decision that applies to everyone. Most integrated markets use MCPs as the basis for setting hourly energy prices. Pay-as-bid is the de facto pricing approach when CBET is a collection of independently negotiated bilateral agreements.

Both pricing approaches incentivize generators to offer energy into the market based on their marginal cost of generation. Doing otherwise—that is, submitting a higher offer price—reduces the likelihood that the offer would be accepted and paid. The MCP approach, however, enables most generators (other than the marginal generator whose offer has set the MCP) to earn a profit. The likely profit margin of MCPs above marginal cost informs a generation developer's decision to build new capacity.

3.6 Governance

Using India's market reforms as a vehicle for enhanced regional CBET could require special attention to market governance. "Governance" refers to a market's permanent stakeholder structure, and not the regulatory body with authority over market participants. The stakeholder process is the main forum for investigating problems involving operations and market rules. The governance structure defines what happens to solutions coming out of the stakeholder process—whether they are sent to the regulatory body as a petition or implemented directly if they are within the scope of previous orders from the regulator.

A South Asian market might have issues similar to those faced by some RTOs in the United States, where market operations affect the energy policies of many state governments, but regulatory jurisdiction over the RTO is assigned by law to the federal government. In the case of South Asia, the question would be how the sovereign governments of participating nations might have a role in common market structures that affect their electricity sectors. One possible model, used in several U.S. RTOs, is a governmental council that provides special executive-level input into decisions by the RTO's governing board. The council is one part of a permanent stakeholder process.

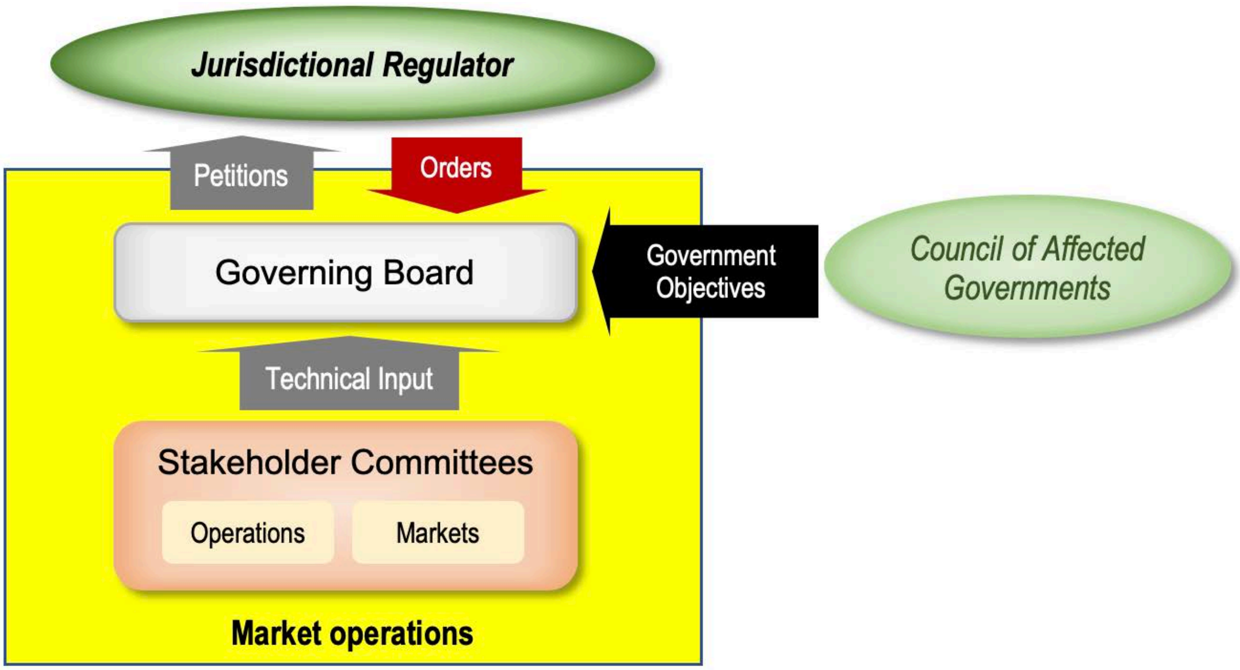


Figure 5. General flow of market governance

NREL illustration

Figure 5 illustrates governance generally. At the apex of the stakeholder process is a governing board, which is answerable to the regulator. Below the governing board are permanent committees and subcommittees comprising representatives of all stakeholder groups. The council of affected governments may advise the board of their support for or opposition to a change in market operations or policy. Once the board takes action and sends a petition to the regulator, the regulator can give weight to whether the board sufficiently considered issues raised by affected governments, as might be required by the laws that define the regulator's authority.

4 Foundational Issues of National Policy

The CBET models outlined in this report have implications for public policies at many levels of government. Here, we frame the key issues as threshold questions: bedrock policy decisions to guide later decisions about details. Among the most important decisions of national policy is the assignment of regulatory authority and clarifying which agencies are empowered to address which specific areas.

4.1 General Clarifications

General clarifications might include the following:

- Should CBET be isolated from other bilateral trade issues?
- Which entities should regulate which aspects of CBET?[6]
- What market-making functions are needed and who should provide them?[7]

4.2 Clarifications Regarding MBED

Questions to clarify neighboring countries' participation in India's MBED markets include the following:

- If other South Asian countries participate in MBED, how should these countries have input into the evolution of market rules?
- If a market participant in another country causes harm to India by market manipulation or other rule violations, which authority in India should prosecute such violations?

[6] The use of foreign currency is one example of possible coordination among regulatory agencies. Rules governing the settlement of CBET transactions in currencies besides the Indian rupee (as well as foreign currency deposits required by banks) could involve coordinated regulations between electricity authorities, the Ministry of Finance, and the Reserve Bank of India.

[7] "Market-making functions" are those that enable companies in India to engage in CBET as competitive buyers or sellers. Normally, an operational entity would provide these functions on a nondiscriminatory basis, meaning that the same rules would apply to any company buying or selling wholesale power. Examples of market-making functions include metering, scheduling, dispatch, and other services related to operating the grid and maintaining reliability. These are different from power marketing functions, which include the buying and selling of wholesale electricity. An important question is whether Indian state enterprises have an unfair advantage over other buyers and sellers who are wholly in the private sector.

5 Regulatory Issues

Strategic expansion of CBET would involve coordination among a number of policy areas. Some of these policies might require legislation, and many would involve implementation and oversight by national regulatory agencies.

India's ability to lead or participate in CBET of any type is bounded by its national policies on foreign trade. Therefore, a review of national statutes and executive orders on foreign trade could be an important step in ensuring that CBET outcomes are in Bangladesh's public interest. Such a review could identify potential conflicts in legislative intent, complementary policies, and clarifications of statutory authority. Key areas include rules governing foreign ownership of assets, trade tariffs, and financial requirements governing the use of foreign currencies.

5.1 Regulatory Actions

Clarifying regulatory authority would be an important outcome of the government's review of national policies affecting CBET. The following areas are grouped by their applicability to different types of CBET: integrated markets only; integrated markets and bilateral agreements; and applicability to all types of CBET.

5.1.1 Actions Applicable to Integrated Market Participation (MBED)

- **Registration of MBED market participants in India**: Authorizing Indian entities to participate in MBED is a basic regulatory step. Registration would help the government ensure that MBED participation remains consistent with India's national interest. Registration requirements could include proof of creditworthiness, disclosure of ownership (including foreign ownership shares), qualifications of executive management, geographic areas of operation, and recent financial statements. The government could also set bonding requirements.
- **Demand response**: Demand response is the ability and willingness of end-use customers to reduce their load at a specific time in response to a price signal. This is one of the hallmarks of a modern power sector and is becoming valuable in markets similar to MBED worldwide. For example, integrated markets often include procedures for allowing demand response to provide ancillary services, which can greatly increase demand response's opportunities for value. Large end-use customers in India could be demand response providers in the evolving market. The government could establish demand response rules that would both provide domestic value to India and lay the foundation for additional value if cross-border demand response were to expand under MBED.

5.1.2 Actions Applicable to Integrated Markets and Bilateral Agreements

- **Switching service from a utility to another provider**: CBET might enable large customers to replace service from their traditional utility with service arranged by competitive third-party providers. If India elects to enact policies to enable switching, the government might need to establish rules to ensure that other remaining customers are not harmed economically when a large customer leaves the utility.
- **Reasonably competitive pricing**: The government might also need authority to investigate whether the prices under a new CBET arrangement are unreasonably high. If

any supplier has some ability to control wholesale prices (due to its size in the market or due to some other unfair advantage), customers might need protection against predatory pricing. Besides authority, the government would require sufficient resources to evaluate and mitigate potential market power by a foreign supplier.

5.1.3 Actions Applicable to Integrated Markets, Bilateral Agreements, Tenant Generation

- **Transmission siting approval**: Generally, a regulator's siting authority over new transmission addresses whether a proposed line would be sufficiently used and whether the use would benefit the public. When a line enables CBET, regulators also need to protect customers under their jurisdiction from paying an unfair share of the new costs. To make such a determination, the commission would need authority to compel the release of data and other information that it would need to quantify the distribution of benefits between countries.
- **Reporting requirements**: Regulatory authorities might consider standards for all market participants to report CBET outcomes on a regular basis. The government could use this information and other market data to monitor national outcomes and trends that affect India (discussed further in Section 6).

5.2 System Planning and Operator Actions

CBET—especially if it eventually involves participation in India's MBED reforms—would create three areas of resource planning: generation and transmission investments needed to ensure beneficial participation in CBET; new generation that would not participate in CBET but instead would solely support domestic demand; and distribution system planning. Planning might include joint modeling with regional counterparts, along with participating in regional coordination meetings and trainings.

The government would need some degree of regulatory oversight over system planning. The public interest objective would be to avoid the cost of building new resources if the same service could be acquired from the market at a lower cost. This aim would relate to the government's basic goals of ensuring reliability and keeping rates at just and reasonable levels.

6 Oversight and Monitoring

Tracking key metrics can help regulators assess whether CBET outcomes are consistent with legislative intent and the public interest. Government oversight is also important to policing the behaviors of market participants. This section describes some of the metrics that the government could monitor to assess the effect of CBET policies.

Collecting data on these metrics is only the first step in effective market oversight. Government specialists must find trends in the data over time that indicate how well CBET policies are working. Detecting, understanding, and explaining the trends in the data is a special art that combines expertise in behavioral economics, power system engineering, and the nation's utility laws. Credibility and objectivity are also important; in many countries monitoring is done by the government itself or by a special independent entity with no financial ties to any market participant.

6.1 Volume of Power Trading

Energy imported, **energy exported, balance of exchange (in total MWh)**: Exchange volumes are the starting point for regulatory oversight. Volumes during the early years of a CBET strategy can reveal how quickly generators and load-serving entities adapt to the new rules. Because the pace of striking deals could vary according to the type of CBET involved (tenant generation, bilateral contracts, integrated markets), breaking out exchange volumes by type of arrangement could provide additional visibility into market trends. This could help identify the need for policy adjustments or new regulations.

6.2 Prices

Power purchase agreements (PPAs): Negotiated bilateral contract prices between utilities and independent power producers can provide a benchmark for all other price analyses included in regulatory oversight. Reliable, consistent PPA price data could be assured by promulgating rules for reporting that would be applicable to all generators. Regulators in many countries exercise such authority (FERC 2002). In most cases, public release of aggregated data can protect contract-specific data that might be competitively sensitive.

Market exchange prices: Energy market platforms, such as the Indian Energy Exchange, report on wholesale power exchange prices regularly by region. Besides monitoring prices at state hubs in India, authorities might consider a study with Indian power exchanges about tracking bilateral CBET transactions.

Market clearing prices for energy (MCPEs): As India's market reforms evolve, MCPEs will grow in importance as indicators of market performance. The SCED software used by POSOCO (see Section 3.3) determines these prices for each hour in the day-ahead market, and on a sub-hourly basis in real time. Prices for zones where CBET occurs will provide highly detailed information about the value of imports and exports. Among the important insights revealed by MCPE analysis:

- Seasonal pricing patterns
- Hourly pricing patterns

- Same-time differences between injection zones and withdrawal zones, such as the injection of hydropower from Nepal and withdrawal of power into Bangladesh.

6.3 Transmission Congestion

Loading on CBET transmission paths: One possible effect of increased CBET is more congestion on cross-border transmission paths. This, in turn, could suggest a future need for transmission improvements. One indicator of future congestion is how frequently line flows approach a path's thermal limit. This can be expressed visually as a duration curve—power flow for each hour of the year as a percentage of the path's thermal loading limit, with the values arranged in descending order. Figure 6 illustrates two sample CBET transmission paths, using 75% of the path's thermal limit as an example benchmark.[8] In this example, Path A is used more than Path B and is more likely to be congested with increased CBET.

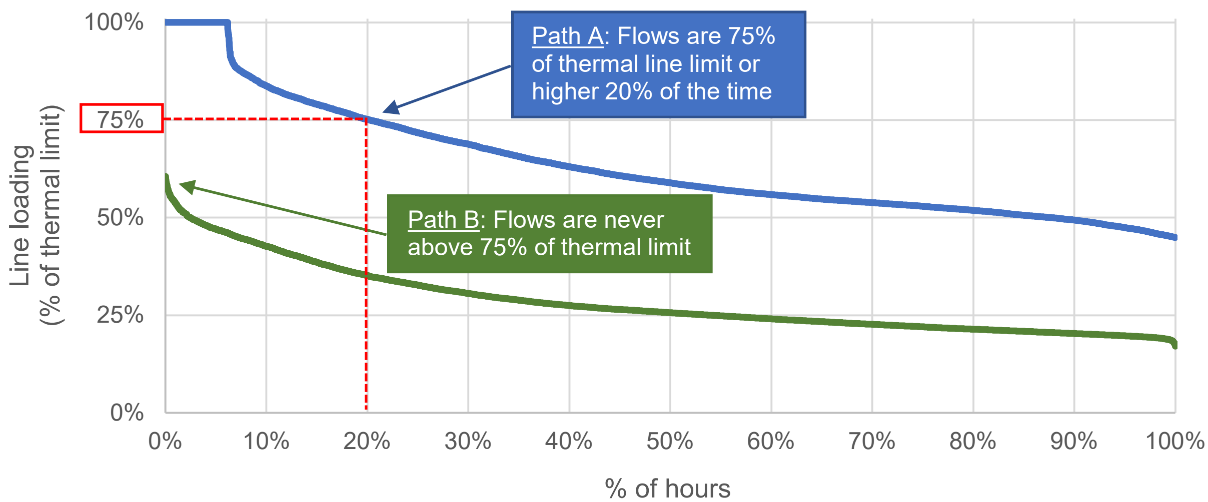


Figure 6. Loading duration curves of two sample transmission paths with 75% utilization metric

NREL illustration

6.4 Reliability: Reductions in Load Shedding

Reductions in load shedding and other supply-related service disruptions is a particularly important area for India. The government can monitor the reliability impact of CBET in two ways: by changes in actual incidents of load shedding; and by modeling reliability metrics such as loss of load expectation.

Number of load shedding hours: Reductions in the number of load-shedding hours could indicate whether CBET is contributing to greater domestic reliability.

Curtailed load: This refers to the actual level of demand at the time the curtailment occurs. It is measured on the basis of energy and not capacity. For example, a substation might have a maximum loading capacity of 10 MW but might be serving only 2 MW of load at the time it is

[8] The path utilization metric can be based on any threshold that is deemed useful. In the United States, for example, the Western Electricity Coordinating Council often compares metrics for three thresholds—75%, 95%, and 99%—to provide a more complete picture of path utilization. (WECC 2018)

interrupted. The load actually dropped—2 MW—would be a more accurate measure of actual lost load.

Simulated loss of load: The effect of CBET on reliability can also be simulated. A loss of load expectation is the number of days that available generation capacity plus imports would not be enough to meet demand. A similar measure, loss of load probability, is the probability that a load loss event might occur. A relationship between CBET and these loss of load indicators could provide regulators with an estimate of how imports can affect future reliability.

6.5 Utilization of domestic generation

Capacity factor (plant load factor): Capacity factors for generator groups aggregated by geography, age of plant, storage capability, and other factors can provide a more detailed picture of CBET benefits from the perspective of generators. This includes analysis of capacity factors by the generator's primary CBET type (integrated market participation, bilateral trading, or tenant generation). Greater generator use resulting from more CBET could increase investor confidence. This, in turn, could reduce obstacles to financing new projects.

7 Summary

CBET can take a number of forms. Each one requires different preparation and places different demands on policy and regulation. Bilateral trading and participating in an integrated wholesale power market are not mutually exclusive, but policies supporting one are not necessarily applicable to the other. Nor would effective regulation of one model be useful in regulating the other.

A major policy decision before India is whether to facilitate neighboring countries' participation in its MBED reforms. While India's market reforms could be a platform to facilitate these countries' national goals, participation would be far more demanding that a bilateral trading regime would be. Entities would have to spend at least a year to get ready, and the government would need to decide how to address a number of sovereignty questions. All participating countries would have an interest in ensuring efficiency and fairness, but it would require common rules.

An integrated market, such as the one contemplated in MBED, fundamentally changes the relationship between the public and private sectors. The government controls fewer outcomes but takes on a larger oversight role. It may prosecute more cases of market abuse, fraud, and anticompetitive behavior—actions that seldom arise with cost-of-service regulation of a monopoly utility. For the regulatory agency, participation in an integrated regional market would create special staff needs: besides normal expertise in engineering and utility accounting, the regulators would need expertise in applied economics and antitrust law.

Monitoring CBET outcomes could help improve benefits over time and would provide public accountability. This paper lists metrics that can be tracked regularly and over time. The ability to quantify benefits could help political acceptance of CBET activity, and wider public scrutiny of the data could discourage fraud.

The technical issues involved in making CBET efficient are unique and may lead to treating it as an area separate from other trade and diplomatic issues. Benefits are at stake for all sides, and as with other traded commodities, the market is likely to produce better results for the public if there are few out-of-market disruptions.

Technical analysis can show the theoretical benefits of integrated markets and CBET, but implementation depends on each country's utility laws and regulatory institutions. Building an integrated power market is complex and often requires regulators to enforce transparency, patience, and careful attention to detail. Because institutional evolution does not necessarily proceed at the same pace in all countries, cooperation among regulators is key to managing the process and ensuring that each country enjoys the full benefits of CBET.

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Appendix A. SAMAST Checklist

Table A-1. SAMAST Checklist

	Activity	Days from start
1	Identification of intra-country entities	7
2	Demarcation of interface boundary for each intra-country entity	14
3	Assessment of meters—main, check, and standby	21
4	Assessment of automatic meter reading logistics requirement	30
5	Assessment of IT infrastructure (hardware and software) requirement	45
6	Preparation of Bill of Quantities (considering logistics already in place)	60
7	Preparation of detailed project report and completion of first stakeholder workshop	90
8	Approval of the SAMAST scheme*	120
9	Commencement of load forecasting by LDC**	120
10	Commencement of interchange scheduling by LDC** for all the intra-country entities	120
11	Formation of a National Power Committee (NPC) for preparation of account	120
12	Establishment of National Regulatory Pool Account	120
13	Application for funding from Central Government/PSDF	150
14	Inviting tenders	150
15	Placement of award	210
16	Adequacy of human resources in LDC** as approved by the government*	210
17	Implementation of the recommended IT infrastructure-hardware	225
18	Completion of boundary metering and automatic meter reading system	240
19	Implementation of the recommended IT applications- Software A. User registration B. Short-term open access processing C. Scheduling D. Meter data processing and validation E. Accounting F. Settlement G. Billing and clearing H. Data archival and retrieval I. Management information system J. LDC** website	300
20	Computation of transmission losses for each 15-min interval by LDC**	330
21	Preparation of energy accounts by NPC/LDC** and publication of applicable information on NPC/LDC** website	345
22	Clearing of Pool A/c Credit/Debit for at least four weeks and its Reconciliation	345
23	Two stakeholder workshops by LDC** on SAMAST system	345
24	Quarterly Reconciliation Certificate from all National Pool members	365
25	Annual peer review of SAMAST by LDC**	365

*Regulatory task
**Load dispatch center functions
Source: Forum of Regulators (2016)