These areas are often associated with state boundaries and have physical and political constraints as well as contractual considerations. Discoms often 'self-schedule' generators with which they have PPAs. Power that is not procured through the self-scheduled bilateral contracts is acquired in the wholesale market. This makes up less than 10 percent of the power procured by discoms.

As the peakier demand curve across the country and the intermittency of RE power generation cross paths, it can lead to a significant supply–demand mismatch. Hence, increasing coordination and trading between balancing areas will increase the efficiency of energy flow across the network, improve economic efficiency of power procurement, and enable better integration of variable renewable generators.

The Green Energy Corridor is a central government scheme, amounting to ₹ 43,000 crore, focusing on transmission augmentation to facilitate the evacuation of RE into the national grid.[105,106] This ties in with the setting up of renewable energy management centres (REMCs) which are equipped with advanced RE forecasting and visualisation tools to help grid operators. To aid all this, power market reforms, such as RTM, and trading mechanisms, such as RECs, have been introduced. Regional interconnections can address multiple technical and managerial issues faced by discoms, but their success hinges on the close coordination between multiple central and state government nodal agencies with the discoms (see Table 8).

Table 8: Summary of regional interconnection and balancing

Solution Option	Technical Issues Addressed	Business Issues Addressed	Managerial Issues Addressed
Regional interconnection and balancing	• T&D congestion	• High APPC • Uneconomic dispatch	• Near and long-term planning
Benefits to Discoms			
• **Price discovery:** Dispatching power on short-term / near real-time intervals improves utilisation of generation assets and allows for better integration of zero marginal costs generators by using short-run marginal production cost for the merit order dispatch. • **Increased transparency and competition:** Market transparency and short-term power trading enable discoms to accurately balance supply and demand at short time intervals while also allowing them to sell surplus power that has fixed costs in existing contracts.			
How to make it work?			
• **CERC**: Enable more interstate trading by amending rules that require 15-minute firm trading blocks to allow for greater participation of VRE. • **GoI**: Invest in adequate interstate transmission capacity to meet future need in high RE penetration regions. • **SLDCs, REMC, RLDCs, Discoms**: Share best practices across regional load dispatch centres and increase coordination. • **Discoms and Gencos:** Increase liquidity on the power exchanges by moving more procurement to the wholesale market and continue to shift away from heavy reliance on long-term PPAs. • Improved intrastate trading with balancing areas larger than state level will require regulatory (state) and management changes that are currently constrained to state level only.			

5.2 RENEWABLE PURCHASE OBLIGATIONS

RPOs are a policy instrument to ensure the uptake of renewable energy. They require discoms, energy producers and certain consumers to obtain a share of their electricity from renewable sources.[x]

Renewable deployment remains highly concentrated in a few resource-rich states. The top six states account for 78 percent of all the RE generated.[107] The must-run status of RE means that some states end up purchasing more than what they are required to while others do not even meet their RPOs. Enabling greater inter-regional transfer of RE can help reduce the financial burden on discoms.[108] This can be done through the physical transfer of power through grid interconnections, as discussed in previous section, or through the mechanism of tradable renewable energy certificates.[xi]

Despite tradeble RECs and grid interconnections helping less resource-rich states procure RE and meet their RPOs, RE consumption continues to be localised. In 2019–20, only four states—already rich in RE generation—achieved or exceeded their RPO target: Karnataka, Andhra Pradesh, Rajasthan and Tamil Nadu.[109] A stringent implementation of the RPO mandate would ensure a fairer distribution of the excess cost of absorbing RE.[110]

5.3 ADVANCED RE FORECASTING

Variable renewable generation is inherently uncertain. It requires grid operators to undertake measures to balance supply and demand when generators over- or under-produce as compared to the expected or contracted amount. Increasing the accuracy of RE generation forecasts lowers the need for real-time system balancing and the fees associated with the Deviation Settlement Mechanism (DSM) penalty imposed on discoms. More accurate RE forecasts also improve grid reliability and stability while allowing for a more cost-optimum economic dispatch of other generators in the fleet (see Table 9).

Many RE-rich countries have already identified the need for more accurate forecasting. Lessons from the experiences of such countries can help us prepare for RE integration challenges (see Box 7 for case study).

x In June 2018, the RPO requirement was raised from 17% to 22%, with 10.5% from solar, up from 6.75%, and 10.5% from non-solar renewable sources by 2022, up from 10.25%. This increase has been in line with the government's ambition to deploy 450GW of renewables by 2030.

xi RECs are tradable certificates used by generators and other entities to sell RE generation on the power exchange for other obligated entities to meet their RPO requirements without having to deal with actual power procurement.

Box 7: International experience in RE forecasting[111]

The German power sector hosts more than 75 GW of solar and wind power today. Germany has bestowed a 'must-run' status upon renewables, like India. But unlike in India, where RE power producers are expected to submit RE forecasts and are penalised for deviation in forecasts, in Germany the Transmission System Operators (TSOs) manage RE forecasting activities, relieving the power producers from submitting their individual forecasts.

The TSOs have built expertise in forecasting by leveraging meteorologists. They are capable of evaluating various forecasts and deploying post-processing schemes based on different forecast service providers. TSOs leverage several RE forecasts from different providers to increase knowledge about forecast uncertainty.

A similar model is witnessed in Australia where the Australian Energy Market Operator (AEMO) runs the state-of-the-art Anemos platform, one of the best power prediction systems for renewable energy. The prediction platform allows the incorporation of several RE forecast models from various providers.

Table 9: Summary of advanced RE planning and forecasting

<table>
<tr><th>Solution Option</th><th>Technical Issues Addressed</th><th>Business Issues Addressed</th><th>Managerial Issues Addressed</th></tr>
<tr><td>Advanced RE planning and forecasting</td><td>• RE curtailment
• System congestion
• Grid outages</td><td>• High APPC</td><td>• Near and long-term planning
• RE purchase obligation</td></tr>
<tr><th colspan="4">Benefits to Discoms</th></tr>
<tr><td colspan="4">• Power Procurement Cost: As RE generators are deemed with a 'must-run' status, inaccurate forecasting of RE generation can disturb the merit order dispatch of power plants for the discom which can increase the overall cost of power procured.
• DSM Penalty: Inaccurate forecasts in RE generation can lead to an over or underestimation of the actual power generated. If RE generation is lower than forecasted, discoms are forced to overdraw from generators inducing a DSM penalty.
• Grid Disturbances and Outages: Large errors in RE forecasting can lead to real-time mismatch between power supply and demand and force discoms to induce grid outages.</td></tr>
<tr><th colspan="4">How to make it work?</th></tr>
<tr><td colspan="4">• Discoms: Develop an approach to increase the visibility of distributed PV and create a methodology for including behind-the-meter RTS into discoms and LDCs operation plans.
• SERCs and Discoms: Introduce Artificial Intelligence based advanced weather forecasting tools to improve the accuracy of day-ahead and real-time renewable energy production.</td></tr>
</table>

5.4 DECENTRALISED RENEWABLE ENERGY

There is a renewed interest in decentralised renewable energy (DRE) systems today due to the sharp fall in prices (especially of solar photo-voltaic), the imperative of decarbonisation, the continuing shortage or unreliability of electricity in many parts of the country, and the desire for greater resilience. DERs such as RTS plants and mini-grids offer opportunities to both discoms and consumers, but there are several unresolved issues holding back greater deployment.

5.4.1 Rooftop Solar

RTS power is a clean source of energy that lets producers monetise an otherwise idle asset, their rooftops. As most of the energy produced is consumed on the same premises, the loss associated with this source is very small. However, India is lagging in achieving its RTS goal of 40 GW installation by 2022—till June 2020, only 15 percent (or 6 GW) had been attained.

The state-level performances vary based on the policy and regulatory frameworks and support, business and investment environment, as well as consumer experience. MNRE's *State Rooftop Solar Attractiveness Index* (SARAL) measured states' performance across these broad buckets and ranked Karnataka as the best state for RTS. At the same time, it also highlighted administrative inconsistencies, inadequate financing, complexity of institutional frameworks, etc., as hurdles in greater adoption.[112] DER can also pose other challenges for stakeholders such as discoms. These include:

- Discoms perceive the rising RTS adoption/captive generation and use of OA market among C&I customers as unfavourable since they form the bulk of their revenue stream.
- Further, discoms prefer gross metering over net metering[xii] for smaller consumers since the tariff differential in gross metering could potentially mitigate some of their lost revenue.
- Even with policy changes that enable integration of mini and micro grids into the central grid, discoms will still need to set up the required interconnections as well as pay the necessary feed-in-tariffs[xiii] to mini-grid developers.[113],[114] Introduction of variable renewable energy to the grid may also require discoms to deal with congestion/accommodate surplus electricity on the grid during low demand. This can lead to curtailment of solar/RE projects violating the 'must-run' clause they carry. This can discourage existing and potential solar/ RE developers.

Discoms need to encourage the adoption of RTS generation across all consumer segments for India to meet its ambitious RE goals by 2022. There is a need for discoms to draft

xii In gross metering, the consumer is paid a fixed rate (the feed-in-tariff, FIT) for the total number of units of solar energy he generates and exports to the grid. The consumer continues to pay the discom at the retail supply tariff for the electricity he consumes from the grid. In net metering, the consumer's electricity exports are adjusted against his imports – effectively, the consumer is paid at the retail supply tariff.

xiii Feed-in tariffs are a policy mechanism under which renewable energy producers receive a long-term assurance of power purchase at guaranteed prices.

long-term integrated resource plans that identify specific deployment goals for RTS that can benefit with T&D loss reduction, peak-load management and power-procurement optimisation.

5.4.2 Minigrids

While the country has nearly achieved universal electrification, the quality of power supplied in many parts of the country is far from being reliable or consistent.[115] Mini-grids are a collection of DERs that can supplement the existing electricity distribution network or act as standalone electricity generation and distribution systems in off-grid and sparsely populated areas. For this reason, mini-grids are seen as sustainable and potentially cost-effective, which can help advance electricity access in areas where the cost of expanding the grid exceeds the revenue potential for discoms, such as in remote rural areas. Mini and micro-grids, by virtue of being located close to the community to be served, can minimise T&D losses, thereby improving the quality of service and in effect, increasing the willingness to pay for the service. Improving access can also stimulate economic activity and positively impact development.

There are over 14,000 micro and mini-grids and over 20 lakh solar home systems operating in India.[116] Given the quality of rural energy access, it is estimated that in Bihar alone around 28 lakh households could be served by 11,200 mini grids[117] (see Box 8 for case study).

Box 8: Bihar's mini-grid story – an alternate way to provide electricity in rural India[118,119,120,121,122,123]

Although India achieved 100% household electrification in 2019, 37 percent of the rural households in Bihar lack access to reliable electricity. Mini-grids are seen as dependable alternative sources of power in the state, with over 8 percent of the nation's mini-grids found in Bihar. The state's policy aims to build on this momentum and install a further 100MW of sub 500kW renewable-based mini-grids. Private energy service companies (ESCOs), such as Husk Power, have been leading the way in the state.

Husk Power relies on establishing a base demand through anchor loads such as agricultural facilities, telecom towers, or similar industrial users, which improve the utilisation rate for the mini-grid, reducing the average cost of supply.

Tariffs set by Husk Power are cost-reflective and offer no subsidies, allowing for tariff setting at the mutual discretion of the developer and consumers. Despite higher tariffs as compared to centralised grids (which are now available where mini-grids operate), most customers are happy to pay the premium for a reliable supply of electricity.

For example, Husk Power's 32kW biomass-solar hybrid plant near Piprakothi in Bihar, continues to serve 250 customers despite grid extensions in the area. Hence, despite fears that insufficient regulations and uncertainty about grid arrival might deter investment, Husk Power managed to raise ₹2 crore in 2018.

To prevent mini-grids from becoming stranded assets due to the expansion of the centralised grid, the state policy has laid out a number of options for developers, including continued operation in parallel with the grid, selling power to the discom at a regulator-determined feed-in tariff, transferring ownership of assets and network to the discom and engaging with the discom as a distribution franchisee.

Husk Power's success is also attributed to its use of smart technology, such as remote monitoring of mini- grids and mobile-enabled smart prepaid meters with a 'pay-as-you-go' system suited for customers with irregular income streams.

Husk Power's story in Bihar reinforces the consumers' willingness to pay greater tariffs for electricity that is more reliable. It also reinforces the importance of support from the government via relevant reforms and policies.

5.4.3 Energy Storage and Aggregated DERs

Energy storage is increasingly in the spotlight as a big opportunity for grid modernisation. Storage can play a major role in firming up the grid and enabling high penetrations of renewable generation. Batteries and pumped hydro-storage systems are already being used in various places across the world while other storage technologies, such as flywheels, supercapacitors, and green hydrogen, are in the early stages of development.

Pumped hydro-storage plants involve storing excess power by using it to pump water into a reservoir at a height. When required, the water can be released through a turbine to generate electricity. This is a proven and efficient way to store energy. It can also provide ancillary services such as frequency and voltage regulation, and black start facility.

Batteries represent a wide range of technologies that can provide numerous benefits to the grid. Importantly, a single battery can provide several services over its life. For example, a battery system can be installed for the primary purpose of shifting peak electricity consumption from a time when the distribution or transmission is congested to a time when capacity is available. This may only require the battery to be dedicated to this service for a few hours each day. When that battery is not providing this peak shifting service, it can be used as a firming or flexibility resource to smoothen renewable generation to better match demand.

The CEA has run a modelling exercise to estimate the generation capacity mix in 2030. The model suggests a likely installed capacity of over 10 GW of pumped storage and 27 GW of four-hour battery storage.[124]

Several pilots on energy storage have been in the works across the country:

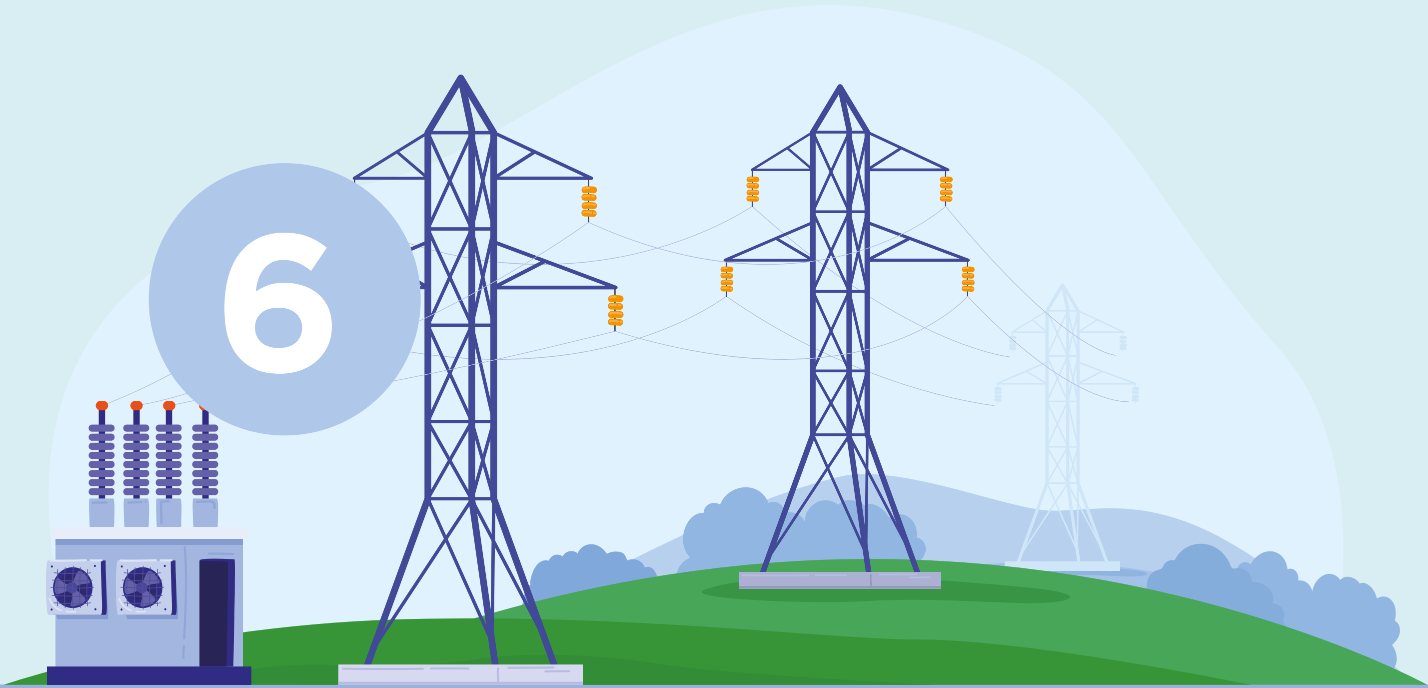
- In Delhi, TPDDL has installed a 10 MWh battery bank commissioned by AES and Mitsubishi in 2019 at the substation level.[125] The battery bank is capable of applications ranging from peak load management, frequency regulation to system flexibility. It helps balance distributed energy resources including RTS.

- A 1.25 MW battery storage pilot was also commissioned in Puducherry in 2017 for PGCIL with the objective of testing the technical and economic effectiveness of grid-connected battery energy storage systems in providing dynamic frequency regulation, capacity firming, energy time shift of renewable energy generators, peak shaving and load following, dynamic reactive compensation and voltage support.[126]
- Also in Delhi, BRPL is planning to deploy a 10 MW BESS for managing the distribution network congestion and for reducing peak power purchase requirements along with other incidental benefits to the distribution system[127].

Aggregating distributed energy resources (DERs) across a network and controlling the collective operation of the fleet allows the network of decentralised resources to provide a similar set of grid services as a traditional centralised generator or energy storage system. The objective of aggregated DER is to optimise the interconnected assets through a central control room while allowing the ownership of those assets to remain independent of the discom. A central control room or DER system operator dispatches the aggregated resources to adjust to balancing needs of the grid in the same way a centralised generator does (see Table 10).

Table 10: Summary of energy storage and aggregated DERs

Solution Option	Technical Issues Addressed	Business Issues Addressed	Managerial Issues Addressed
Energy storage, aggregated DERs, and virtual power lines	• System reliability • RE curtailment • System congestion • Resilience to weather events	• High APPC • Competition from DERs and open access	• RE purchase obligation
Benefits to Discoms			
• Provides inexpensive balancing reserves. • Allows for increased demand and supply-side flexibility.			
How to make it work?			
• **CERC**: Develop ancillary service market that includes participation of large DERs and aggregated small and medium DERs. • **Discoms**: Accelerate smart meter infrastructure rollout and ensure bi-directional communication networks are adopted. • **CERC and State Government**: Develop performance-based regulation that encourages accurate DER generation forecasts and load management.			



Managerial Reforms

6.1 VISION AND LEADERSHIP

Discoms are service providers that follow standard operating procedures like most enterprises. The majority of discoms are publicly owned. As noted above, some of them have tremendously improved by implementing operational and managerial reforms.

Bold leadership from government institutions, private enterprises, civil servants and elected officials has significantly reformed the electricity sector. Effective reforms are typically a result of stable leadership and vision sustained over time. Good leadership endures shifts in political leanings, navigates technological hype cycles, and holds the line over time to deliver its vision through persistence and dedication to transformation.

Reform journeys in Gujarat, Delhi and Andhra Pradesh were led by elected officials who retained their position in power for at least a decade. These officials were successful because they drafted long-term strategies with regulators and discoms and could ensure the rollout of policies and implementation of reforms. TPDDL, for example, had a distribution license for 25 years that allowed it to prepare long-term strategies that resulted in steady and incremental improvement.[128]

Transformation is enabled by innovation, and decision-makers across the ecosystem must be open to new ideas and processes, and ways of doing business. This, however, is contingent on the acceptance and integration of such innovation into the organisation. This applies to the use of technology upgrades for organisational improvements, implementing management information systems (MIS) and performance review systems, as well as for improving billing and collection, and consumer interfaces.

6.2 CUSTOMER FACILITATION

Many states have tried to improve their customer-facing processes. Maharashtra, for example, set up a centralised call centre. Gujarat initiated online bill payment facility, SMS service, and Jan Seva Kendra for its consumers, with a view to reduce AT&C losses.[129] Delhi, Odisha, and Andhra Pradesh successfully deployed technology to improve their overall customer experience.

Customers today can be more engaged in how they interact with the grid. Discoms can benefit greatly from this opportunity by rolling out proactive initiatives such as ToD tariffs, which could benefit both discoms and customers. If discoms do not capitalise on this opportunity, customers might choose to defect from discoms towards self-generation or OA.

6.3 EMPLOYEE INCENTIVES AND WORKER PROTECTION

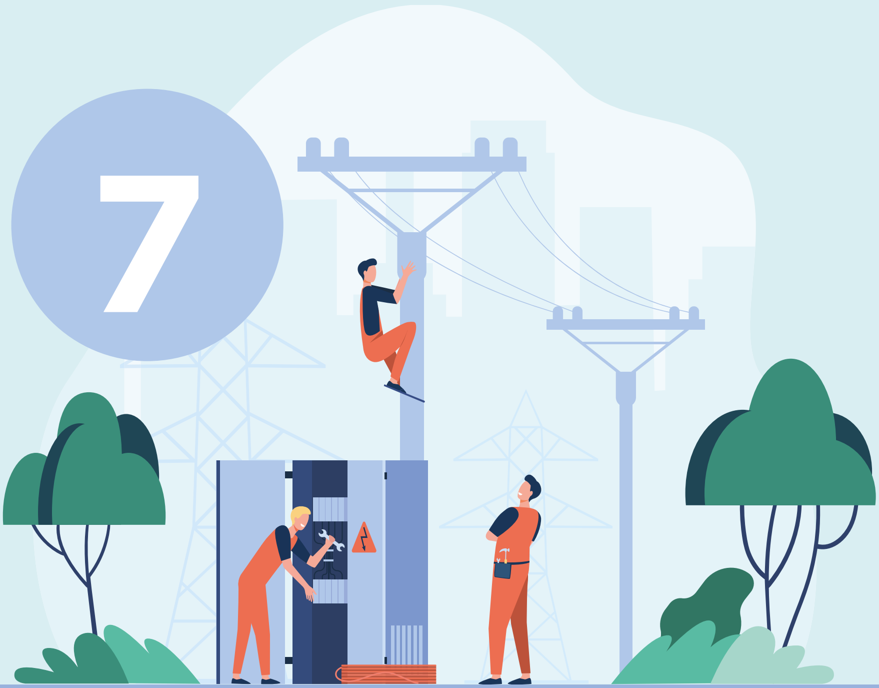
Discom employees should be incentivised to align with the organisation's interests. This can help improve operations and financial performance. The incentive need not be limited to remuneration. Job security, cultural buy-in, and healthy competition among the employees can improve the discom's performance.

For instance, Tata Power–DDL made managers responsible for the costs and revenues in their areas and provided incentives on the basis of their performance. Distributed leadership was implemented to run the setup as individual business units with adequate manpower. A three-tier performance management system was conceived for encouraging competition and organisational alignment among the employees.[94] In Manipur, structural and role accountability were established via periodic reviews at the field level. In Gujarat, the discoms introduced a performance-incentive scheme, where utilities pay an additional 4 percent of wages to incentivise and encourage workers to outperform targets.[130]

As mentioned in the section above, job security can be a powerful incentive in improving employee performance. It can be especially salient in the case of privatisation of discoms, where concerns among the employees about job loss could adversely impact performance.

Section 133(2) of the Electricity Act, 2003, states that the service conditions of employees would not be in any way inferior to those that were there while the discom was state-owned. The case of Odisha is a good example—despite the discom changing ownership several times since the late '90s, the employees were insulated from any adverse impacts.[131]

A contrasting example can be traced back to Uttar Pradesh, where lack of consultation and consensus with the employee unions in Kanpur forced Torrent Power to abandon operations in the city despite winning the DF bid.[132]



Best Practices and Recommendations

7.1 REVIEW OF BEST PRACTICES

Table 11 presents a summary of the experiences of selected states/utilities in their transformation efforts. These states were chosen to illustrate the crucial roles that managerial and operational reforms played in their path to loss reduction. The table also attempts to distil key common lessons that can serve as guiding principles for good operational and managerial/ management practices for discoms.