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How can India Create a Demand Flexibility Market?

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A Roadmap for a Flexible Power System

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How can India Create a Demand Flexibility Market?

A Roadmap for a Flexible Power System

Report | June 2026

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The Council on Energy, Environment and Water (CEEW)—**a homegrown institution** with headquarters in New Delhi—is **among the world's leading climate think tanks.** We use **data, integrated analysis, and strategic outreach** to support public policy, transform markets, shape technology, and nudge behaviour. CEEW seeks to explain—and change—the use, reuse and misuse of resources. The Council addresses pressing global challenges through an **integrated** and **internationally focused** approach. It prides itself on the independence of its high-quality research and strives to i**mpact sustainable development at scale.**

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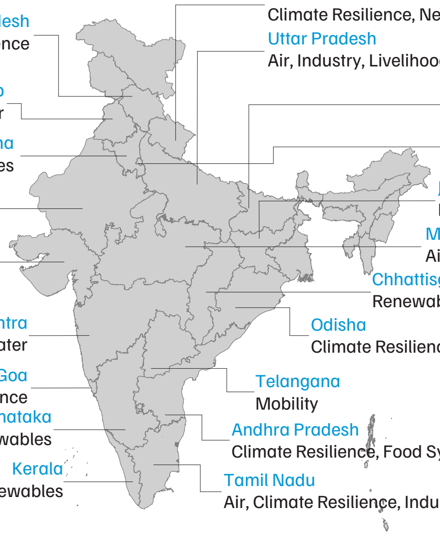

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Executive summary

Why does India need a demand flexibility market?

As the share of renewable energy in India's rapidly growing power system rises, the grid faces complex real-time operational challenges. In parallel, India is seeing growing power demand with rising cooling demand, industrial electrification, and electric vehicle (EV) adoption, similar to power grids globally. Relying solely on conventional supply-side solutions to establish a flexible grid could increase costs, prompting a need to explore new ways to source, value, and integrate grid flexibility.

In this context, a growing decentralised system with distributed energy resources (DERs) such as rooftop solar units, EVs, smart appliances, and behind-the-meter storage[1] offers a more cost-effective way to support crucial grid functions, if supported by regulations and a smart metering infrastructure (Figure ES1). Although time-of-day (ToD) tariffs can encourage load to shift from peak to off-peak hours, they are too coarse and inflexible to address real-time, location-specific grid constraints (Rawson 2026a, 2026b). As India rapidly electrifies the economy and scales up renewable energy capacity, new demand-side mechanisms to manage demand in real time will be essential to reduce pressure on the grid.

A demand flexibility (DF) market can help address these challenges by aggregating and coordinating DERs and aligning their use with real-time grid conditions through clear price signals. Clear pricing rules and standardised contracts between utilities and aggregators[2] can transform these resources from unpredictable loads into dependable assets that can help resolve local network congestion, support RE aggregation, and defer the need for costly infrastructure upgrades (Electron 2024; Lovell 2025).

Currently, regulations in India allow DF to serve peak demand and provide ancillary services (Figure ES1). However, a well-functioning DF market – that is, one with multiple buyers and sellers trading services using standard contracts, open APIs, and shared data – does not yet exist. Transitioning to this market-led approach to DF will lower barriers to aggregator participation, make flexible services scalable, and help utilities meet their DF obligations within a lower-cost, lower-emissions power system (Electron 2024).

Figure ES1. Demand flexibility can serve critical functions in India's grid

DF can be an effective alternative for discoms to manage evening peak supply	• Demand is expected to grow 4.6% annually in FY 2026–30, with a secondary peak after solar hours (CEA 2022). • 70% of the instances when short-term prices on the IEX's DAM and RTM hit the price ceiling occurred during evening hours (6–11 pm) in FY 2024–25.
Flexible demand can help avoid clean energy curtailment and serve demand reliably	• India's grid flexibility requirements are likely to grow five to six times by 2030 (Agarwal et al. 2025). • Shifting demand to solar hours can help avoid around INR 140 million (INR 14,000 crore) in battery and transmission costs (Agarwal et al. 2025).

[1] Behind-the-meter storage refers to battery systems installed on customers' premises and used for their own consumption. These systems can charge from the grid or from rooftop solar, and discharge to reduce grid offtake and electricity bills.

[2] Aggregators are third-party market entities that bundle flexible demand across multiple consumers, unlocking DF value at scale.

DF can cost-effectively complement supply-side reserve resources	• Faster demand growth than new capacity addition could lead to shortages (Abhyankar et al. 2024). • Global experience shows that the capacity provided by flexible demand can be more cost-effective than peaking plants (Hledik and Peters 2023). • By mitigating peak loads, DF minimises reliance on expensive, high-emission fossil fuel backup and prevents overbuilding generation capacity (BEIS and Ofgem 2021).
Conducive conditions for large-scale DF markets are emerging in India	• More than 70 million (7 crore) smart meters have been installed, providing the granular consumption data essential for monitoring, verification, and settlement of DF markets (MoP 2026b). • National and state-level regulations enable DF markets to provide ancillary and peak demand management services (CERC 2022; MERC 2024). • The IES aims to design open digital public infrastructure to break down utility data silos and seamlessly connect aggregators to markets (Kallakuri et al. 2025).

Source: Authors' analysis.

Note: BEIS = Department for Business, Energy & Industrial Strategy (UK); CEA = Central Electricity Authority (India); CERC = Central Electricity Regulatory Commission (India); DAM = day-ahead market; discom = (power) distribution company; IES = India Energy Stack; IEX = Indian Energy Exchange; MERC = Maharashtra Electricity Regulatory Commission; MoP = Ministry of Power (India); Ofgem = Office of Gas and Electricity Markets (UK); RTM = real-time market.

How did we develop this road map?

We surveyed the key revenue streams that are accessible to DF across mature power markets. We identified two global case studies and analysed the critical regulatory, technical, and institutional enablers that led to the integration of DF in wholesale power markets in Great Britain (GB) and Australia.[3] We discuss the selection of markets below.

- **Why GB?** GB's power system, with 44 per cent RE penetration in 2025 and increasing DER adoption, has integrated DF into its capacity, balancing, and distribution markets (NESO 2023a, 2026a). Clear market rules and policy frameworks that allow revenue stacking across multiple services have led to the expansion of local flexibility markets from no formal procurement in 2019 to ~9 GW in 2025 (Ferguson 2025). GB's case illustrates how market rules, digital infrastructure, and focus on revenue stacking can help scale DF.
- **Why Australia?** Australia has the highest per-capita rooftop solar capacity, leading to high volatility in wholesale power prices and growing balancing costs. Policy efforts have focused on establishing interoperability standards, improving utilities' visibility of DERs, and using regulatory sandboxes to test market mechanisms before scaling them. Together, these measures have supported the integration of DER flexibility into power markets. As of May 2025, about 70 MW of DERs participate in the WDRM (AEMO 2025c). The latest regulatory reforms envision complete integration of DERs with the wholesale market.

We also conducted an online survey of representatives from 14 Indian power distribution companies (discoms) and five semi-structured interviews to gain their perspective on DF opportunities, potential revenue streams, procurement preferences, and readiness to implement DF in India. Annexure 1 provides the details of the survey sample and the list of institutions we interviewed.

[3] We have studied Great Britain since the electricity grids of England, Scotland, and Wales are connected, while the United Kingdom includes Northern Ireland, which operates under a separate electricity market.

Image: CEEW

CEEW's Mirambika Sikdar and Kashish Shah discussing the smart metering progress, challenges and emerging use cases with a power distribution company in Assam, India.

What were the critical enablers of demand flexibility markets globally?

The GB and Australia cases show that scaling DR/DF requires a coordinated stack of building blocks (Figure ES2).

Figure ES2. Key building blocks (five pillars) for scaling demand flexibility

1 Advanced metering infrastructure and data exchange architecture

Smart meter data infrastructure forms the digital backbone for consumption monitoring, settlement, and consent-based third-party data access for DF.

2 Device-level visibility and flexibility readiness

DF requires a portfolio of automated flexible loads, interoperable DER communication standards, and measurable load profiles from key end uses such as cooling, heating, and EV charging.

3 Retail pricing signals for consumers

Time-based tariffs incentivise consumer to shift electricity use by creating early economic value for flexible demand and smart technologies.

4 Market access and revenue stacking pathways for flexibility services

DF scales when resources can participate in electricity markets, access multiple revenue streams, and operate under clear aggregator roles, baseline methodologies, and settlement frameworks.

5 Evidence-based regulatory designs and institutional collaboration

Effective proof-of-concept demonstrations and innovation programmes must generate operational evidence that informs regulatory reform, helps reduce implementation risk, and translates findings into regulatory reform before scaling.

Source: Authors' analysis.

Note: MVS = measurement, verification, and settlement.

How do Indian electricity distribution companies perceive the emerging demand flexibility landscape in India?

Our online survey of discom officials indicates that while discoms recognise DF as a potential resource, their ability to integrate it with regular operations remains limited due to the lack of granular data on DF's potential benefits and uncertain consumer participation.

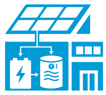
Respondents viewed residential cooling loads as the most promising source of flexibility. They favoured discom-led or tender-based procurement models that prioritise peak cost reduction and delay or avoid network expansion. However, gaps in data on DF's real-time capability to reduce load during peak hours and the lack of regulatory clarity on business models, continue to inhibit confidence in scaling DF programmes (Figure ES3).

While our survey sample was limited, the results offer interesting insights into how the DF market may evolve in India and the biggest challenges that need to be addressed while integrating it.

Figure ES3. India's demand flexibility market would require a diversity of consumer segments and business models

86% of respondents said they track demand patterns at the state or discom level and perform only limited feeder or transformer-level analytics.

~30% of respondents said residential ACs have the highest potential to offer flexibility, followed by commercial rooftop solar systems with batteries and thermal storage.



~30% of respondents said that lowering peak power purchase costs and deferring T&D network upgrades are the most important areas where DF can contribute to India's energy system.

36% of respondents considered discom-owned programmes or tender-based procurement models with energy and capacity payments to be the most suitable approaches for procuring DF.

~30% of respondents identified gaps in data on DF's potential, unpredictable customer enrolment rates, and the lack of regulatory clarity on cost recovery as the biggest barriers to a large-scale DF market.

Source: Authors' analysis.

Note: discom = (power) distribution company (India); T&D = transmission and distribution

Image: CEEW

CEEW's Dhruvak Aggarwal discussing systems being put in place by power distribution companies to monitor and use smart meter data, Madhya Pradesh, India.

What are the supporting regulations required for implementing demand flexibility in India?

India's existing regulatory and institutional enablers (Figure ES4) span all five pillars of DF creation, as outlined in Figure ES2. Notably, the Maharashtra Electricity Commission's (MERC) 2024 regulations mark a meaningful shift in how Indian discoms approach grid flexibility, embedding DF and demand-side management as core operational obligations for discoms rather than optional measures. Discoms must meet escalating DF portfolio obligations, from 1.5 per cent of peak demand in FY 2026 to 3.5 per cent by FY 2030. There are also defined financial penalties of INR 2 million/MW (INR 0.20 crore/MW) for non-compliance and an equivalent incentive for achievement beyond the obligation. The demand-side management programmes are subject to cost-effectiveness screening to protect consumers from adverse tariff impacts, and independent third-party verification ensures measurable grid benefits (MERC 2024).

Figure ES4. Current enablers for facilitating demand flexibility implementation

Foundational infrastructure for metering, consumer data access, and machine-readable dispatch signals: The RDSS has facilitated ~70 million smart meter installations as of May 2026. The IES proposes to create a standardised digital public infrastructure for India's power sector and create unique digital identifiers[4] for all consumers and grid assets so that data is interoperable across systems and transactions can be accurately tracked and attributed.

Formal recognition of demand-side resources: The CERC permitted DR to provide balancing services at the national level (CERC 2022). At the state level, SERC (draft and notified) regulations in Maharashtra, Rajasthan, Karnataka, and Assam are progressively integrating DR into distribution-level procurement frameworks. However, no state has yet operationalised a competitive flexibility tender.

[4] Analogous to Aadhaar for individuals, each consumer connection, meter, and grid asset (such as a transformer) will be assigned a distinct, persistent digital ID, enabling unambiguous tracking across utilities and platforms.

Mandatory ToD tariffs: 30 Indian states and UTs have introduced simpler ToD tariffs for the C&I consumer segment, instituting foundational price signals for shifting demand through behavioural nudges.

Device standards and interoperability readiness: BEE's S&L Program establishes minimum energy performance and communication readiness requirements for appliances; the EV-charging infrastructure guidelines promote open communication protocols for smart charging.

Evidence base for regulatory design: Eleven publicly documented pilots between 2012 and 2025 tested DF across consumer segments, but the evidence base remains insufficient regarding consumer enrolment rates at scale, segment-level quantification of dispatchable DF potential, and incentive designs robust enough to sustain regulatory frameworks.

Source: Authors' analysis based on MoP (2024, 2026); Rural Electrification Corporation (REC), Power Finance Corporation (PFC), and MoP (2021); Kallakuri et al. (2025); CERC (2022); MERC (2024); Rajasthan Electricity Regulatory Commission (RERC) (2026); Karnataka Electricity Regulatory Commission (KERC) (2025); Assam Electricity Regulatory Commission (AERC) (2024); Vasudha Foundation and BEE (2024); Malhotra et al. (2024); and Patankar et al. (2025).

Note: BEE = Bureau of Energy Efficiency; C&I = commercial and industrial; CERC = Central Electricity Regulation Commission; IES = India Energy Stack; RDSS = *Revamped Distribution Sector Scheme*; S&L = *Standards & Labelling*; SERC = state electricity regulatory commission; UT = union territory.

What challenges does India need to address to enable a demand flexibility market in the future?

The GB and Australia case studies demonstrate that while early utility-led pilots played a foundational role in support DF, scale is only achieved when flexibility is standardised, monetised across multiple value streams, and integrated into core market operations. Drawing on the combined evidence from the global case studies and consultations with Indian discoms, we identified next steps for India to establish a market for DF services in the long term (Table ES2).

Table ES2. Next steps to expedite the creation of a demand flexibility market in India

Pillar	Enabler	Near-term action
1.	Accurate MVS	• Standardise meter data schemas and interoperability protocols under RDSS. • Build a sector-specific consumer consent architecture for smart meter data sharing. • Enable API-based third-party data access via the IES.
2.	Distributed asset visibility and responsiveness to grid signals	• Introduce a DR-readiness category within the *BEE S&L Program*. • Establish nationally recognised communication standards for grid-edge devices (such as ACs with smart controls, smart EV chargers and grid-connected batteries), aligned with the IES. • Encourage discoms to publish LV network maps, strengthen monitoring, and link performance with the RDSS. • Conduct regular end-use surveys by building type and climate zone to map the potential for flexibility.

Pillar	Enabler	Near-term action
3.	**Price signals that incentivise consumers to shift load and invest in flexible assets**	• Update ToD tariff designs based on regular evaluation of their impact on various consumer segments, using smart meter interval data. • Design tariffs and billing mechanisms to incentivise DER adoption and participation in grid services such as ToD tariffs with net metering or net billing.
4.	**Improved access for aggregators to multiple revenue streams to support viable business models**	• Extend the Demand flexibility portfolio obligations (DFPO) framework to more states, with penalties proportionate to the returns discoms earn from capital investment in network assets. • Establish central aggregator registries with defined telemetry and verification standards. • Mandate discoms to use IES data infrastructure and open APIs for DF procurement. • Mandate discoms to publish location-specific network congestion/overload data and the estimated value of deferred upgrades.
5.	**Pilot programme designs and integration with regulatory frameworks to obtain actionable evidence**	• Establish a competitive, grant-based national demonstration fund for multi-state DF programmes. • Harmonise methodologies for estimating a baseline for DF, defining products, and bidding templates across states. • Channel pilot findings into SERC and CERC reviews of DFPO trajectories and DF procurement guidelines.

Source: Authors' analysis based on AERC (2024); Vasudha Foundation and BEE (2024); Malhotra et al. (2024), and Patankar et al. (2025).

Note: API = application programming interface; BEE = Bureau of Energy Efficiency; CERC = Central Electricity Regulatory Commission; DFPO = demand flexibility portfolio obligation; discom = (power) distribution company (India); IES = India Energy Stack; LV = low voltage; MVS = measurement, verification, and settlement; RDSS = *Revamped Distribution Sector Scheme; S&L = Standards & Labelling*; SERC = state electricity regulatory commission.

1. Why does India need a demand flexibility market?

India's power supply and demand has become more variable, peak-driven, and digitally coordinated; hence, the future grid will likely be fundamentally different from the present one. On the supply side, India's renewable energy (RE) generation capacity is increasing on an unprecedented scale. The government aims to install more than 250 gigawatts (GW) of additional capacity in FY 2026–30, including significant solar and wind capacity (Central Electricity Authority [CEA] 2022). Unlike conventional thermal power generation, variable renewable energy, such as solar and wind, is weather-dependent, non-synchronous, and often most available during hours of the day when demand is low (Abhyankar et al. 2024).

On the demand side, India has achieved near-universal electricity access (Agrawal et al. 2020); per capita consumption continues to rise with economic growth, urbanisation, and the increasing use of electric appliances. The growing demand for electricity for various purposes, such as air cooling, mobility, digital infrastructure, and industrial expansion, has contributed to the variability and peakiness of the power grid (Pachouri et al. 2023).

These supply- and demand-side shifts are converging with the rapid expansion of digital infrastructure: discoms have installed over 70 million smart meters as of May 2026 (MoP 2026b), and the India Energy Stack initiative (Kallakuri et al. 2025) is building digital public infrastructure to standardise transactions and data exchange in the power sector. Together, these measures advance the technical feasibility of active demand-side participation in grid operations.

Balancing supply and demand in real time will become more complex and costly as RE penetration increases and demand patterns evolve, especially if addressed solely by employing conventional supply-side resources such as coal and hydroelectric sources, and batteries (Agarwal et al. 2025; Hledik and Peters 2023). The current market structure, designed around centralised thermal generation and passive demand, is not equipped to balance the volatility of RE on the one hand and rising peak demand on the other.

This creates a structural need to rethink how flexibility can be sourced, valued, and incorporated into the power system (Figure 1).

Figure 1. Regulations should focus on defining and standardising market design principles and the underlying technical framework to create a well-functioning, interoperable demand flexibility market

Market design layer	**What flexibility products exist?**	**Who can participate in flexibility markets?**	**How are flexibility pathways made economically viable?**	**How flexibility is procured to optimise grid service?**
	Standard DF product definitions, contracts, and pricing frameworks	Aggregator registration and pre-qualification frameworks	Accessible revenue stacking pathways to aggregators	Location-specific flexibility procurement and dispatch
Technical layer	**How should flexibility be measured across diverse resources?**	**How can flexibility delivery be verified and rewarded?**	**How can interoperability be achieved across devices and platforms?**	**How can grids gain real-time visibility of DERS?**
	Standardized baseline methodologies by load and resource type	Robust MVS framework and smart-metering infrastructure	Open network-based communication protocols and standards	Unified data framework for DERS and distribution network

Source: Authors' analysis.

Note: MVS = measurement, verification, and settlement.

2. What does this study cover?

Demand flexibility (DF) refers to the capacity of demand-side loads to modulate consumption by reducing, increasing, or shifting them across the hours of the day in response to price signals or direct dispatch instructions triggered by certain grid conditions. Demand response (DR) is a subset of DF that refers specifically to event-triggered curtailment or load reduction programmes typically contracted and operated by an electricity utility. This brief uses DF as the encompassing term and DR when referring specifically to curtailment-based programmes.

Unlocking DF at scale requires regulations that focus on key components (Figure 1) beyond time-of-day (ToD) tariffs and utility-led DF programmes. ToD tariffs can shape everyday behaviour but do not help manage local congestion or short-duration peak loads. Utility-led programmes, including dynamic tools such as critical peak pricing or direct load control, are difficult to scale and operate across diverse locations and grid conditions. A well-designed DF market resolves both limitations by enabling aggregators to coordinate flexible load where and when the grid needs it the most, and to stack revenue across multiple streams, making participation commercially viable (Rawson 2026a, 2026b).

While the value of DF for consumers and the grid is generally recognised, much of it remains untapped. For example, the International Energy Agency (IEA) estimates that globally, with installed generation capacity of 8000 GW, less than 100 GW of DR is utilised (IEA 2025). To understand what it takes to unlock this potential in India, this roadmap draws on three approaches. The objective is to provide policymakers, regulators, and utilities with a structured approach to move past the 'pilot paralysis' stage in implementing DF (Singh et al. 2025).

> Of the global DR potential capacity of 1000 GW, less than 100 GW has been utilised, according to the International Energy Agency.

First, sections 3, 4, and 5 review how DF has been demonstrated across consumer segments, the operational models through which it is delivered, and the revenue pathways it has access to globally. Second, section 6 presents case studies of the regulatory evolution in GB and Australia, examining the coordinated actions of system operators, economic regulators, distribution utilities, aggregators, and retailers that enabled DF markets to scale. Third, section 7 presents findings from a structured survey of 14 power distribution companies (discom) officials and five semi-structured interviews, assessing India's operational readiness for DF implementation. The section also outlines short and medium-term next steps for each pillar, based on the survey and global case studies. Section 8 details and consolidates the action points.

3. Where does demand flexibility potential lie across consumer segments?

The commercial and industrial (C&I) segment has historically demonstrated the highest potential due to high load density and well-developed energy management systems. For example, in utility-led DR programmes in the US, most peak-demand savings come from C&I consumers, while residential programmes account for a smaller share (Federal Energy Regulatory Commission [FERC] 2024).

In the domestic sector, electrified loads such as electric vehicles (EVs), heat pumps and air conditioning enable device-level and schedulable flexibility. A large-scale smart charging demonstration in Amsterdam achieved roughly a 1.2 kilowatts (kW) reduction in peak demand per charging station under coordinated control conditions (Bons et al. 2021). In GB, field evidence shows that residential heat pumps can reduce peak demand by about 1.7 kW per unit when actively controlled (Love et al. 2017). GB's 2023–24 *Demand Flexibility Service* (DFS) enrolled 2.6 million households, delivering 3.3 gigawatt-hours (GWh) of verified reductions through opt-in behavioural events (Figure 2) (National Energy System Operator [UK] [NESO] 2024a).

Water and wastewater utilities represent an underused but commercially viable industrial flexibility resource. The water sector is well-suited to DF due to its large, interruptible pumping loads and extensive storage infrastructure, which allow energy-intensive operations to be shifted in time without disrupting service delivery. California demonstrated a sustained 30 per cent reduction in pump power demand at a water pumping station for up to four hours per event without affecting service reliability (California Energy Commission [CEC], 2023).

Distributed energy resources (DERs) are increasingly recognised as flexibility assets. Examples include California's *Demand Side Grid Support Program*, which offers incentives for load reduction through automated DER response during conditions of grid stress, and Australia's *National Consumer Energy Resources Integration Roadmap*, which has designated solar panels, batteries, and EVs as foundational flexibility resources (CEC 2025; Department of Climate Change, Energy, the Environment and Water [Australia] [DCCEEW] 2024).

Across segments, the evidence shows that meaningful flexibility exists across a wide variety of loads. However, realising this potential at scale depends not just on who can flex, but on how that flexibility is operationalised. The next section examines the common models for DF globally.

> DF potential exists across C&I facilities, water utilities, and residential resources such as EVs, heat pumps, air-conditioning systems, and distributed energy resources.

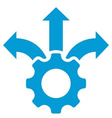
4. How is demand flexibility operationalised?

DF can be operationalised using multiple models, from behavioural programmes to supplier-managed automated interventions. DF interventions can be broadly categorised as shown in Figure 2. Each category offers increasing levels of control, predictability, and system value.

These are the most common operational models, but they can become valuable only when the economic pathways are defined and accessible. The next section provides an overview of the same across key global markets.

Figure 2. Demand flexibility interventions vary by the mode and intensity of consumer participation

Opt-in behavioural programmes rely on consumer-initiated actions in response to price signals, notifications, or incentives. While simple to deploy, they may suffer from low and inconsistent participation due to awareness gaps and perceived complexity.



Automation-assisted flexibility shifts real-time decisions from consumers to connected/grid-edge devices. Consumers set the preferences once – such as by programming a smart thermostat or smart EV charger –and the device responds autonomously to grid signals within those bounds. This preserves consumer autonomy while improving response speed, predictability, and scale by enabling many small actions to occur simultaneously without ongoing human intervention. Unlike behavioural programmes, which require consumer-facing communication channels, automation-assisted flexibility depends on a reliable two-way communication infrastructure between grid-edge devices and the utility or system operator.

Supplier-managed models transfer the operational control of assets to third parties such as aggregators, suppliers, or system operators with prior consumer consent. Unlike automation-assisted flexibility, where consumers retain control over their device preferences, third parties directly control devices within pre-agreed parameters in supplier-managed models. This enables DERs to be aggregated and dispatched as grid assets, delivering capacity, balancing, or wholesale market services with greater precision and reliability than automation. However, this model requires stronger consumer trust, clearer consent frameworks, and more advanced infrastructure for dispatch and control.

Source: Authors' analysis.

5. What revenue pathways are accessible for flexibility services?

Globally, flexible resources are monetised through six major revenue streams (described in Annexure 1): (1) the capacity market, (2) the energy market, (3) the ancillary services market, (4) emergency and reliability services, (5) distribution-level/local congestion management, and (6) RE integration support services. Not all revenue streams are available in every system. Table 1 provides a comparative overview of DF integration in four major power markets in the world, based on the latest data available for 2024–25. Aggregators can stack distinct revenue streams to build a viable business case.

Beyond central wholesale and capacity mechanisms, GB has developed the largest local flexibility market in the world, creating an additional location-specific revenue stream for distributed assets.

Image: iStock

Table 1. Mature markets allow demand flexibility resources to earn revenue from multiple streams

Market (region)	Peak load (GW)	Active DR capacity (GW)[a]	Energy market	Capacity/ RA credits	Ancillary services	Emergency DR	Distribution-level flexibility markets
Australia (NEM)	33.7	0.07[b]					Pilot stage[c]
California (CAISO)	48.5	1.4[d]					
GB (ESO)	46	0.72 (T-1), 1.1 (T-4) + 9 (DSO auctions)[e]					
PJM Interconnection (Mid-Atlantic USA)	160.6	6.26[f]					

Source: Authors' analysis based on various sources (AEMO 2025a, 2025b, 2025c; FERC 2025; CAISO 2025; CPUC 2021; NESO 2021, 2024b, 2026a; Ferguson 2025; Monitoring Analytics 2025; US Energy Information Administration 2024).

Notes: Blue cells indicate established access or availability of the DR revenue stream. Grey cells indicate that the revenue stream does not exist in that market. The markets only consider downward flexibility (DR), except in PJM and GB, where market rules also accommodate upward flexibility from demand-side resources in balancing/ancillary markets. AEMO = Australian Energy Market Operator; ARENA = Australian Renewable Energy Agency; CAISO = California Independent System Operator; CPUC = California Public Utilities Commission; dEX = decentralised exchange; DNSP = distribution network service provider; DSO = distribution system operator; ESO = electricity system operator; GW = gigawatt; NEM = National Electricity Market (Australia); RA = resource adequacy; WDRM = wholesale demand response mechanism.

[a] Includes both load curtailment and behind-the-meter/on-site backup generation unless otherwise noted.

[b] The total demand reduction capability (in megawatts) that DR service providers have registered with the AEMO under the WDRM (AEMO 2025c).

[c] Where applicable, 'pilot stage' denotes early, limited deployment without standardised mechanisms or widespread enrollment. ARENA-supported projects (e.g., the dEX platform) test locational DER coordination with DNSPs. It is not yet a formal market across DNSPs (ARENA 2025).

[d] DR contributed about 1.4 GW (2.6 per cent) of CAISO's RA capacity for the summer of 2024, mainly from utility-led programmes, with a smaller share from third-party DR aggregator-led channels (CAISO 2025).

[e] DR cleared 0.72 GW of de-rated capacity in the GB Capacity Market T-1 (one-year-ahead procurement round) auction and 1.1 GW in the T-4 (four-year-ahead procurement round) auction for delivery year 2024/25 (NESO 2021, 2024b). GB's local flexibility markets contracted 9 GW capacity in 2025 (Ferguson 2025).

[f] Demand-side resources cleared 6.26 GW of reliably available capacity for delivery year 2024/25, accounting for 4.5 per cent of the total cleared capacity in the forward capacity auction held in 2021 (Monitoring Analytics 2025).

Table 1 reveals several cross-cutting patterns in how DF is monetised across markets, discussed below. **Utility and supplier-led DR programmes serve as the most widely accessible entry point for demand-side participation, often preceding formal aggregator access to markets.** For example, in California, utilities such as the Pacific Gas and Electric Company (PG&E) began offering SmartAC (direct-load control programmes for residential air conditioners [ACs] using smart thermostats) in 2007, seven years before the California Independent System Operator (CAISO) opened market access to third-party aggregators (California Public Utilities Commission [CPUC] 2014; PG&E 2008). Such programmes are available to residential and C&I consumers in all four markets listed in Table 1, employing tariff-based mechanisms, such as Time-of-Use (ToU)[5] and critical peak pricing, as well as incentive-based, automation-assisted DR primarily designed for load curtailment or shifting.

Emergency DR is an established service across all four major markets. In PJM Interconnection (a Mid-Atlantic USA power market) and CAISO, DR programmes with pre-registered resources are activated by the system operator during declared emergencies, with availability payments and performance verification managed through utilities or contracted aggregators (CPUC 2023; Monitoring Analytics 2025). The Australian Energy Market Operator (AEMO) procures emergency reserves outside the energy market for dispatch during forecast shortfalls (AEMO 2024). In GB, NESO pays households and businesses to reduce electricity use during peak stress periods to support system reliability (NESO 2026b). In all cases, the system operator declares emergency conditions and manages the dispatch, while the programme administrator (e.g., the utility, a market operator, or an aggregator) contracts with consumers, validates response and makes payments for availability and actual performance[6].

PJM and GB have enabled demand-side resources to compete alongside conventional generation in forward capacity auctions and earn capacity payments in exchange for firm curtailment commitments (through utilities or third-party aggregators). Capacity market participation offers a more predictable revenue stream than event-based or out-of-market emergency DR. Resources with capacity credits can also be dispatched during emergencies, making the two mechanisms complementary rather than strictly mutually exclusive.

In the absence of a formal capacity market, California has adopted an alternative model where resource adequacy (RA) obligations are assigned to utilities and retail electricity suppliers through bilateral contracts. Demand-side resources can qualify for a utility's RA planning if they meet the firm delivery, telemetry, and availability requirements set by CAISO and CPUC. Notably, this framework accommodates both utility-led and aggregator-led procurement channels within the same RA structure. In the summer of 2024, approximately 80 per cent of the 1.4 GW DR capacity participating in the RA programme was delivered through utility-led programmes and the remainder through third-party aggregators (CAISO 2025).

Beyond central wholesale and capacity mechanisms, GB has developed the largest local flexibility market in the world, creating an additional location-specific revenue stream for distributed assets. The UK regulatory framework RIIO-2 (revenue = incentives + innovation + outputs) incentivises distribution utilities to procure flexibility as a cost-effective alternative to network reinforcement (Department for Business, Energy & Industrial Strategy [UK] [BEIS] and Office of Gas and Electricity Markets [UK] [Ofgem] 2021). Independent platforms such as Piclo Flex enable distribution system operators (DSOs) to publish locational flexibility requirements and run competitive tenders for standardised DF products (Piclo 2023), allowing distributed asset owners to stack local revenues on top of wholesale and capacity market earnings.

The next section deep-dives into two international case studies to define the regulatory, policy, technical and institutional changes required to enable DF access to some of the revenue streams that were discussed above.

> In the absence of a formal capacity market, California meets resource adequacy (RA) requirements through bilateral contracts between utilities and retail electricity suppliers.

[5] We use "time-of-use (ToU)" in the global context, as it encompasses the range of retail tariff structures, including time-of-day, seasonal, and critical peak pricing offered by competitive retailers. "Time-of-day (ToD)" is used specifically in the Indian context, reflecting the terminology adopted in CERC and SERC regulations.

[6] In DF markets, availability payments compensate aggregators for keeping flexible capacity on standby, while performance payments are made upon verified delivery of the contracted response.

6. How have regulations evolved to enable a demand flexibility market?

Our review of global DF market developments suggests that even when DF's technical potential is high, delivery at scale depends on the coordinated evolution of five pillars: (1) advanced metering infrastructure (AMI), data exchange, and consent architecture; (2) device-level visibility and flexibility readiness; (3) consumer-facing price signals; (4) market access and revenue-stacking pathways for flexibility services; and (5) evidence-based regulatory designs and institutional collaboration. This five-pillar framework that structures our analysis is detailed in Annexure 2.

The two case studies that follow illustrate how these five interdependent pillars progressively enabled market access for different DF services in GB and Australia. Both case studies demonstrate that no single reform is sufficient on its own (Figure 3). The institutional structure of the GB and Australian power markets is described in Annexure 3.

Figure 3. Scaling demand flexibility requires coordinated progress across five interdependent pillars, from metering and data infrastructure to governance

1
Advanced metering infrastructure and data exchange architecture

Smart meter data infrastructure forms the digital backbone for consumption monitoring, settlement, and consent-based third-party data access for DF.

2
Device-level visibility and flexibility readiness

DF requires a portfolio of automated flexible loads, interoperable DER communication standards, and measurable load profiles from key end uses such as cooling, heating, and EV charging.

3
Retail pricing signals for consumers

Time-based tariffs incentivise consumer to shift electricity use by creating early economic value for flexible demand and smart technologies.

4
Market access and revenue stacking pathways for flexibility services

DF scales when resources can participate in electricity markets, access multiple revenue streams, and operate under clear aggregator roles, baseline methodologies, and settlement frameworks.

5
Evidence-based regulatory designs and institutional collaboration

Effective proof-of-concept demonstrations and innovation programmes must generate operational evidence that informs regulatory reform, helps reduce implementation risk, and translates findings into regulatory reform before scaling.

Source: Authors' analysis.

Note: MVS = measurement, verification, and settlement.

6.1 Case study 1: Great Britain's demand flexibility road map

GB's power system is characterised by high RE penetration (44 per cent of electricity production in 2025), winter-peaking demand, declining winter reserve margins, and increasing local grid congestion due to the rapid uptake of DERs such as rooftop solar panels, EVs, and heat pumps (NESO 2026a). Increased variability on both the supply and demand sides requires additional balancing by the NESO. Consequently, NESO's balancing-service spending jumped from GBP 949 million in 2021–22 to GBP 2.6 billion in 2022–23, with the costs borne by consumers through higher system charges (NESO 2023a). Additionally, localised grid congestion is strengthening the case for flexibility as a least-cost alternative to infrastructure investment. Modelling studies estimate that scaling flexible demand could save between GBP 30 billion and GBP 70 billion in system costs over 2020–50 (Department for Energy Security & Net Zero [UK] (DESNZ), Ofgem, and NESO 2025). National policy frameworks prioritise enabling flexible demand to reduce system costs, support RE integration, and improve network efficiency (BEIS and Ofgem 2017, 2021; DESNZ, Ofgem, and NESO 2025).

We analyse the steps that led to the evolution of a DF market in GB, based on the five-pillar framework discussed above. Figure 4 summarises the major system gaps identified and the institutional and regulatory interventions introduced to address them.

Pillar 1: Advanced metering infrastructure, data exchange, and consent architecture

- **Metering:** The smart meter roll-out began in 2008 under a national government programme and with regulatory targets set for suppliers through licence conditions. It reached around 70 per cent saturation among households as of September 2025 (DESNZ 2025b). Smart meter communications are routed through a centrally managed network operated by the Data Communications Company (DCC), which ensures secure data transfer and continuity even when consumers switch suppliers (Smart DCC Limited 2025).

- **National consent framework for third-party access to energy data:** The 2018 Data Access and Privacy Framework established that while daily consumption data is shared with suppliers by default for billing purposes, explicit opt-in consent is required for sharing more granular data with any third-party service provider/retailer (DESNZ and BEIS 2018). As part of the *Data Sharing Infrastructure Programme,* Ofgem is developing a digital mechanism that will allow consumers to grant, manage, and withdraw consent across authorised energy data users in a more streamlined and interoperable manner (Ofgem 2024a).

- **Framework for consumers' access to smart meter data:** Consumers can access their consumption data via a free in-home display tool or directly through a smart meter that has devices connected to it through the home area network for more real-time access (DESNZ and BEIS 2018). Real-time third-party access through consumers' smart meters is also enabled, subject to consumer consent via the DCC network. Smart meter data has also progressively been made available in aggregated form to distribution utilities to improve LV network visibility (Ofgem 2022a). Impact assessments estimate average electricity consumption reduction of about 3 per cent among households equipped with smart meters, primarily driven by behavioural interventions facilitated by smart meter data (DESNZ 2023).

Pillar 2: Device-level visibility and flexibility readiness

- **Device- and market-level interoperability:** At the device level, adoption of communication standards for appliances such as heat pumps and batteries remains voluntary, though smart EV- charging regulations have mandated open protocols, such as the Open Charge Point Protocol (OCPP), for charging points (UK Parliament 2018). At the market level, flexibility procurement platforms use different application programming interfaces (APIs), data formats, and dispatch protocols, making multi-region participation prohibitively expensive for smaller providers. The Open Networks Programme identified Open Automated Demand Response (OpenADR) 3.0 as the standard dispatch API to be adopted across all GB flexibility markets (Latief 2025; Nordman et al. 2024).

- **DER visibility:** Ofgem is developing the Flexibility Market Asset Registration framework to create a harmonised registry for assets participating across wholesale and local flexibility markets, with implementation expected through NESO and distribution utilities (Ofgem 2025).

- **Expanding the stock of DERs:** Along with smart EV-charging regulations, heat pump deployment programmes combined with targeted ToU tariffs have expanded the pool of controllable electrified heating loads (DESNZ, Ofgem, and NESO 2025). Empirical evidence from over 6,500 households in GB showed that a ToU tariff designed for heat pumps halved evening peak consumption; load shifting was demonstrated to be feasible on cold days and across building types, while annual energy bill amounts reduced by 18 per cent (Bernard et al. 2024).[7]

Pillar 3: Consumer-facing price signals

Peak and off-peak tariffs have been available to consumers in GB since the late 1970s. As the smart meter roll-out provided access to more interval data starting in 2013, retailer-specific dynamic tariffs such as Octopus Agile (Octopus Energy n.d.) emerged to enable consumers to benefit from wholesale price fluctuations. The *Market-wide Half-Hourly Settlement* (Ofgem 2021) proposes to further enable this by aligning supplier costs with actual half-hourly consumption, creating a strong incentive to offer ToU tariffs. Personalised tariffs based on consumption patterns also increase the value of flexible technologies for consumers.

Pillar 4: Market access and revenue stacking pathways for flexibility services

- **Granular price signals for flexibility in wholesale markets:** Reforms improved real-time imbalance prices so that system stress and the cost of load shedding are reflected in the prices paid by market participants when they deviate from the schedule. This increases the value of flexible demand that can quickly reduce or shift load during tight system situations (Ofgem 2014). It served as a necessary upstream condition for retail ToU tariffs to become more cost-reflective over time.
- **Regulatory support for flexibility:** RIIO is the regulatory framework for setting the revenues that distribution utilities are allowed to earn over a multi-year period. RIIO-ED1 (2015–23) introduced a Totex (or total expenditure) model that treats capital and operating expenditures equivalently, removing the bias towards capital investment and enabling lower-cost non-wire alternatives to compete with network expansion (Girouard 2019). This is reinforced under RIIO-ED2 (2023–28) by a performance incentive that adjusts the utility's return on equity up or down based on how well it develops and operates flexibility markets (Ofgem 2022b). Complementing this, the 2020 regulations require utilities to regularly report how they procure flexibility and compare its costs and benefits with those of conventional network upgrades (Ofgem 2024b).
- **Market access for DF across multiple value streams:** The capacity market made demand-side resources eligible for forward capacity (2014), while the parallel access to balancing services (2020), bespoke services such as the DFS (2022), and distribution flexibility markets enabled participation across multiple value streams (Department of Energy & Climate Change [UK] [DECC] 2013; Elexon Limited n.d.). For example, local flexibility markets allow aggregated DERs above a defined capacity to earn payments for DF at congested network locations. However, coordination of products and settlement rules for efficient revenue stacking are an ongoing challenge (Blake and Brooks 2023).
- **Operational coordination across markets:** In the UK, this was enabled through standardisation under the Open Networks programme, which addressed the fragmentation where multiple, inconsistent contract and participation requirements acted as a barrier to scale. This included common definitions of flexibility products (defined by response time, duration, and firmness of commitment), a common asset pre-qualification questionnaire, contract frameworks, and standard methodologies for comparing flexibility with network reinforcement (Energy Networks Association [ENA], n.d.).

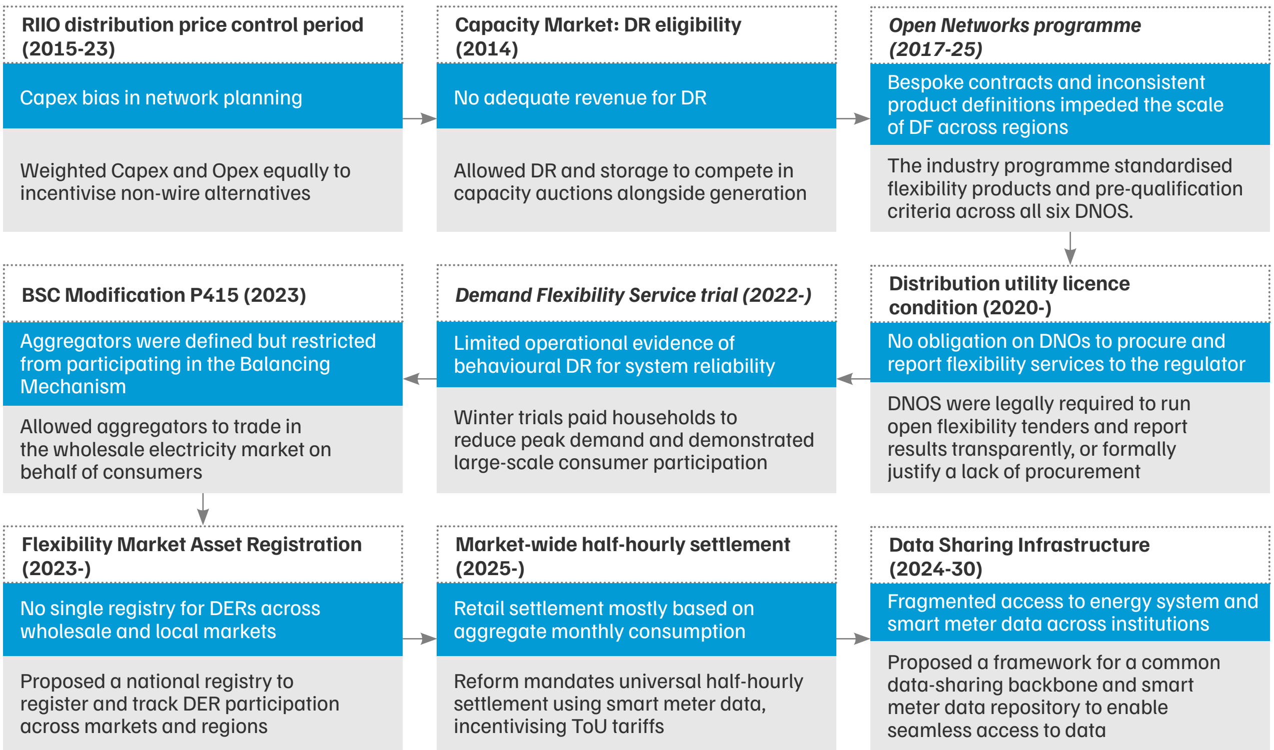
[7] The Centre for Net Zero study draws on Octopus Energy's Cosy Tariff customer base, meaning the sample comprises households that have already opted into a flexible heat pump tariff plan. While the large sample size (6500+ households) and staggered roll-out strengthen causal identification, findings on participation rates and bill savings may not fully generalise to the broader population of heat pump users.

Pillar 5: Evidence-based regulatory designs and institutional collaboration

- **Pilot-to-programmes framework:** Innovation allowance and competitive funding under RIIO can support trials of DR and other smart grid projects (Ofgem 2015, 2026). Further, the Open Networks programme institutionalised the following approach: Funded trials were undertaken by distribution utilities; the results were transparently reported and reviewed by industry working groups, and then translated into common standards and tools before being adopted across all networks as business-as-usual (ENA and Ofgem 2021).

- **From successful pilots to programmes:** The DFS began as a trial in the winter of 2022–23 to test large-scale behavioural DR, initially operating as a day-ahead contingency service that guaranteed registered participants a maximum of 12 test dispatch triggers. To build provider confidence and maximise early participation, the pilot's design explicitly avoided performance penalties for under-delivery and offered registered participants a highly lucrative, guaranteed acceptance price of GBP 3,000 per megawatt-hour (MWh) over a defined number of day-ahead dispatch triggers (NESO 2023b). As the service evolved into a regular, all-year-round, merit-based balancing tool, NESO introduced enhanced API capabilities for automated bidding and data sharing, which reduced operational friction and made it easier for aggregators to scale. In the 2024–25 winter season, the service reached nearly 2 million registered households and businesses, shifting ~5.4 GWh of demand during peak periods (NESO 2025).

Figure 4. Demand flexibility in GB evolved through coordinated market reforms, regulatory incentives with a strong emphasis on cost-effectiveness, and revenue-stacking pathways (2014–30)



Source: Authors' analysis.

Notes: The title of each box represents the name of the cross-institutional intervention or regulatory reform and the time period in which it was implemented. Blue boxes indicate the core system gap addressed, and grey boxes highlight the resulting system capability added through the reform. Capex = capital expenditure; BSC = Balancing and Settlement Code; DNO = distribution network operator; Opex = operational expenditure.

6.2 Case study 2: Australia's demand flexibility road map

With rooftop solar units generating over 25 per cent of its energy, Australia has the highest per-capita rooftop solar penetration globally (AEMO 2026). This has resulted in frequent midday demand troughs, steep evening ramps, and rising wholesale price volatility (Australian Energy Regulator [AER] 2025). Further, the lack of visibility of virtual power plant operations leads to increased errors in demand forecasting, exacerbating the procurement costs of frequency control ancillary services (Australian Energy Market Commission [AEMC] 2024b; AEMO 2023b). At the same time, the high wholesale price spreads and growing DER ownership present an increasingly convincing case for the economic viability of flexible resources. Fully orchestrated flexibility from grid-connected DERs could generate system-wide savings of AUD 14 billion annually by 2050, primarily through avoided investments in generation, storage, and networks (Energeia 2025). Therefore, the primary goal of the government is to convert the growing DERs into coordinated and dispatchable portfolios that behave like virtual power plants (DCCEEW 2024).

Figure 5 summarises the major system gaps identified and the institutional and regulatory interventions introduced to address them.

Pillar 1: Advanced metering infrastructure, data exchange, and consent architecture

- **Metering:** Australia initially followed a market-led roll-out in states apart from Victoria, which mandated advanced meters from 2009 onwards. In 2024, the Australian government authorized an accelerated roll-out, setting a target of universal smart meter coverage by 2030. The distribution network service provider (DNSP) is required to schedule a date and get regulatory approval for retiring clusters of legacy meters, and the retailer has to replace them with smart meters, coordinating with the metering service provider. Current penetration is over 55 per cent nationally, with higher penetration in Victoria (AEMC 2023; AEMO 2021).

- **National consent framework for third-party access to energy data:** The Consumer Data Right legal framework provides a standardised consent-based mechanism for consumers to share their energy data with accredited third-party service providers. The retailers and the market operator are the primary and secondary data holders who must authenticate the consumer's consent and facilitate the transfer of the requested data to the third party (AEMO n.d.-a). The standardised consent architecture ensures that third-party aggregators can access consumer energy data without the need for bespoke bilateral agreements with each retailer.

- **Framework for consumers' access to smart meter data:** Minimum data provision requirements mandate that retailers and DNSPs provide consumers with up to 24 months of validated interval data in standardised formats, ensuring nationally consistent data delivery (AEMO 2021). However, access remains request-based and retailer-mediated rather than real-time or API-enabled. From November 2028, new smart meters must provide free access to real-time meter data via the home area network to consumers and authorised third parties, using the interoperability and security standards set by the market operator (AEMC 2025). The rules also enhance DNSPs' access to data on power quality, as measured at the consumer-end meter, to improve LV network visibility and support consumer energy resource integration (AEMC 2024a).

Pillar 2: Device-level visibility and flexibility readiness

- **Communication interoperability:** Through the *Distributed Energy Integration Program* (DEIP), cross-sector technical working groups have developed nationally aligned standards for smart inverters and batteries (DEIP Interoperability Steering Committee 2023). The standards specify remote control capabilities and emergency grid support functions to enable secure integration with distribution networks (DEIP Interoperability Steering Committee 2023). Further, dynamic operating envelopes allow DNSPs to adjust DER export limits based on real-time network capacity using standardised control frameworks, thereby enabling active management of rooftop solar panels and batteries on LV networks (AER 2023).

- **DER visibility:** The market operator manages the DER Register and the Distributed Service Provider Information Portal, which provides system-wide visibility of rooftop solar units, batteries, and the participation of demand-side resources. These tools support forecasting, reliability modelling, dynamic operating envelopes, and improved LV network management (AEMO 2023a).

- **Expanding the stock of DERs:** Federal support for small-scale behind-the-meter batteries to complement new and existing roof-top solar installations expanded the pool of dispatchable distributed storage for future DR programmes (DCCEEW 2025).

Pillar 3: Consumer-facing price signals

Retail tariff reforms under the 'power of choice' programme supported the implementation of cost-reflective ToU and demand-based network tariffs to reflect peak network costs and encourage consumers to shift consumption away from congested periods (AEMC 2012). Several Australian retailers have introduced 'solar sponge' tariffs, which offer very low or zero import prices during periods of high solar generation, directly incentivising households to shift flexible loads such as EV charging, hot water systems, and pool pumps to these periods (AEMC 2021). The Australian government is also introducing the *Solar Sharer Offer* from July 2026, a new electricity pricing plan that will give all households access to free daytime power during peak solar generation, thereby helping to lower bills and make optimal use of Australia's excess solar energy (DCCEEW 2025). Collectively, this constitutes the consumer-facing price signal layer in Australia's DF architecture.

> In Australia, the rapid growth of DERs is driving efforts to aggregate them as flexible, dispatchable resources, with potential annual system savings of up to AUD 14 billion by 2050.

Pillar 4: Market access and revenue-stacking pathways for flexibility services

- **Granular price signal for flexibility in wholesale markets:** The wholesale power market was previously dispatched at 5-minute intervals, but settlement occurred at the 30-minute average price, which undervalued flexibility. The Five-Minute Settlement reform aligned dispatch and settlement intervals and sharpened the price signals, rewarding fast-response assets such as batteries and exposing wholesale market participants[8] to more granular costs and revenues (AEMO 2017).

- **Regulatory support for flexibility:** Distribution regulatory reforms introduced performance-based incentives on utilities for investing in non-wire alternatives rather than network expansion (AER 2021a).

- **Market access for DF across multiple value streams:** The wholesale DR mechanism allowed aggregators to bid and dispatch through the same National Electricity Market (Australia) (NEM) market bidding process used by supply-side resources. Participation requires metered loads with at least 1 MW of dispatchable capacity and a proposed baseline method that meets the standards defined for accuracy and bias. This opened a clear pathway for implementation and embedded DF (only load curtailment) within core market operations rather than treating it as a separate programme (AER 2021b). Further reforms by the regulator also provided a technical framework to allow device-level metering and settlement and unlock granular monetisation of DERs[9] (AEMC 2024c).

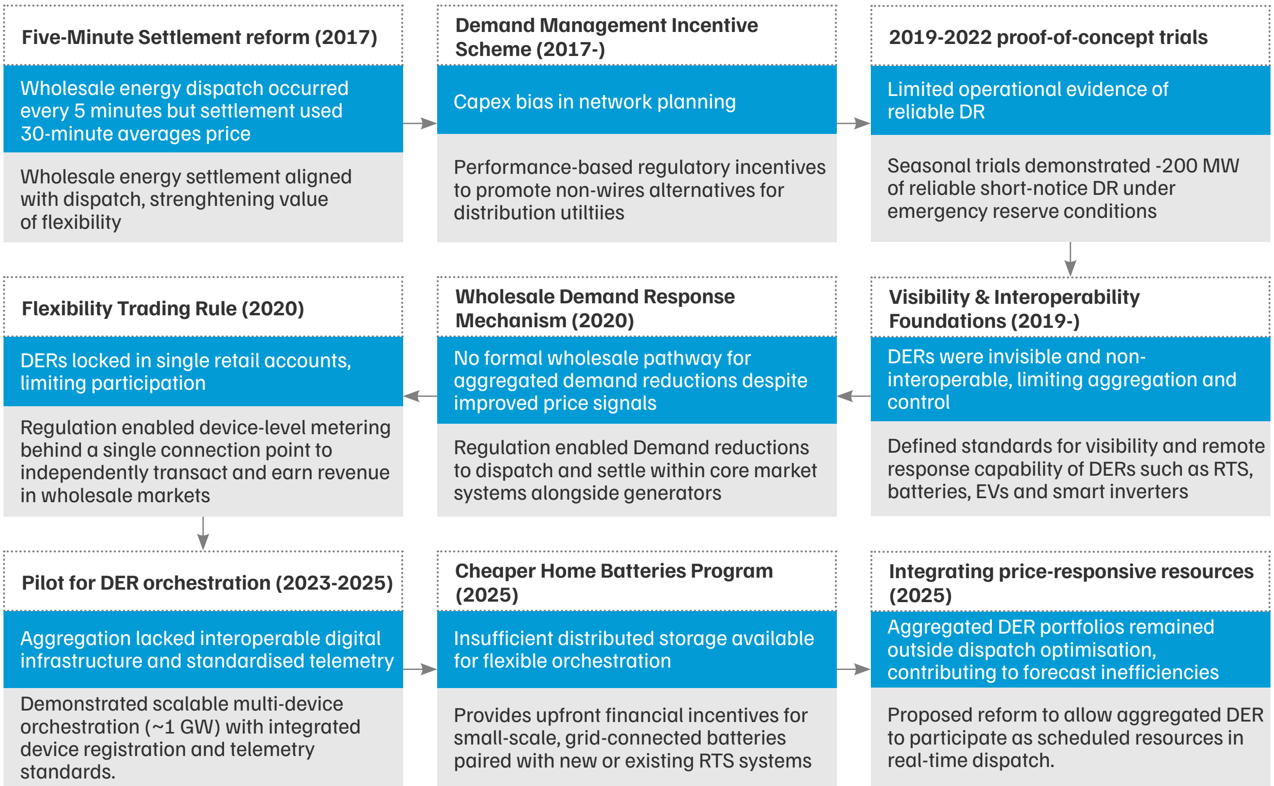
[8] Wholesale market participants include generators, retailers, large industrial consumers, and aggregators who buy and sell electricity in the wholesale market and are directly exposed to spot prices and settlement outcomes

[9] The *Flexibility Trading Rule* (2024) introduced a secondary settlement architecture allowing individual devices behind a single retail connection, such as batteries or controllable loads, to have their own metering and settlement identity. This enables each device to be independently measured, billed, and compensated for market participation without being bundled into the site's overall consumption meter.

Pillar 5: Evidence-based regulatory designs and institutional collaboration

- **Pilot-to-programmes framework:** The Australian Renewable Energy Agency (ARENA) is a non-rule-making body that invests in proof-of-concept projects of technologies that are not yet cost-competitive but can deliver system-wide value and generate the operational evidence used to inform regulatory reform from multi-year regulatory sandboxes.
- **From successful pilots to large-scale programmes:** The ARENA-funded short-notice RERT[10] proof-of-concept trial (2019–22) outperformed the 200-MW target in two out of three years, leading to the incorporation of DR into NEM's reliability framework. It succeeded by standardising baselines, running strict performance tests before each season (summer/

Figure 5. Demand flexibility reforms in Australia were sequenced through iterative market rules, changes in technical codes, and proof-of-concept demonstrations (2017–25)



Source: Authors' analysis.

Notes: The title of each box indicates the intervention or reform and the time period in which they were implemented. Blue box indicates the core system gap identified at the time, while Grey text highlights the resulting system capability added through the reform. Capex = capital expenditure; GW = gigawatt; MW = megawatt.

[10] The RERT is a mechanism that allows the AEMO to procure emergency DR or reserve capacity outside the market to maintain system reliability during supply shortfalls.

winter), and diversifying across residential, small-business, and large C&I customers, thus reducing delivery risk and generating insights from diverse segments. Run entirely through AEMO's existing RERT framework, it gave the market operator full visibility of the participating DF resources, integrating them with existing market mechanisms and helping shape subsequent reforms and DR programmes (AEMO n.d.-b; Briggs et al. 2023).

As these case studies show, a pathway or single destination when developing a DF market. Different systems, through incremental reforms, can make progress towards better integration of demand-side resources. Critically, GB's case study demonstrates that early utility-led programmes and pilots play a foundational role, but scale is achieved only when flexibility is standardised, monetised across multiple value streams, and incorporated into core market operations.

The next section discusses the status of each pillar of market creation in India, the remaining gaps, and the steps needed to fill them in the short and medium term.

7. What challenges does India need to address to create a demand flexibility market?

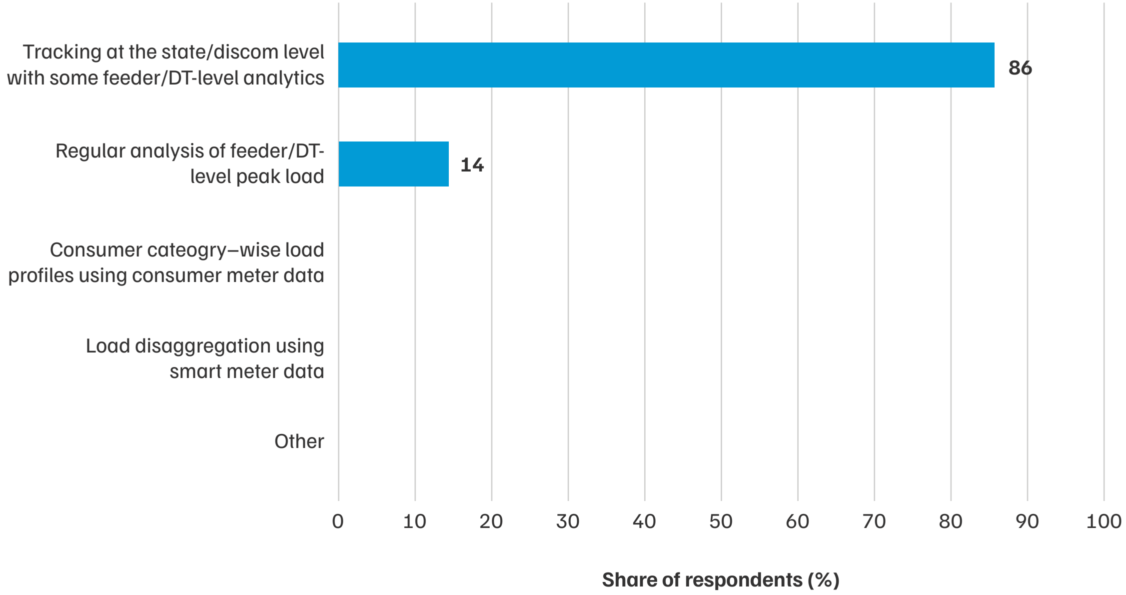
In this section, we discuss the status of each of the five DF market pillars in India. The case studies discussed above illustrate how DF markets emerge from the coordinated actions of system operators, economic regulators, distribution utilities, aggregators, and retailers. We complement these insights from the structured survey responses from 14 Indian power distribution companies (discoms) and five semi-structured interviews. Annexure 4 provides details of the survey sample and the list of institutions interviewed. In India's context, we focused on gathering insights from discoms as they serve multiple important roles in the market creation process – as electricity retailers, operators of the distribution network, or custodians of consumer data. They are crucial to the running of DR programmes with regulatory oversight.

Under each pillar, the road map highlights which institutions must take the lead in implementing (1) urgent, short-term interventions and (2) medium-term interventions that require further evidence and consensus amongst stakeholders. This effort must be coordinated across regulators, market operators, and distribution utilities responsible for operationalising flexibility markets and embedding demand-side resources in planning.

Pillar 1: Advanced metering infrastructure, data exchange, and consent architecture

As the review of GB and Australian DF markets demonstrates, smart metering and consent-based access to the obtained data by consumers, utilities, and third parties are essential to inform tariff design, baselines, measurement, verification, and settlement; they are the building blocks of any DF market.

Figure 6. None of the surveyed discoms currently use smart meter data to understand demand drivers (n = 14)



Source: Authors' analysis based on insights from our survey.

Note: discom = (power) distribution company (India); DT = distribution transformer.

Indian distribution utilities have installed about 70 million cumulative consumer-, distribution transformer (DT)- and feeder-level smart meters as of May 2026 (MoP 2026). However, the analytical utilisation of interval data from smart meters for load research, consumer segmentation, and planning remains limited (Figure 6).

Consultations with discom officials indicate that while consumers with smart meters can view their consumption data through utility or AMI service provider–managed apps, the quality and depth of the analytics vary across discoms, from basic bill summaries and digital payment alerts to readable interval-level consumption graphs.

There is also no standardised digital consent mechanism by which consumers can authorise third parties to access their smart meter data, limiting the ability of aggregators and flexibility service providers to develop consumer-facing services.

Table 2 lists three crucial enablers that can facilitate API-based data portability and address the limited analytical use of smart meter data. The standards should be developed in the short-term, integrated with existing power sector schemes wherever possible, and mandated for adoption in the medium-term.

> Smart meter users can access consumption data through utility or AMI apps, but the depth of analytics ranges from basic billing information to interval-level consumption visualisations.

Table 2. In India, smart meter data architecture needs to address three key issues to enable demand response

Recommendations for stakeholders:	**Short-term (0—3 years)**	**Medium-term (3—7 years)**
Major Stakeholders: CEA, SERCs, AMISPs, Discoms		
1. Establish minimum standards for smart meter data schemas under the RDSS.	■	
2. Develop a digital, secure, API-based consumer consent architecture for smart meter data sharing between discoms and authorised flexibility service providers.	■	■
3. Define regulatory standards for a synthetic smart meter data repository to support estimation of DF potential while the AMI roll-out matures.	■	

Source: Authors' analysis.

Note: A data schema is a structured specification that defines what data fields and metadata exist, how they are formatted and labelled, what units are used, and how they are accessed through APIs, ensuring that the same interval value has the same meaning across all systems. API = advanced programming interface; discom = (power) distribution company (India); RDSS = Revamped Distribution Sector Scheme; CEA = Central Electricity Authority; SERC = State Electricity Regulatory Commission; AMISP = Advanced Metering Infrastructure Service Provider

Pillar 2: Device-level visibility and flexibility readiness

This pillar refers to the grid-level visibility of distributed assets such as ACs, batteries, EV chargers, and grid-interactive building systems and their technical capacity to respond to grid signals through various interventions.

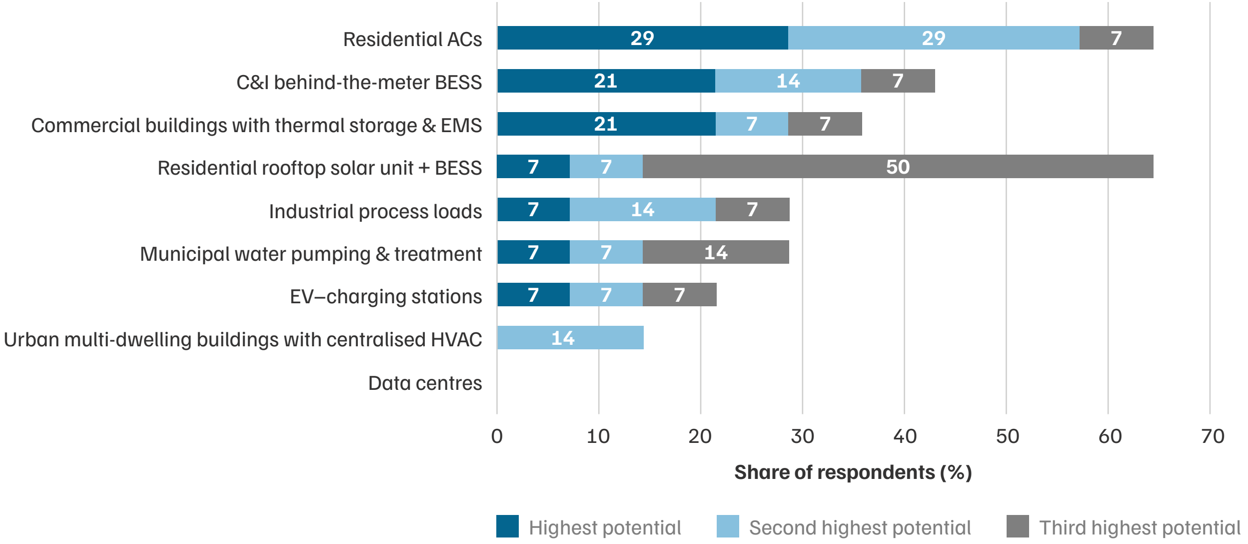
Residential ACs and behind-the-meter battery storage in C&I contexts have emerged as the most prominent end uses with DF potential, according to the surveyed discom officials (Figure 8). Perceived DF capacity by end users varied across discoms based on their consumer mix. In Delhi, nearly 40 per cent of the evening peak load is estimated to come from residential ACs (Ansari et al. 2024), making them the preferred equipment for discoms. In Gujarat, the high rooftop solar penetration (Ministry of New and Renewable Energy [MNRE] 2026) makes it suitable for integration with the battery energy storage systems for flexibility. In Mumbai, municipal water treatment is a proven flexible end use (Tata Power Company Limited 2024).

Buildings are also central in this context because they contain multiple flexible end uses, such as space cooling, EV charging, thermal storage, and behind-the-meter batteries. Global evidence shows that smart, connected buildings equipped with controls and DERs can help materially reduce system costs and emissions (Satchwell et al. 2021). This is consistent with the survey insights, where 21 per cent of the surveyed discoms ranked commercial buildings as the segment with the highest relative DF potential (Figure 7).

Realising this DF potential requires building the stock of grid-responsive devices, establishing the standards to measure and verify their response, and planning for low voltage (LV) network visibility of grid-edge devices for DER orchestration in the future (Table 3).

Addressing these gaps would allow India's existing energy efficiency policy foundations to extend into a device layer that is measurable, interoperable, and structurally aligned with scalable flexibility markets.

Figure 7. Heating, ventilation, and air conditioning (in the residential segment) and BESS (in the C&I segment) have the highest perceived DF potential ($n = 14$)



Source: Authors' analysis based on insights from our survey.

Note: BESS = battery energy storage system; EMS = energy management system; HVAC = heating, ventilation, and air conditioning.

Table 3. Coordinated reforms across appliance standards, building codes, and communication protocols are needed to enable grid-responsive devices

Recommendations for stakeholders	Short-term (0—3 years)	Medium-term (3—7 years)
Major Stakeholders: BIS, BEE, CEA, Forum of Regulators, REC, Discoms		
1. Introduce a voluntary DR-ready designation within the BEE S&L Program.		
2. Define voluntary, automation-ready pathways in building codes to operationalise peak reduction targets.		
3. Commission commercial end-use surveys for key building categories to map flexibility potential by building type and climate zone.		
4. Establish nationally recognised communication and interoperability standards for grid-edge devices, with formal BIS recognition and alignment with IES.		
5. Require discoms to publish LV network monitoring data under the RDSS, specifying the roll-out of DT-level interval metering and its integration with distribution management systems.		
6. Establish minimum interoperable standards for grid communication with DERs aligned with the IES.		
7. Commission national DF potential studies using appliance penetration data and smart meter datasets.		

Source: Authors' analysis.

Note: BEE = Bureau of Energy Efficiency; BIS = Bureau of Indian Standards; CEA = Central Electricity Authority; discom = (power) distribution company (India); IES = India Energy Stack; DT = Distribution Transformer; S&L = Standards & Labelling; REC = Rural Electrification Corporation.

Pillar 3: Consumer-facing price signals

Retail electricity tariffs create economic signals that motivate consumers to shift or reduce load in response to system conditions (Faruqui et al. 2017). The global case studies show that ToU and dynamic tariffs often precede or co-exist with formal DF market reforms (see Boxes 1 and 2).

By 2025, 30 Indian states and union territories had introduced the simpler time-of-day (ToD) tariffs (Malhotra et al. 2024), but only eight extended them to domestic consumers, and just seven offered any rebate during solar hours. Despite the widespread roll-out, there is limited evidence of the effectiveness of ToD tariffs in shifting load in India. This is partly due to the nascent level of smart meter penetration in most states and to the lack of regular measurement and analysis of how individual- or consumer-level load profiles respond to tariff signals. Table 4 identifies the short and medium-term actions for improving retail tariff signals for consumers.

As tariffs remain the most widely used lever to modify consumer behaviour, strengthening ToD design is essential to establish consumers' baseline familiarity with DF.

Table 4. Strengthening time-of-day tariff design and evaluation is the most immediate strategy for building consumer familiarity with demand flexibility in India

Recommendations for stakeholders	Short-term (0—3 years)	Medium-term (3—7 years)
Major Stakeholders: SERCs, Discoms		
1. Use smart meter interval data to evaluate ToD tariff impact by consumer segment.	■	
2. Evaluate how tariff structures impact DER adoption and the flexible asset stock.	■	
3. Introduce critical peak pricing for large C&I consumers based on ToD evaluation evidence.		■

Source: Authors' analysis.

Note: note SERC = State Electricity Regulatory Commission; discom = (power) distribution company (India)

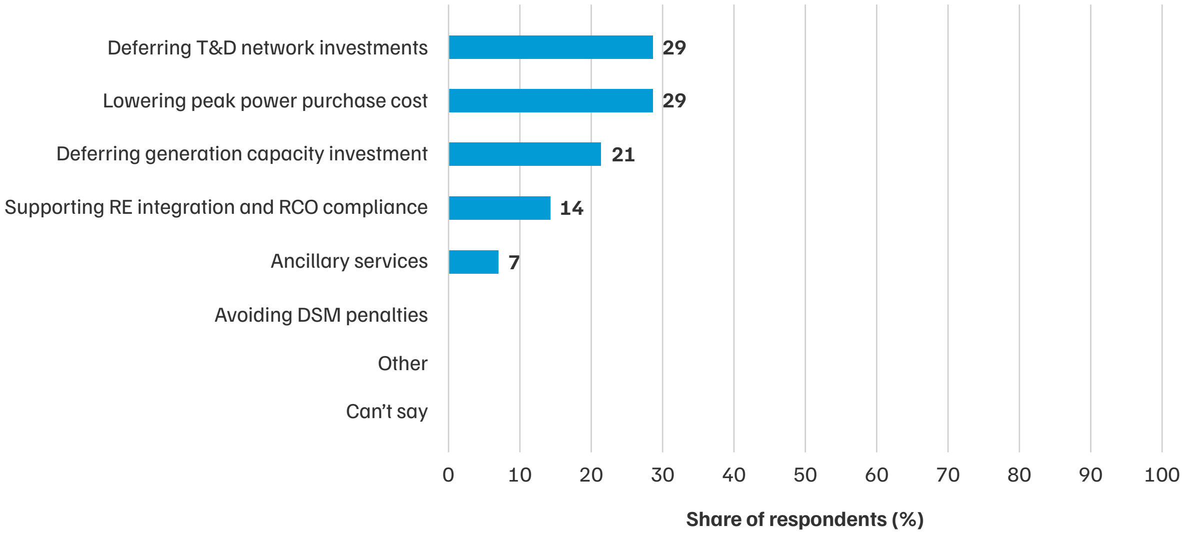
Pillar 4: Market access and revenue-stacking pathways for flexibility services

Australia's experience shows that integrating DF through a single, energy-only wholesale market yields limited registered capacity, while GB's approach of opening multiple revenue streams across capacity, balancing, and local flexibility markets has enabled participation at a much larger scale (Boxes 1 and 2). This pillar discusses key reforms that will enable similar uptake and scaling of DF.

Currently, Indian regulations allow DF to provide secondary and tertiary ancillary services in the national market (Central Electricity Regulatory Commission [CERC] 2022) and peak load services at the state level (Maharashtra Electricity Regulatory Commission [MERC] 2024) – both facilitated by aggregators.

Survey responses and stakeholder consultations indicate that the perceived value of flexibility varies across discoms depending on the system characteristics (Figure 8). Utilities managing dense urban networks, for example, in Delhi and

Figure 8. Savings in power purchase costs and network investments are demand flexibility's biggest perceived value proposition ($n = 14$)



Source: Authors' analysis based on insights from our survey.

Note: DSM = Deviation Settlement Mechanism; RE = renewable energy; RCO = renewable consumption obligations; T&D = transmission and distribution.

Mumbai, emphasised the potential of flexibility to defer distribution infrastructure upgrades where land availability is limited. In contrast, discoms in states with higher RE penetration, such as Gujarat, highlighted the usefulness of flexibility in managing load to absorb RE generation and maintain grid stability.

The value of a specific flexibility service to a discom, and therefore the price it is willing to pay, depends on the avoided costs of the particular system it addresses, such as deferred network investment and reduced peak power purchase or ancillary service procurement.

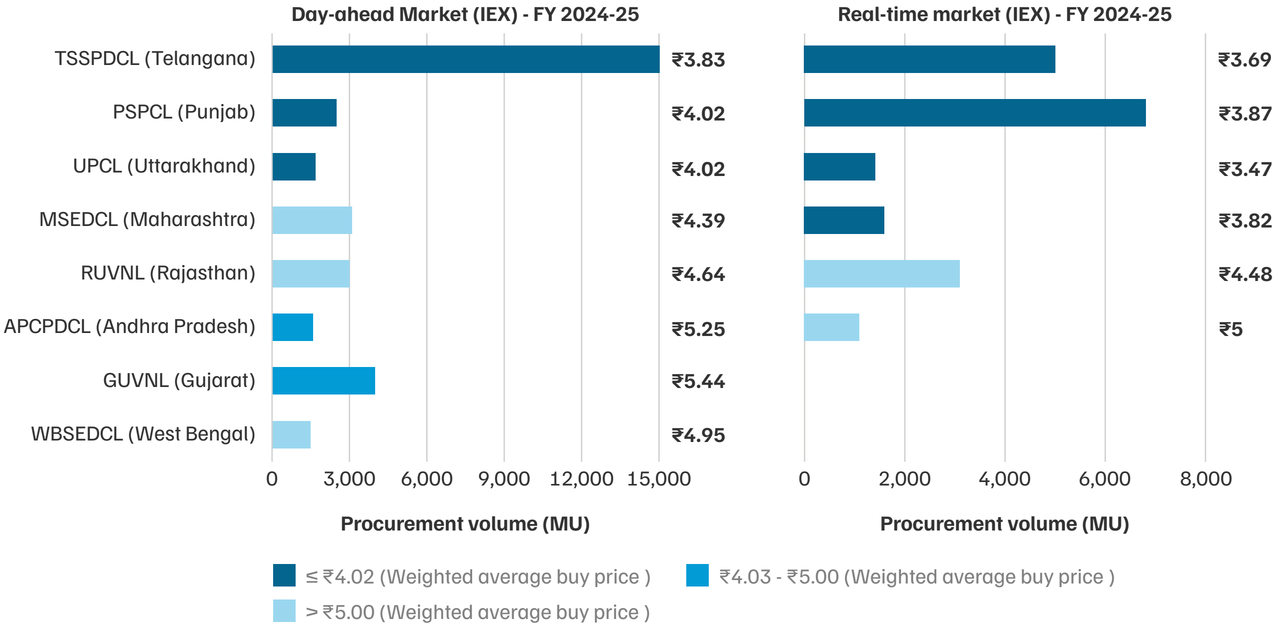
- Avoiding peak power purchase: In states that were among the top buyers on the Indian Energy Exchange in FY 2025, a portion of marginal procurement occurs at average buy prices between INR 3 and INR 6 per kilowatt-hour. If DF can deliver 10 per cent savings in the day-ahead and real-time segments, this would translate to potential savings of approximately INR 3.6 billion (INR 360 crore) and INR 2.5 billion (INR 250 crore), respectively (Figure 9).

- Deferred network investment: DF can also create value through deferral of capital expenditure. At the distribution level, the awarded costs for additional distribution transformers range from approximately INR 0.2 million (INR 2 lakh) (25 kilovolt-amperes [kVA]) to around INR 0.5 million (INR 5 lakh) (200 kVA), indicating the scale of capital expenditure associated with local capacity augmentation,[11] which DF can help defer (MoP, REC, and PFC 2025).

Together, these energy and capacity revenue streams show that a combination of fixed and performance-based payments can help balance the cost of deploying flexibility services, particularly for hardware-intensive interventions. Global evidence also suggests that aggregators need access to multiple value streams simultaneously to justify the investment in automation, enrolment, and coordination that flexibility at scale requires (Briggs et al. 2023).

[11] These estimates are based on aggregated all-India averages for FY 2025; actual costs at locally constrained nodes are likely higher, but such granular, location-specific cost data is not publicly reported.

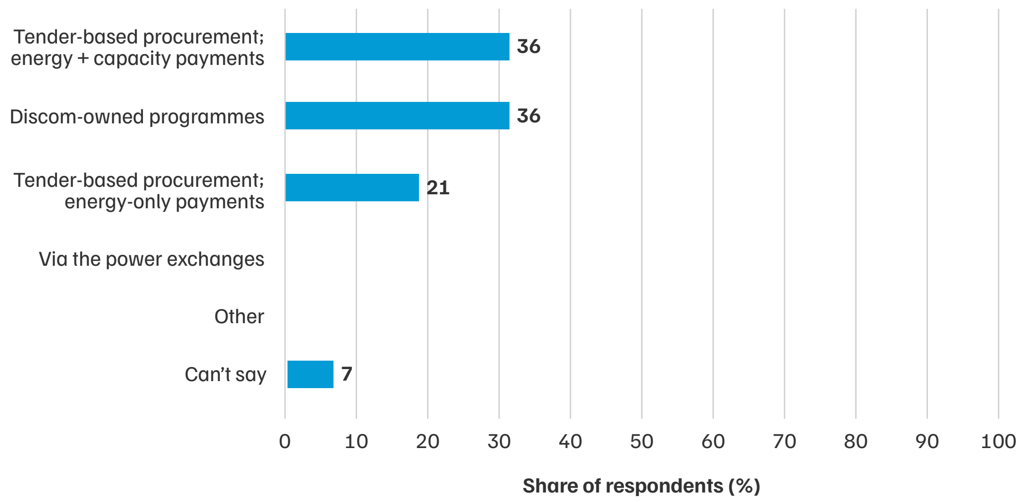
Figure 9. Top buyers on the IEX's DAM and RTM procure marginal power at an average buy price of INR 3 to INR 6 per kilowatt-hour



Source: Authors' analysis based on CERC 2025.

Note: Gujarat does not appear in the Real time market (RTM) panel because GUVNL was not amongst the top 10 buyers in the RTM and hence its procurement data was not reported. APCPDCL = Andhra Pradesh Central Power Distribution Corporation Ltd.; CERC = Central Electricity Regulatory Commission; DAM = day-ahead market; GUVNL = Gujarat Urja Vikas Nigam Limited; IEX = Indian Energy Exchange; MSEDCL = Maharashtra State Electricity Distribution Co. Ltd.; MU = Million Units; PSPCL = Punjab State Power Corporation Limited; RTM = real-time market; RUVNL = Rajasthan Urja Vikas Nigam Limited; TSSPDCL = Telangana State Southern Power Distribution Company Limited; UPCL = Uttarakhand Power Corporation Limited; WBSEDCL = West Bengal State Electricity Distribution Company Limited.

Figure 10. Most respondents prefer bilateral procurement of demand flexibility services with energy plus capacity payments (n = 14)price of INR 3 to INR 6 per kilowatt-hour



Source: Authors' analysis based on insights from our survey.

Note: discom = (power) distribution company (India).

About 36 per cent of the surveyed discoms were open to combining energy and capacity payments if the peak reduction and potential network expansion deferral value were demonstrable and regulator-approved (Figure 10). Our consultations revealed that many discoms prefer not to procure DF through power exchanges, as flexibility needs are typically location-specific rather than driven only by system-wide peak shortages. Utilities, therefore, prefer to have their own programmes, where they can target DF as needed or use location-tagged procurement models for distributed flexibility services (Table 5).

Table 5 identifies the short and medium-term actions needed across market design, regulatory frameworks, and digital infrastructure to establish the foundations for a DF market in India.

The GB and Australia case studies show that regulators and system operators played a central role in incentivising DF uptake, defining third-party aggregators, and providing them access to revenue streams. This facilitated the transition towards an open, interoperable ecosystem with standardised products and unified data sharing, instead of monolithic utility silos. India's regulatory bodies are well placed to lead a similar evolution, building on the foundations that state-level regulations have begun to establish.

Table 5. India needs a clearer market design and stronger regulatory incentives to enable discoms and aggregators to participate in and scale demand flexibility

Recommendations for stakeholders	Short-term (0—3 years)	Medium-term (3—7 years)
Major Stakeholders: CERC, MoP, SERCs, Grid-India, AIDA, FoRs, discoms, IES		
1. Extend the DF obligations framework to more states, ensuring the penalty design serves as a strong market signal beyond compliance formalities.	■	
2. Establish a central registry of qualified aggregators and a national pre-qualification framework to reduce barriers to multi-market entry.	■	
3. Develop a common evaluation methodology, under a national working group, for comparing flexibility savings with network investment.		■
4. Under DF regulations, mandate discoms to assess non-wire alternatives for Capex projects above a defined threshold, using a common evaluation methodology across states.		■
5. Develop standard bidding templates for DF procurement with defined baselines and MVS requirements and mandate discoms to operationalise these through IES core data infrastructure and open APIs.		■
6. Leverage emerging smart metering and data infrastructure to link discoms' regulated returns to service quality and flexibility delivery.		■

Source: Authors' analysis.

Note: A pre-qualification framework, as defined by the FoR, should include minimum load-qualification limits and telemetry standards. Non-wire alternatives refer to demand-side and distributed energy solutions that defer or avoid the need for conventional grid infrastructure investment such as new transmission lines or substations CERC = Central Electricity Regulatory Commission; MoP = Ministry of Power; SERC = State Electricity Regulatory Commission; Grid-India = Grid Controller of India; AIDA = All India Discoms' Association; FoR = Forum of Regulators; discom = (power) distribution company (India); IES = India Energy Stack; capex = capital expenditure; API = application programming interface; MVS = measurement, verification, and settlement.

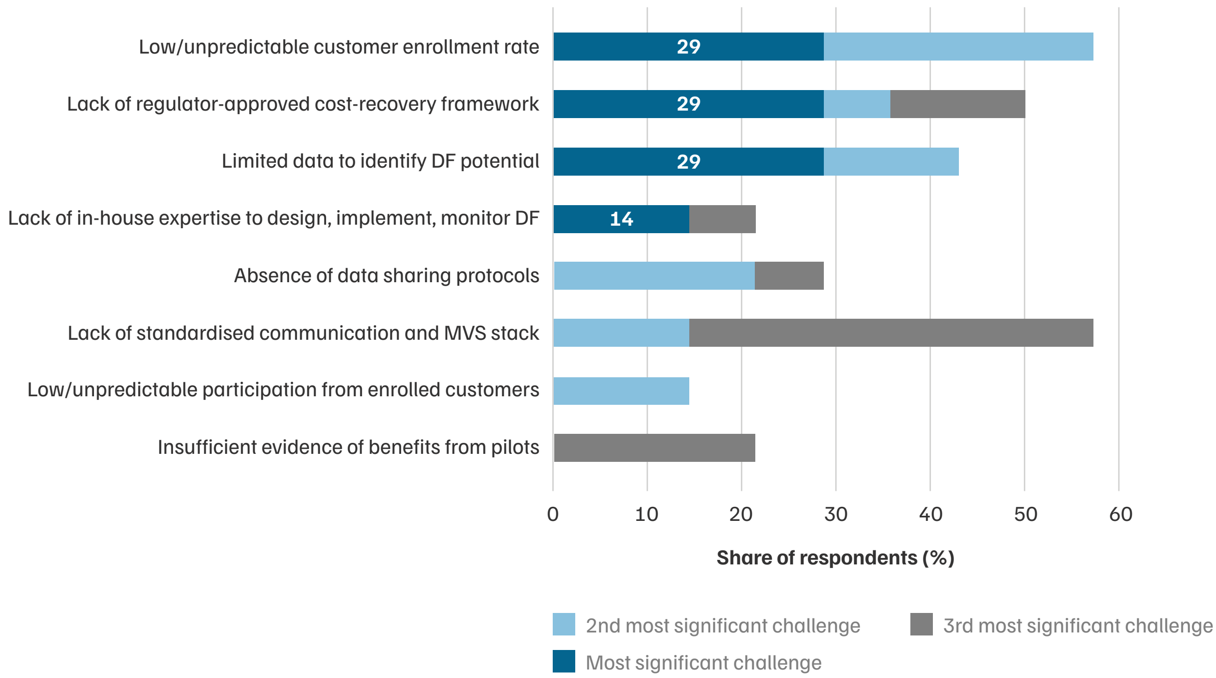
Pillar 5: Evidence-based regulatory designs and institutional collaboration

GB's Open Networks programme and ARENA's portfolio retrospective demonstrate that the institutional architecture for gathering and acting on evidence matters as much as the evidence itself (Boxes 1 and 2). This pillar focuses on evidence generation and regulatory feedback mechanisms, which enable DF to move beyond isolated pilots.

Despite the 11 documented pilots conducted in 2012–25 (Patankar et al. 2025), evidence on consumer enrolment, segment-level DF potential, and successful incentive designs remains insufficient to anchor regulatory reform. A few pilots, such as Tata Power's residential behavioural and automation-assisted DR programmes, have demonstrated consumer participation across multiple seasons, but their findings remain limited in scale, geography, and consumer diversity (Tata Power Company Limited 2024; Singh et al. 2025). Building a robust evidence base for regulation requires demonstrations at a much larger scale, spanning multiple states, consumer segments, and load types and running long enough to capture seasonal and operational variability. These are the features that enabled Australia's ARENA-funded RERT pilot to institutionalise utility-led DR programmes and inform market regulations (see Box 2).

MERC's cost recovery framework requires programmes to demonstrate cost-effectiveness and long-term tariff reduction; hence, it may not be suitable for early-stage demonstrations, whose value lies precisely in generating that evidence. Discom officials consulted in this research cited the absence of a sandbox mechanism as a specific barrier to testing new business models before committing to scale. Our survey also found that unpredictable consumer enrolment rate, lack of regulator-approved cost recovery frameworks and insufficient data to identify flexibility potential are the three biggest perceived barriers to DF market development (Figure 11). These barriers are directly related to insufficient evidence generation.

Figure 11. The lack of cost-recovery frameworks and limited data for valuing demand flexibility are one of the biggest challenges to creating a large-scale demand flexibility market ($n = 14$)



Source: Authors' analysis.

Note: MVS = measurement, verification, and settlement.

If each discom develops its own approach to baseline measurement, product definition, and procurement frameworks, this leads to fragmentation, raises aggregator entry costs, prevents cross-state market development, and makes it challenging for regulators to assess whether programmes are being designed or procured effectively. In the UK, this problem was resolved through an eight-year-long multi-stakeholder programme, *Open Networks*, which iteratively standardised contracts, products, and evaluation frameworks across all distribution operators before concluding in 2025 (Box 1). Discom officials also identified the lack of in-house expertise to design, implement, and monitor DF as a significant barrier (Figure 9), which a shared institutional infrastructure can address more efficiently than each discom independently.

In conclusion, our findings indicate a gap between experimentation and regulatory integration, which is addressed in Table 6.

Addressing these gaps simultaneously with market design and monetisation frameworks will be essential for building the credibility and confidence needed to scale DF.

Table 6. Building a structured evidence base and institutional feedback loop is essential to move demand flexibility from isolated pilots to scalable programmes

Recommendations for stakeholders:	**Short-term (0—3 years)**	**Medium-term (3—7 years)**
Main Stakeholders: MoP, SERCs, CERC, AIDA, REC, IES		
1. Create funding mechanisms at the national and state levels for cross-state, large-scale DF innovation and technology demonstrations.	■	
2. Establish a cross-state working group to standardise flexibility procurement frameworks and integrate demonstration findings into state electricity regulators' reviews of DFPO trajectories and cost-effectiveness thresholds.		■

Source: Authors' analysis.

Note: Flexibility procurement frameworks include standardised processes for procuring demand flexibility, including bidding templates, baseline methodologies, reporting requirements, and regulatory sandbox arrangements. AIDA = All India Discoms' Association; CERC = Central Electricity Regulatory Commission; DFPO = demand flexibility portfolio obligation; discom = (power) distribution company (India); IES = India Energy Stack; MoP = Ministry of Power; SERC = state electricity regulatory commission; REC = Rural Electrification Corporation.

8. Road map for creating a demand flexibility market

The following section details the action points introduced in Section 7, organised under the same five-pillar framework. The recommendations are not sufficient in isolation. Earlier actions create the foundations that later interventions depend on. For example, metering infrastructure enables tariff reform, tariff signals expand the flexible asset stock, and market access mechanisms determine whether aggregators can monetise that stock at scale. The steps are for short-term priority (0-3 years), unless otherwise noted.

Pillar 1: Advanced metering infrastructure, data exchange, and consent architecture

- **Establish minimum standards for smart meter data recording schemas under RDSS.** Even where interval data exists, the non-standardised structure, missing data, incomplete or inconsistent metadata tagging, and lack of access protocols raise integration costs and block interoperability (DESNZ 2025a). The issue is exacerbated in India, as multiple service providers are responsible for installing smart meters and setting up the related infrastructure in each discom under the RDSS (REC, PFC, and MoP 2021). Standardised data schemas would allow third parties to consistently interpret, access, and integrate smart meter data across discoms.

- **Define regulatory standards for a synthetic smart meter data repository to support estimation of DF potential while the AMI roll-out matures.** Synthetic datasets can replicate consumers' energy consumption patterns without exposing their actual profiles. This enables flexibility assessment, tariff response simulation, and DR modelling while the physical AMI roll-out and data-sharing infrastructure mature (CNZ 2025). Establishing minimum quality standards for synthetic data will allow this analytical work to proceed in parallel with infrastructure deployment. This approach will limit the exposure of actual data to only those entities responsible for synthetic data generation, thus preserving consumer privacy while enabling broader innovation.

- **Develop a digital, secure, API-based consumer consent architecture for smart meter data sharing between discoms and authorised flexibility service providers (across short and medium term).** In the absence of a standardised consent architecture, aggregators need to negotiate bilateral agreements with utilities to obtain access to smart meter data, which limits the scalability of their products. India's *Digital Personal Data Protection Act* (2023) establishes the right of individuals to control how their personal data is collected, used, and shared, but it does not operationalise a sector-specific consent architecture for electricity markets. Similarly, RDSS focuses on meter deployment and infrastructure interoperability but not on consumer data governance or third-party sharing (REC, PFC, and MoP 2021). A digital consent framework integrated with smart meter apps – similar to GB's consumer consent service – would streamline consumer recruitment for DF programmes. Standards defined in the short term can then be mandated for all third-party data sharing in the medium term.

Pillar 2: Device-level visibility and flexibility readiness

- **Introduce a voluntary DR-ready designation within the Bureau of Energy Efficiency (BEE) *S&L Program*.** The BEE's *S&L Program* sets minimum energy performance standards and provides strong visibility into efficient appliance stock and market penetration trends (Vasudha Foundation and BEE 2024). However, these frameworks do not define, tag, or track 'DR-capable' devices. After nearly two decades of implementing the S&L Program, a ready institutional pathway is emerging for BEE to introduce a DR readiness designation and extend visibility into the share of appliances that are technically capable of responding to a DR event remotely. This will enable credible potential assessment, certification, and market integration of automation-ready appliances.

- **Define voluntary, automation-ready pathways in building codes to operationalise peak reduction targets.** The Energy Conservation and Sustainable Building Code sets enhanced efficiency standards for commercial buildings and includes a 'Grid Harmonisation' category with peak load reduction targets of 5, 7.5, and 10 per cent (BEE 2024). However, it does not specify the technical pathways for grid integration, nor does it prescribe the minimum automation, interoperability, or communication requirements to achieve these goals. Defining these technical conditions would help convert peak reduction targets from aspirational benchmarks to operationalised demand-side resources.

- **Commission commercial end-use surveys for key building categories to map flexibility potential by building type and climate zone.** BEE's building energy surveys can be extended from whole-building energy performance benchmarking to capture end-use types, equipment inventories, occupancy characteristics, and hourly load profiles obtained from metering across climate zones and building types. It can draw on models such as the California CEUS[12] (CEC 2024), which served as the foundational input to the state's DR Potential Study (Gerke et al. 2024). Commissioning equivalent surveys in India would enable empirical estimation of flexibility potential, prioritisation of high-value end uses, and more targeted DF programme designs.

- **Establish nationally recognised communication and interoperability standards for grid-edge devices, with formal BIS recognition and alignment with IES.** Where smart meters are not yet installed, asset-level devices such as smart plugs can enable measurement and verification. In India, DF pilots have used such grid-edge devices and related protocols for communication (Poojary et al. 2015; Singh et al. 2025). While EV-charging infrastructure guidelines already promote open communication protocols such as OCPP and UEI to ensure interoperability (MoP 2024), similar nationally recognised standards do not yet exist for other flexible loads. Our interviews indicate that the industry communication standards used in pilots lack formal recognition, unlike the Bureau of Indian Standards (BIS) and Central Electricity Authority (CEA)-approved standards for other power system equipment (CEA 2019, 2020). The IES initiative's core infrastructure layer, which is designed to support standardised protocols and technology-agnostic data architecture across utilities, provides an institutional grounding for this standardisation process and would ensure that device-level standards are compatible with the broader digital infrastructure being developed nationally. It must be complemented by formal recognition by the BIS or CEA to give discoms the regulatory basis to accept these standards in official measurement and settlement processes.

- **Require discoms to publish LV network monitoring data under the RDSS, specifying the roll-out of DT-level interval metering and its integration with distribution management systems.** India has made a foundational investment through the RDSS, which has sanctioned communicable smart DT meters for approximately 5.4 million DTs nationally – though only 3 per cent have smart meters in communicating mode as of 2024 (Kulkarni et al. 2025). Existing DT meters are primarily used for AT&C loss calculation rather than real-time load monitoring, and their data is not integrated with discoms' operational systems at an interval resolution. Emerging digital twin initiatives across Indian discoms, such as Gujarat's Urja Sanvardhanam platform (Times News Network 2025), indicate a growing shift towards integrating feeder- and DT-level data to improve real-time monitoring, forecasting, and network-planning workflows. The REC and PFC should include LV monitoring plans as a milestone under

[12] The California CEUS collected detailed electricity and gas usage data, equipment inventories, occupancy schedules, and hourly load profiles from a stratified sample of nearly 27,000 commercial buildings, producing robust load and end-use characterisations for forecasting and planning.

the RDSS, prioritising DTs in high–DER penetration areas and constrained urban feeders where local flexibility needs are likely to emerge first.

- **Establish minimum interoperable standards for grid communication with DERs aligned with the IES (Medium term).** The short-term actions above establish formal recognition for device-level communication standards and expand LV network monitoring. Building on this, medium-term standardisation should extend interoperability requirements to the full range of DERs such as, rooftop solar inverters, grid-connected batteries, and smart appliances, ensuring that device-level communication protocols are compatible with the IES data architecture. This would create a unified technical layer across which aggregators, discoms, and system operators can coordinate dispatch and settlement.

- **Commission national DF potential studies using appliance penetration data and smart meter datasets (Medium term).** As smart meter coverage matures and the DR-ready appliance designation proposed above is introduced, the data conditions for robust national potential studies will improve. Commissioning these studies would produce empirically grounded estimates of flexibility potential by consumer segment, geography, and load type. These estimates would directly inform the state electricity regulatory reviews of Demand Flexibility Portfolio Obligations (DFPO) trajectories and cost-effectiveness thresholds.

Pillar 3: Consumer-facing price signals

- **Use smart meter interval data to evaluate ToD tariff impact by consumer segment.** India's ToD tariffs for C&I consumers have established a foundation of time-varying pricing and early behavioural flexibility signals (Malhotra et al. 2024). However, price differentials remain modest, are not regularly updated, and are weakly aligned with wholesale or network conditions. Consequently, although discoms identify flexibility potential in residential ACs and behind-the-meter storage (Figure 8), consumers have limited incentive to automate or enrol these assets in flexibility programmes. Regulators and discoms should use smart meter data to assess how ToU tariffs affect different consumer groups and identify who responds to price signals to inform innovative tariff designs and DF potential assessment studies.

- **Evaluate how tariff structures impact DER adoption and the flexible asset stock.** Tariff design influences not only consumer behaviour but also the investment decision to install DERs. Regulators should direct discoms to report how ToD differentials, export tariffs, and net metering[13] design affect the payback period and the adoption of rooftop solar panels, batteries, and smart appliances, since these assets form the underlying stock from which future flexibility markets can draw.

- **Introduce critical peak pricing for large C&I consumers based on To Devaluation evidence (Medium term).** As smart meter data matures and ToD impact assessments are completed, SERCs can use this evidence base to design and pilot CPP for large C&I consumers, where load density and energy management systems make response most reliable.

Pillar 4: Market access and revenue-stacking pathways for flexibility services

- **Extend the DF obligations framework to more states, ensuring the penalty design serves as a strong market signal beyond compliance formalities.** To make flexibility services economically viable and scalable, regulatory mandates similar to MERC's DFPOs must be extended to other states grappling with high RE and rapid DER penetration, distribution network congestion, and urban peak stress. Under India's current cost-plus regulatory framework, discoms earn regulated returns on capital investments, which can weaken the incentive to pursue DR as an alternative to network expansion (Malhotra et al. 2024). To address this, SERCs must align

[13] Net metering allows consumers with rooftop solar to offset their electricity bill by exporting surplus generation to the grid.

DFPO penalties with the returns from network investments so that non-compliance carries a comparable financial impact in the short and long terms.

- **Establish a central registry of qualified aggregators and a national pre-qualification framework to reduce barriers to multi-market entry.** Current regulations define aggregators as entities registered with the distribution licensee rather than independently recognised market participants (MERC 2024). SERCs should establish central aggregator registration at the SERC level, with pre-defined telemetry, measurement accuracy standards, and verification protocols for different DF service types. Discoms would retain their procurement and contracting role while allowing qualified aggregators to approach any discom within their state and participate in national ancillary services. The CEA and the Forum of Regulators should develop a standardised national eligibility framework to define common technical and commercial criteria, thereby reducing the administrative burden of multi-market entry and enabling aggregators to build scale across states.

- **Develop a common evaluation methodology, under a national working group, for comparing flexibility savings with network investment (Medium term).** Extending DF obligations and aggregator registration creates procurement activity, but without a common methodology, discoms face inconsistent incentives and regulators lack tools to assess cost-effectiveness. A national working group under MoP or All India Discoms' Association (AIDA) should develop a standard framework covering baseline assumptions, avoided cost calculations, and reporting norms.

- **Under DF regulations, mandate discoms to assess non-wire alternatives for Capex projects above a defined threshold, using a common evaluation methodology across states (Medium term).** This builds directly on the methodology above, giving SERCs a consistent basis for approving network investment decisions.

- **Develop standard bidding templates for DF procurement with defined baselines and MVS requirements and mandate discoms to operationalise these through IES core data infrastructure and open APIs (Medium term).** This ensures procurement is interoperable and scalable across states.

- **Leverage emerging smart metering and data infrastructure to link discoms' regulated returns to service quality and flexibility delivery (Medium term).** More than half the discoms do not publish any regular or consistent outage data (Borah and Sane 2025), and even where reliability indices are reported, there are no mechanisms that automatically link service quality performance to financial consequences for discoms (Mandal et al. 2019). This means service quality rules for discoms are weakly enforced in practice. Regulators could remedy this by linking a portion of regulated discom returns to measurable performance on flexibility procurement and supply reliability. A key constraint today is the lack of real-time data at the feeder and transformer levels, which makes performance difficult to verify. However, the ongoing smart meter roll-out under RDSS and progress with the National Feeder Monitoring System (MoP 2026) will progressively enable this, allowing regulators to tie a portion of discom returns to measurable improvements in flexibility delivery and supply reliability.

Pillar 5: Evidence-based regulatory designs and institutional collaboration

- **Create funding mechanisms at the national and state levels for cross-state, large-scale DF innovation and technology demonstrations.** While there are avenues to fund early-stage risk in innovation in generation and transmission (CERC 2026), there is a dearth of funding at the distribution level. We recommend that the Ministry of Power (MoP) consider establishing a competitive, grant-based national demonstration fund for multi-party, multi-state DF programmes, covering automation-assisted DR, DR aggregation, and storage-as-a-service, with mandatory obligations on transparent reporting, rigorous evidence collection, and alignment with national policy initiatives, including the IES and smart metering roll-out. This would support long-duration demonstrations and technology testing, which is key to generating robust evidence for improved programme design. At the state level, we recommend that states establish DF innovation and research funding mechanisms aligned with Maharashtra's *Renewable Energy and Energy Storage Policy 2025–36,* which explicitly mentions DR as one of its R&D focus areas (Industries, Energy, Labour, and Mining Department 2026).

- **Establish a cross-state working group to standardise flexibility procurement frameworks[14] and integrate demonstration findings into the state electricity regulators' reviews of DFPO trajectories and cost-effectiveness thresholds (Medium term).** India's constraint is no longer insufficient demonstrations but the lack of institutional capacity to make their findings comparable across states, cumulative, and regulatory-actionable. We recommend establishing a cross-state technical working group, convened under the MoP or a body such as AIDA, with participation by SERCs, discoms, and independent researchers. The key purpose will be to develop and iteratively refine a harmonised framework covering standard baseline methodologies by load type, replicable sandbox governance and bidding templates, minimum reporting norms for publicly funded demonstrations, and a formal channel for findings to inform SERC and CERC review of DFPO trajectories, product definitions, a cost-effective technology stack, and innovative incentive programmes for consumer enrolment. This will complement the technical interoperability design proposed under the IES.

9. Conclusion

India stands at an inflection point: With over 65 million smart meters deployed, emerging regulatory frameworks, and a rapidly growing DER base, the foundational conditions for a DF market are taking shape. Yet infrastructure alone is insufficient. As the experiences of GB and Australia demonstrate, sustained scaling requires coordinated progress across metering, device standards, price signals, market access, and evidence-based regulation. India must move decisively from pilots to programmes, transitioning distributed loads from passive consumers into active grid assets. A well-designed DF market will not only lower system costs but also accelerate the clean energy transition.

[14] Flexibility procurement frameworks include standardised processes for procuring demand flexibility, including bidding templates, baseline methodologies, reporting requirements, and regulatory sandbox arrangements.

Annexures

Annexure 1. Six revenue pathways for monetising demand flexibility

Table A1 presents the six revenue streams representing distinct grid services that can compensate for the demand-side resources. Access to these revenue pathways can be from different procurement channels, such as utility-led and third-party aggregator-led procurement.

Table A1. Six revenue pathways for monetising demand flexibility

Value stream	Service provided	Compensation and procurement
Capacity market participation	Load reduction during system peaks or adequacy events, enabling deferral of firm capacity investment	Fixed per-kW payments through capacity auctions or bilateral contracts, often with RA credits
Energy market participation	Load shift in response to real-time or day-ahead price signals	Per-MWh revenue based on price arbitrage through spot market participation
Ancillary services provision	Fast-response load modulation for frequency control and ramping up reserves	Availability and activation payments via competitive ancillary service tenders
Emergency and reliability response	Guaranteed load curtailment during grid emergencies	Event-based per-kW payments outside the wholesale market, with strict penalties for non-performance
Distribution-level flexibility	Localised demand reduction to manage congestion or defer network upgrades	Location-specific per-kW availability payments via DSOs or local flexibility markets
RE integration support	Demand shifting to absorb VRE surplus or follow RE generation	Incentives linked to VRE integration, curtailment avoidance credits, or clean energy power purchase agreements

Source: Authors' analysis.

Note: DSO = distribution system operator; kW = kilowatt; MWh = megawatt-hour; RA = resource adequacy; RE = renewable energy; VRE = variable renewable energy.

Annexure 2. The five-pillar framework for DF market development

Demand flexibility market creation is not a single regulatory event but a layered process requiring coordinated action across technical, commercial, and institutional domains. Drawing on the comparative analysis of GB and Australia, this brief organises the key enabling conditions into five interdependent pillars. Together, they describe the sequenced reforms needed to move from isolated pilot programmes to a functioning, scalable DF market.

Table A2. The five-pillar framework for demand flexibility market development

No.	Pillar	Relevance to DF market development
1	Advanced metering infrastructure, data exchange, and consent architecture	Without interval-level metering and standardised data access, accurate settlement, dynamic tariff design, and verification of DR performance are not possible. This pillar determines who can participate, on what terms, and with what level of measurement confidence.
2	Device-level flexibility readiness and orchestration	Flexible devices must be visible to system operators and capable of responding to dispatch instructions without manual intervention. This pillar creates the technical orchestration layer that converts passive distributed assets into active, dispatchable flexibility resources.
3	Retail pricing and utility-led flexibility activation	Price signals translate technical capability into consumer action. This pillar builds the first commercially accessible value streams for flexibility – particularly for consumers without direct market access – and generates the participation evidence needed to design more sophisticated market mechanisms.
4	Flexibility market access and revenue-stacking pathways	This pillar determines whether flexibility can compete on an equal footing with conventional generation and access multiple value streams simultaneously. Revenue stacking across markets is essential for building the commercial case for aggregator investment and consumer enrolment at scale.
5	Evidence-based regulation and institutional coordination	DF market creation involves significant regulatory and technical uncertainty. This pillar reduces implementation risk by ensuring that reforms are evidence-driven, institutions are aligned, and lessons from pilots are systematically incorporated into market design before scaling.

Source: Authors' analysis.

Note: DF = demand flexibility; DR = demand response.

Annexure 3. Market and institutional architecture of Great Britain and Australia

A3.1. Great Britain's power markets

1. **Rule makers:** Ofgem regulates and sets the policy direction for electricity markets, including frameworks for demand-side participation, access, and consumer protection. It approves the rule changes developed by code administrators and oversees reforms to enable fair and efficient market access.

2. **Market operator:** The National Energy System Operator (NESO) is responsible for balancing supply and demand in real time, operating ancillary services, and designing and procuring flexibility products such as the DFS. It coordinates with distribution network service providers to ensure the system-level integration of distributed flexibility.

3. **Economic regulators:** Ofgem also acts as the economic regulator, approving network price controls, setting revenue allowances, and incentivising distribution network service providers to procure flexibility as an alternative to traditional reinforcement under mechanisms such as RIIO.

4. **Aggregators:** In GB, these are referred to as Virtual lead parties, and they combine distributed loads and flexible assets to provide services in wholesale, balancing, and capacity markets. These are third-party market participants and don't necessarily own a supply licence.

5. **Innovation-funding vehicle:** UK Research and Innovation, via Innovate UK and other bodies, along with Ofgem's Strategic Innovation Fund, supports pilots and demonstration projects that advance interoperability, digitalisation, and flexibility services across residential and commercial sectors. These programmes help de-risk participation and inform regulatory design.

A3.2. Australian power markets

1. **Rule makers:** The AEMC designs and amends the market rules and technical frameworks that govern how DF can participate in pricing, settlement, and dispatch.

2. **Market operator:** The AEMO manages dispatch, settlement, forecasting, and reliability planning across the NEM and is responsible for the system changes required to integrate distributed resources with market operation.

3. **Economic regulators:** The AER enforces the National Electricity Rules, monitors compliance among all market participants, and approves network revenue determinations and costs that pass through to consumers.

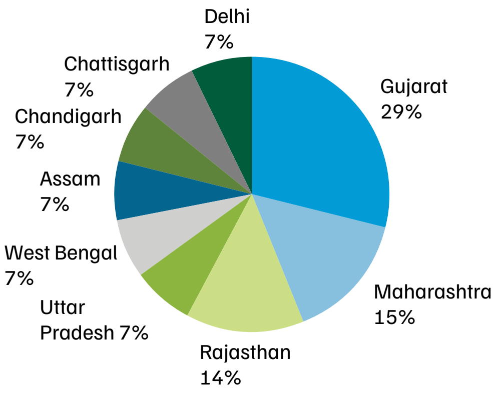
4. **Aggregators:** In Australia, these are referred to as Demand Response Service Providers (DRSP), and they perform the same function of aggregating distributed loads to make it easier to deliver multiple flexibility services at scale.

5. **Innovation-funding vehicle:** ARENA is a non-rule-making body that invests in proof-of-concept projects of technologies that are not yet cost-competitive but can deliver system-wide value, such as DF that generates the operational evidence used to inform regulatory reform.

Annexure 4: Online survey sample description and list of institutions whose officials were interviewed

The survey sample size was 14.

Figure A1. Sample distribution across states and list of discoms that participated



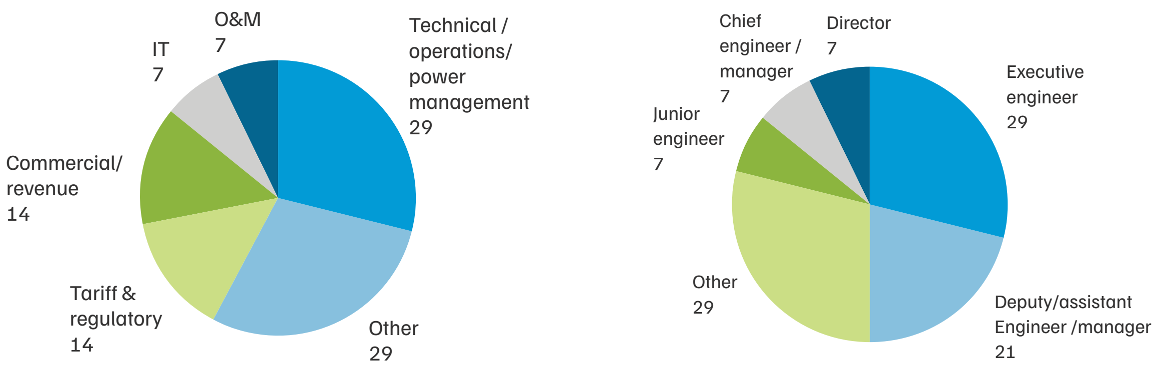
Sample distribution by state and participating discoms (%)

1. Madhya Gujarat Vij Company Limited
2. Paschim Gujarat Vij Company Limited
3. Adani Electricity Mumbai Limited
4. Tata Power Distribution Company, Mumbai
5. Jaipur Vidyut Vitaran Nigam Limited
6. Ajmer Vidyut Vitaran Nigam Limited
7. West Bengal State Electricity Distribution Company Limited
8. Assam Power Distribution Company Limited
9. Chandigarh Power Distribution Company Limited
10. Chhattisgarh State Power Distribution Company Limited
11. BSES Rajdhani Power Limited
12. Pashimanchal Vidyut Vitran Nigam Limited

Source: Authors' analysis.

Note: discom = (power) distribution company (India).

Figure A2. Sample distribution across discom departments and designations



Respondents by department (%) **Respondents by designation (%)**

Source: Authors' analysis.

Note: discom = (power) distribution company (India); O&M = Operations & Maintenance; IT = Information & Technology.

Table A3. List of institutions whose officials were interviewed

No.	Institution
1	BSES Rajdhani Power Limited
2	Green Energy Training and Research Institute
3	Assam Power Distribution Company Limited
4	Tata Power Company Limited, Mumbai
5	Adani Electricity Mumbai Limited

Source: Authors' compilation.

Acronyms

AC	air conditioner
AEMC	Australian Energy Market Commission
AEMO	Australian Energy Market Operator
AER	Australian Energy Regulator
AERC	Assam Electricity Regulatory Commission
AIDA	All India Discoms Association
AMI	advanced metering infrastructure
AMISP	AMI service provider
API	application programming interface
ARENA	Australian Renewable Energy Agency
AT&C	aggregate technical and commercial
BEE	Bureau of Energy Efficiency
BEIS	Department for Business, Energy & Industrial Strategy (UK)
BESS	battery energy storage system
BIS	Bureau of Indian Standards
Capex	capital expenditure
C&I	commercial and industrial
CAISO	California Independent System Operator
CEA	Central Electricity Authority
CEC	California Energy Commission
CERC	Central Electricity Regulatory Commission
CEUS	Commercial End-Use Survey
CNZ	Centre for Net Zero
CPUC	California Public Utilities Commission
DAM	day-ahead market
DCC	Data Communications Company
DCCEEW	Department of Climate Change, Energy, the Environment and Water (Australia)
DECC	Department of Energy & Climate Change (UK)
DEIP	Distributed Energy Integration Program
DER	distributed energy resource
DESNZ	Department for Energy Security & Net Zero (UK)
dEX	decentralised exchange
DF	demand flexibility
DFS	Demand Flexibility Service
DFPO	demand flexibility portfolio obligation
discom	(power) distribution company (India)
DNSP	distribution network service provider
DR	demand response
DSM	Deviation Settlement Mechanism
DSO	distribution system operator
DT	distribution transformer
ENA	Energy Networks Association
ESO	electricity system operator
EV	electric vehicle
FERC	Federal Energy Regulatory Commission
GB	Great Britain
GW	gigawatt
GWh	gigawatt-hour
HVAC	heating, ventilation, and air conditioning
IES	India Energy Stack
IEX	Indian Energy Exchange
KERC	Karnataka Electricity Regulatory Commission
kVA	kilovolt-ampere
kW	kilowatt
kWh	kilowatt-hour

LV	low voltage
MERC	Maharashtra Electricity Regulatory Commission
MNRE	Ministry of New and Renewable Energy
MoP	Ministry of Power
MVS	measurement, verification, and settlement
MW	megawatt
MWh	Megawatt-hour
NEM	National Electricity Market (Australia)
NESO	National Energy System Operator (UK)
OCPP	Open Charge Point Protocol
Ofgem	Office of Gas and Electricity Markets (UK)
OpenADR	Open Automated Demand Response
Opex	operational expenditure
PFC	Power Finance Corporation
PG&E	Pacific Gas and Electric Company
R&D	research and development
RA	resource adequacy
RCI	renewable consumption obligations
RDSS	Revamped Distribution Sector Scheme
RE	renewable energy
REC	Rural Electrification Corporation
RERC	Rajasthan Electricity Regulatory Commission
RERT	Reliability and Emergency Reserve Trader
RTM	real-time market
S&L	Standards & Labelling
SERC	state electricity regulatory commission
T&D	transmission and distribution
ToD	time-of-day
ToU	time-of-use
UEI	unique energy identifier
VRE	variable renewable energy
WDRM	wholesale demand response mechanism

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