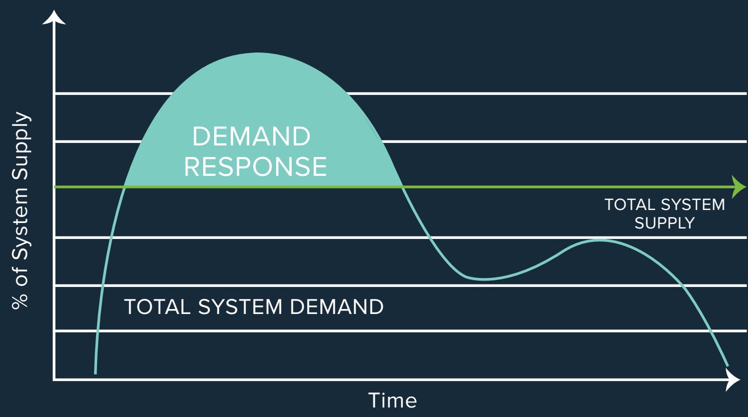
AUTOMATED DEMAND RESPONSE PILOT IN DELHI

Insights and Transferrable Learning to Scale-up Program Designs



JANUARY 2025

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This report is prepared jointly by the Alliance for an Energy Efficient Economy and Schneider Electric in collaboration with BSES Yamuna Power Ltd.

Project Team

Alliance for an Energy Efficient Economy:

Pramod Kumar Singh

Sumedh Agarwal

Paras Bhattarai

Bhuvan Sharma

Schneider Electric:

Nandan Mahale

Ankit Jhille

Ramakant Kumathe

BSES Yamuna Power Ltd. Team:

Mukesh Dadhich

Sunil Kumar Sharma

Meenu Mishra

Sandhya Srivastava

Keywords: Demand Response, Demand Flexibility, BYPL, AEEE

Acknowledgement:

We extend our special thanks to BSES Yamuna Power Ltd (BYPL) and Schneider Electric for their partnership, collaboration, and support for this study. In addition, the authors would like to acknowledge Mahesh Patankar of MP Ensystems, and Satish Kumar from AEEE for reviewing this report and providing valuable comments.

Designed by:

Tanuj Joshi, Executive (Graphics and Video)
Himanshu Sharma, Senior Executive in Graphics and DTP Design

Copy editing:

Dinesh

Key Points

- **Enhancing Grid Reliability via Automated Demand Response (ADR):** Demand Response can play a pivotal role in reducing peak electricity demand, alleviating network congestion, and enhancing grid reliability, particularly in heat-stressed regions like Delhi. Automating the demand response process can further boost the effectiveness of demand response efforts.

- **Residential Sector Focus:** With around 60% of Delhi's peak electricity demand stemming from the residential sector, this segment can be the primary target for ADR programs in Delhi.

- **Notable Impact on Electricity Demand:** ADR can provide notable results, with demand reductions up to 78% (at 50 % co-incidence usage of ACs) during peak periods. Timing ADR events during high-demand periods, particularly in the summer, can enhance the effectiveness and benefits.

- **Benefits Exceed Costs:** Implementing ADR is economically viable, offering substantial benefits such as deferred capital expenditures for upgrading distribution infrastructure and reduced power procurement costs. The payback periods can range from 1.2 to 3.6 years for different co-incidence factors of AC operation.

- **Customer Engagement is Critical:** The success of ADR hinges on increasing awareness about financial and environmental benefits among participants and promoting local community involvement to build trust and ensure participation in ADR. To ensure that demand response programs are financially attractive and scalable, it is crucial to design attractive incentives that incorporate load reduction performed by customers into account.

- **Policy and Regulatory Support Can Play a Key Role:** The availability of regulatory frameworks to support demand response is essential. This includes mandating demand response as a core resource, integrating it into resource adequacy strategies, and incorporating it into long-term power planning.

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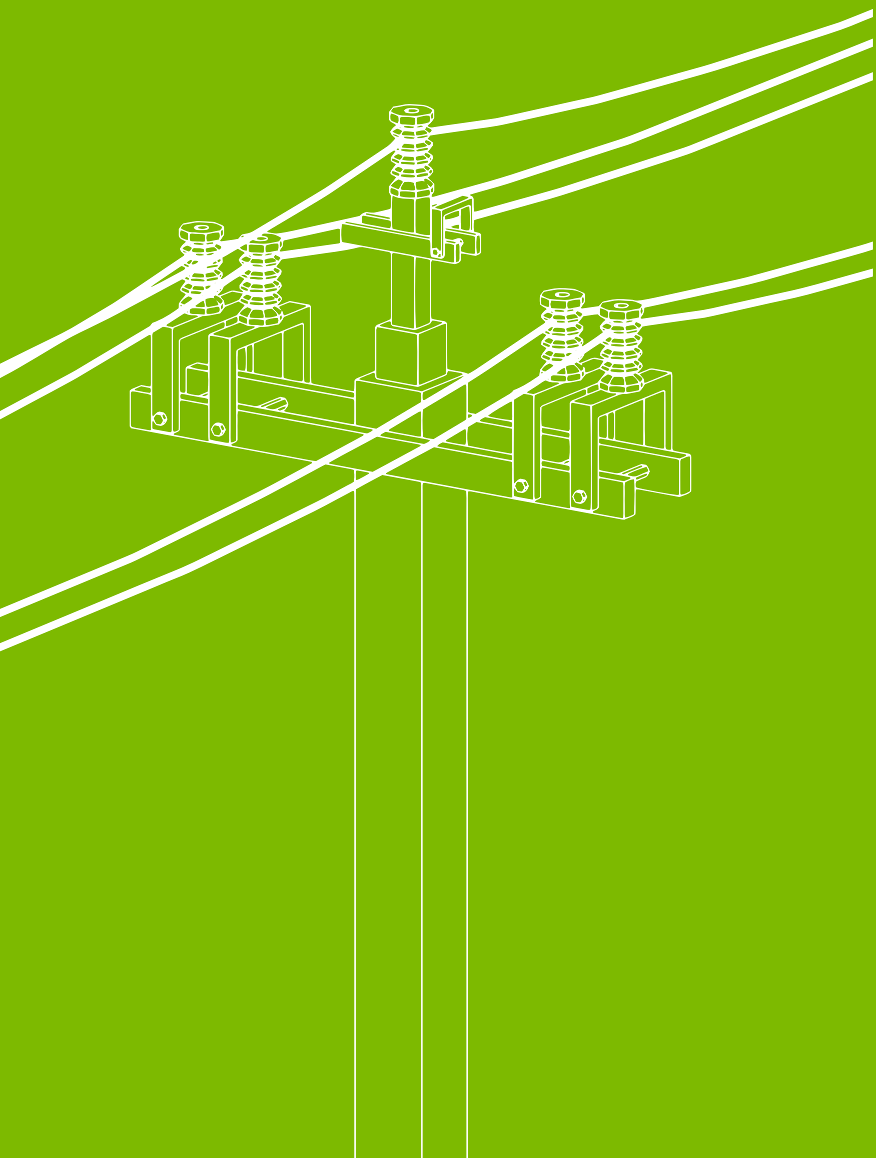
Introduction



As a tropical country, India experiences very high temperatures and heat waves in the summer. During this time, northern India suffers from extreme heat, with many cities witnessing temperatures exceeding the 50-degree Celsius mark, pushing the resilience of millions of people to the brink [1]. The impact of heat stress is particularly severe in densely populated urban areas like Delhi, which experienced an unprecedented 32 days with temperatures exceeding 40˚C during the summer of 2024—the highest number of such days in the past 14 years [2]. With the average temperature expected to rise by 2.4-4.4 degrees Celsius in India by 2100, the impact of heat stress is only likely to intensify, leading to increased heat-related illnesses, deaths, and disruptions to daily life [3]. The effect is also evident from the increase in Cooling Degree Days (CDD)—a metric used to measure energy demand for cooling—which is projected to rise in Delhi from 2,781 in 2017 to 2,960 by 2041[1], a stark reminder of the escalating threat [4].

Concurrently, India's economic growth and rising disposable incomes have led to improvements in living. This has translated into increasing demand for comfort and convenience, driving a surge in appliance ownership, notably air conditioners (ACs). As a result, electricity consumption is increasing consistently. For instance, Delhi's peak electricity demand grew at a compound annual growth rate (CAGR) of around 5% over the past decade, reaching approximately 8.6 GW during the summer of 2024 [5], [6]. This trend is expected to continue, with demand projected to reach 11.6 GW by 2028, driven primarily by a surge in residential AC usage [7].

A higher-than-anticipated demand can significantly threaten the reliability of electricity distribution infrastructure. The distribution system operates under stressed conditions to meet the peak demand as it operates above its design capacity, leading to deteriorated voltage profiles and overloading of distribution transformers, which leads to outages [8]. When a transformer fails, it can cause overload in the neighboring transformers, leading to their failure as well. This can create a domino effect, disrupting power supply to a large number of customers. Widespread power outages have serious economic consequences and disrupt essential services such as hospitals and transportation systems. The unpredictable nature of electricity peak demand, driven by diverse appliances and usage patterns, further complicates peak demand management. Additionally, the rising peak electricity demand forces power Distribution Companies (DISCOMs) to enter into agreements or invest in additional generation, transmission, and distribution infrastructure, which is capital-intensive and remains underutilized for most of the year.

1.1 Need for Automated Demand Response (ADR)

To manage peak demand, DISCOMs often procure power from real-time markets, subject to price volatility and uncertainty, especially during peak demand conditions, which incur higher power procurement costs. The situation is expected to worsen in the evening, mainly due to the non-availability of sufficient renewables to support the grid [9]. According to a report from India Energy and Climate Center (IECC), despite the planned completion of all ongoing thermal and hydro capacity projects, India could face significant evening power shortages between 20-40 GW due to the non-availability of electricity generation from solar [9].

An effective strategy for reducing peak demand is through the implementation of Demand Response (DR) programs. These programs can be broadly categorized into three main types: Manual, Behavioral, and Automated. In comparison to manual or behavioral DR, Automated Demand Response (ADR) can regulate electricity demand by utilizing automated technologies (such as smart sensors, control systems, communication technologies, and metering). It can improve the delivery of demand response by providing

1 A cooling degree day is a measurement designed to quantify the demand for energy needed to cool a building. It is the number of degrees that a day's average temperature is above 65˚ Fahrenheit (18˚ Celsius), which is the temperature above which buildings need to be cooled.

a signal to initiate predetermined operation sequences, such as HVAC control, to reduce a facility's electrical demand. Therefore, ADR systems can respond more quickly and be more precise in their energy reduction, which can be advantageous in situations where response time for demand reduction is critical. The most significant benefit of ADR is that automation increases customer convenience to participate in a DR program. The DISCOMs' skepticism about relying on customers' behavior to manage grid stability is also addressed as automation makes the solution reliable and controllable, like other supply-side resources. The additional benefits of ADR are listed below.

Reduce Grid Congestion: Due to higher reliability, ADR can quickly reduce instances of grid congestion/ instability. It can also be an impactful solution for incorporating higher renewable penetration.

Deferred Cost on System Upgrade: By reducing peak demand/and network congestion, ADR can allow existing infrastructure to cater to the same customer base without investing in network upgradation, which saves substantial costs. Moreover, due to a higher certainty level, ADR can provide multiple utility benefits, including deferred infrastructure costs and improved system operations.

Reduced Cost of Power Procurement: By reducing peak demand, ADR can reduce power procurement cost, which is usually high during peak demand hours.

Incentive to Participating Customers: Customers participating in the ADR program provide demand reduction to DISCOMs. In response, customers can receive incentives and rebates on their electricity bills according to the demand reduction provided by them.

In India, numerous pilot projects have been conducted to demonstrate the impact of DR. These pilots aim to minimize peak demand and control deviation settlements to ensure that supply matches demand in real-time[2], employing either manual, behavioural, or automated approaches, with each utilizing distinct strategies and technologies to optimize peak demand[3]. The early pilots primarily targeted commercial and industrial (C&I) customers due to their high load reduction potential and relative ease of program implementation and administration. However, due to cross-subsidization, the electricity tariff for residential customers in India is lower than that for C&I customers, which reduces DISCOMs' fear of revenue loss associated with the implementation of DR. As a result, more recent pilots have increasingly focused on residential customers. Additionally, factors such as the residential sector being the largest customer base and the increasing adoption of energy-guzzling appliances, such as air conditioners, in homes have further driven this shift.

2 In an electricity system, deviation settlement refers to the process of resolving discrepancies between the scheduled (or forecasted) electricity generation or consumption and the actual electricity generated or consumed by Distribution Companies. It is critical in the electricity distribution system, as it helps maintain balance and stability in the power grid.

3 A manual approach to demand response includes human intervention. The behavioural methods typically motivate customers to voluntarily adjust their energy usage during peak hours, often through incentives or information-based strategies. Automated approaches use advanced technologies, such as smart thermostats and automated load control, such as direct controlling of appliances enabled by add-on controls or incorporating DR-enabled controls in the design of appliances, to manage energy consumption dynamically without requiring direct customer intervention.

Furthermore, in recent times, DR has also received support through various regulations, policies, and planning documents. For instance, in 2024, Maharashtra notified the Demand flexibility regulation, and Assam has published a draft demand response regulation for public comments, which specifically includes elements like peak demand reduction target, program design, communication standard, and monitoring of DR programs. Figure 1 summarizes the long developmental journey of demand response in India.

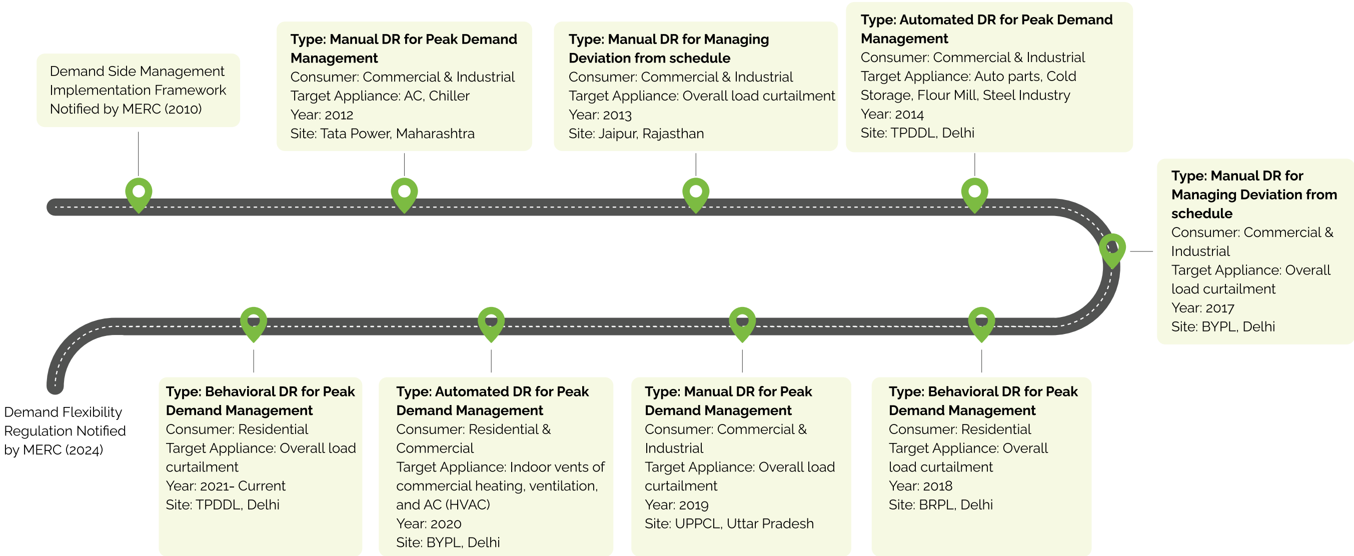


Figure 1: Overview of Demand Response in India: From Policy Formulation to Pilot Implementation

Source: Roadmap for Demand Flexibility, AEEE

Note: Tata Power DR program in 2012 was the only DR pilot approved by the regulatory commission

Among various DR methods, ADR pilots have consistently shown superior effectiveness in reducing demand. This is primarily because ADR encourages customer participation without requiring manual intervention from customers, thereby enhancing customer satisfaction. For instance, an ADR pilot in Delhi achieved close to 50 % customer participation, with a load shed potential of approximately 12 MW and a maximum shed of 7.2 megavolt-amperes (MVA) [10].

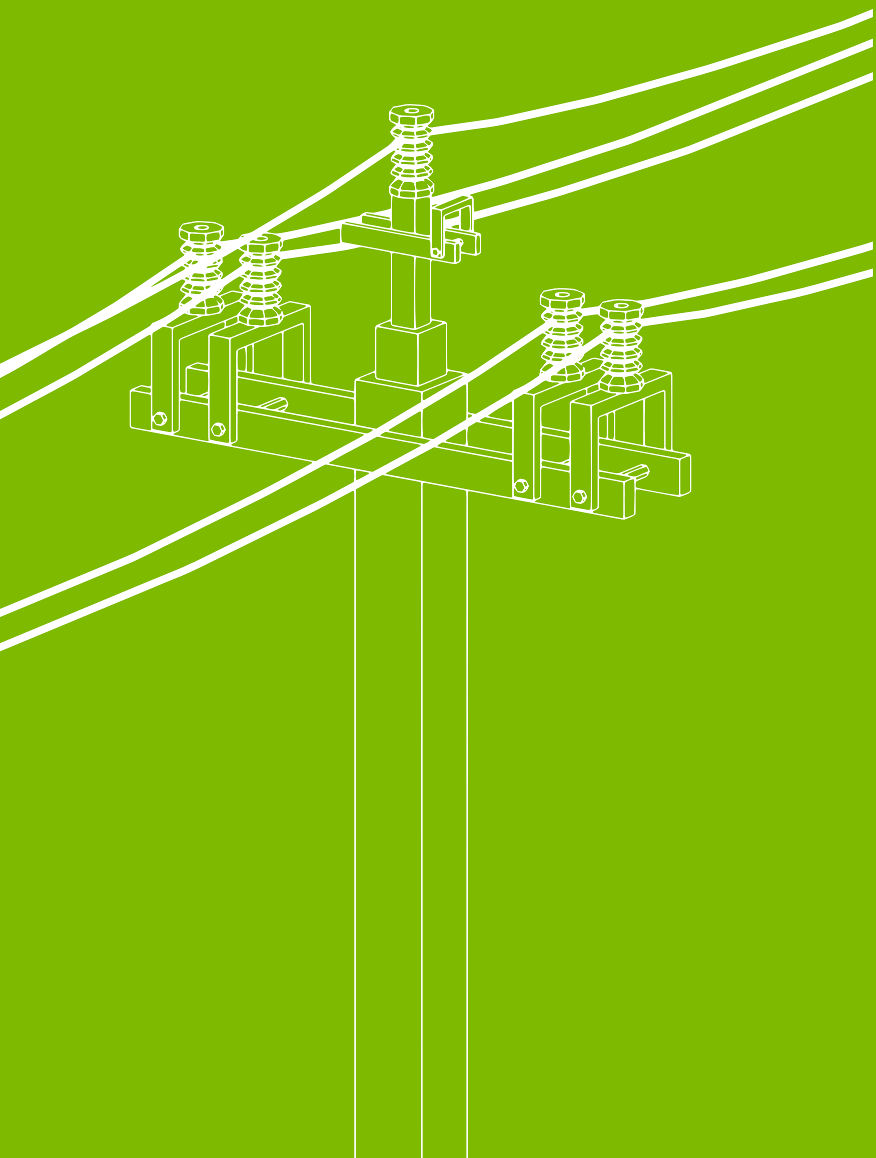
1.2 Significance of ADR in Residential Sector

In Delhi, residential customers account for approximately two-thirds of the total electricity consumption. The residential demand contributes to about 60% of the city's peak electricity demand, with roughly half of the residential electricity demand driven by cooling requirements. [11]. According to the Multiple Indicator Survey (2020-2021), 32% of Delhi's 35,46,200 households have access to air conditioners, amounting to 11,34,784 households with AC penetration [11]. Air conditioners have become the preferred cooling solution in the city, with the number of AC units projected to increase to 4.6 million by 2030 [7]. A large residential customer base in Delhi, along with higher AC ownership (around 33%), significantly acts as a powerful catalyst, amplifying the intensity of these evening peaks. As a result, peak residential peak demand is expected to reach 4.5 GW by 2030, with 2.5 GW (approximately 56%) coming solely from air conditioners [7]. This surge will be primarily driven by the higher use of ACs during evening hours when residents return home, leading to a spike in electricity demand. As a result, residential customers have become the most critical target group for DR programs aimed at peak electricity demand in Delhi.

CHAPTER

02

Implementation of Pilot



In May 2023, Schneider Electric and BSES Yamuna Power Limited (BYPL) initiated an ADR pilot in Delhi. Alliance for an Energy Efficient Economy (AEEE) conducted the analysis and compiled the findings from the pilot.

The pilot was implemented in the four residential societies in Delhi. The selection of societies was performed based on the following criteria:

1. Most of the customers in selected societies own at least an AC and a refrigerator unit.
2. Availability of Wi-Fi networks in households and the participants' willingness to install a gateway device for the automatic control of household appliances.

The pilot tested a cluster-based Demand Response (DR) strategy by focusing on a specific cluster— in this case, a single society— and targeting selected appliances. This approach allows for precise control over peak demand reduction within a specific area, enabling targeted and efficient demand response. Although the pilot employed a cluster-based DR strategy, it didn't use data on transformers loading during the cluster selection process. An illustrative visual representation of cluster based, targeted, surgical DR implementation is presented in Figure 2.

Figure 2: Implementation of ADR can enable targeted and precise demand response

Source: AEEE's modifications on the Redalyc journal image, the transformers indicated in "red" are overloaded where ADR can be utilized to relieve the stress on overloaded transformers by ring-fencing the DR for customers affecting the overloaded transformers.

The pilot began in June 2023 and was fully implemented by October 2023. In total, 48 households from four residential clusters (societies) participated in the pilot. The customers were provided with load interruption devices for selected appliances (mostly ACs), allowing for remote control of these appliances' power status (ON/OFF) (also called DR events). Although, there are multiple communication technologies, such as Wi-Fi, PLC and RF mesh, the pilot particularly tested appliance-level DR intervention using Long-Range communication technology (LoRA). The solution architecture for DR implementation is presented in Figure 3.

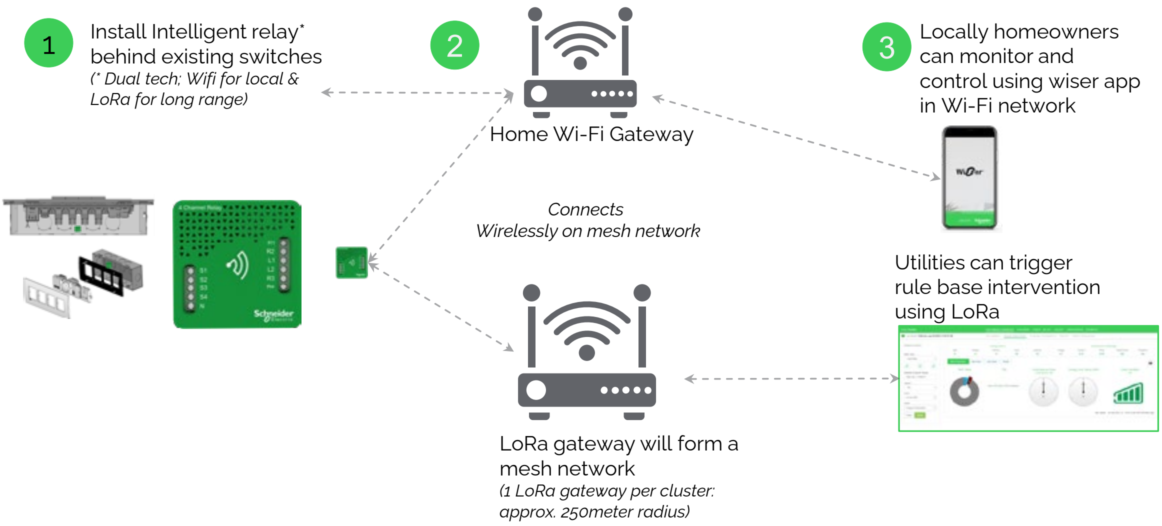


Figure 3: Architecture of the solution implemented in ADR pilot in BYPL

Source: Schneider Electric

The LoRA technology was preferred as it provides wide area coverage (extended range) with minimal infrastructure and power consumption. It offered connectivity through a long-range communication gateway. While, LoRA supported triggering the ADR event, Wi-Fi was still used to provide network connectivity for data collection and storage on the server. A snapshot of LoRA system installed at AC unit is illustrated in Figure 4.

Figure 4: LoRa system installed on the customer's air conditioning unit

Note: The device employed for the ADR event was retrofitted, with all wires and components being encapsulated following installation.

Source: Schneider Electric

In the pilot, DR events were carried out across the months. The number of such number of such events is listed in Table 1, and the sample of events triggered in October 2023 are listed in Table 2.

Table 1: Overview of ADR events during the pilot

Month	June	July	August	September	October
No. of DR Events	5	11	3	6	18

Table 2: Sample of events triggered in October 2023

Date	DR event start time (on command)	DR event end time (off command)
02-10-2023	8:33 pm	8:48 pm
03-10-2023	4:45 pm	5:02 pm
04-10-2023	3:59 pm	4:18 pm
05-10-2023	4:02 pm	4:18 pm
05-10-2023	1:59 pm	11:17 pm
06-10-2023	3:58 pm	4:19 pm
06-10-2023	10:59 pm	11:16 pm

Source: Schneider Electric

2.1 Methodology for Assessing Pilot Impact

Assessment of the the exact impact of ADR requires a robust and rigorous evaluation. Establishing the baseline is key to determining the true impact of ADR. Three distinct methodologies – Spot Reduction, High X of Y (HXY), and Last of Y (LOY) – were utilized to assess the baseline for measuring the effectiveness of ADR programs [12]. These three methods are discussed in detail below and visually represented in Figure 5:

High X of Y (HXY) Method for Baseline Estimation: The HXY method uses a historical period of Y non-DR (Demand Response) days before a DR event to establish a baseline. The baseline is calculated by averaging the demand of the historical X days with the highest consumption within the selected Y days. For the analysis, the "High 2 of 5" approach (the two highest demand values from the last five selected days) is used to estimate the customer's baseline demand profile during the DR event. The choice of five days as the historical period is intended to allow for the inclusion of more DR events in the analysis.

Last of Y (LOY) Method for Baseline Estimation: The LOY method estimates the baseline by averaging the demands at the relevant timestamps over the entire Y non-DR days in the historical period. The assessment uses the average demand from the last five non-DR days to develop the baseline demand profile**.**

Spot Demand Reduction: The Spot Demand Reduction method quantifies the impact of ADR by measuring real-time demand changes. For instance, if the DR event begins at 12:15 PM, this method evaluates the ADR impact by comparing difference in average demand (X - Y) and peak demand (M - N) for the 15-minute periods immediately before and during the DR event.

High XofY (HXY) method for baseline estimation

Day	Timestamp	Demand (kW)	Sorted Demand (kW)	High 2of5
Day 1	00:01 min	1	1	-
Day 2	00:01 min	4	2	-
Day 3	00:01 min	2	3	-
Day 4	00:01 min	3	4	4
Day 5	00:01 min	5	5	5

High 2of5 = (4+5)/2 = 4.5

Last of Y (LOY) method for baseline estimation

Day	Timestamp	Demand (kW)
Day 1	00:01 min	1
Day 2	00:01 min	4
Day 3	00:01 min	2
Day 4	00:01 min	3
Day 5	00:01 min	5

Last of 5 = (1+4+2+3+5)/2 = 3

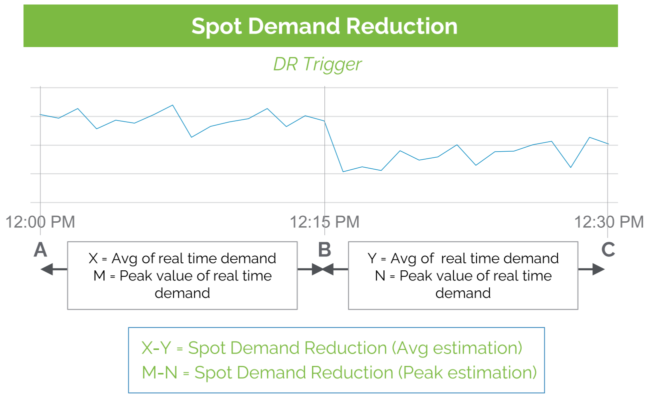


Figure 5: Methodology for assessing ADR impact: Spot Demand Reduction, HXY, and LOY methods

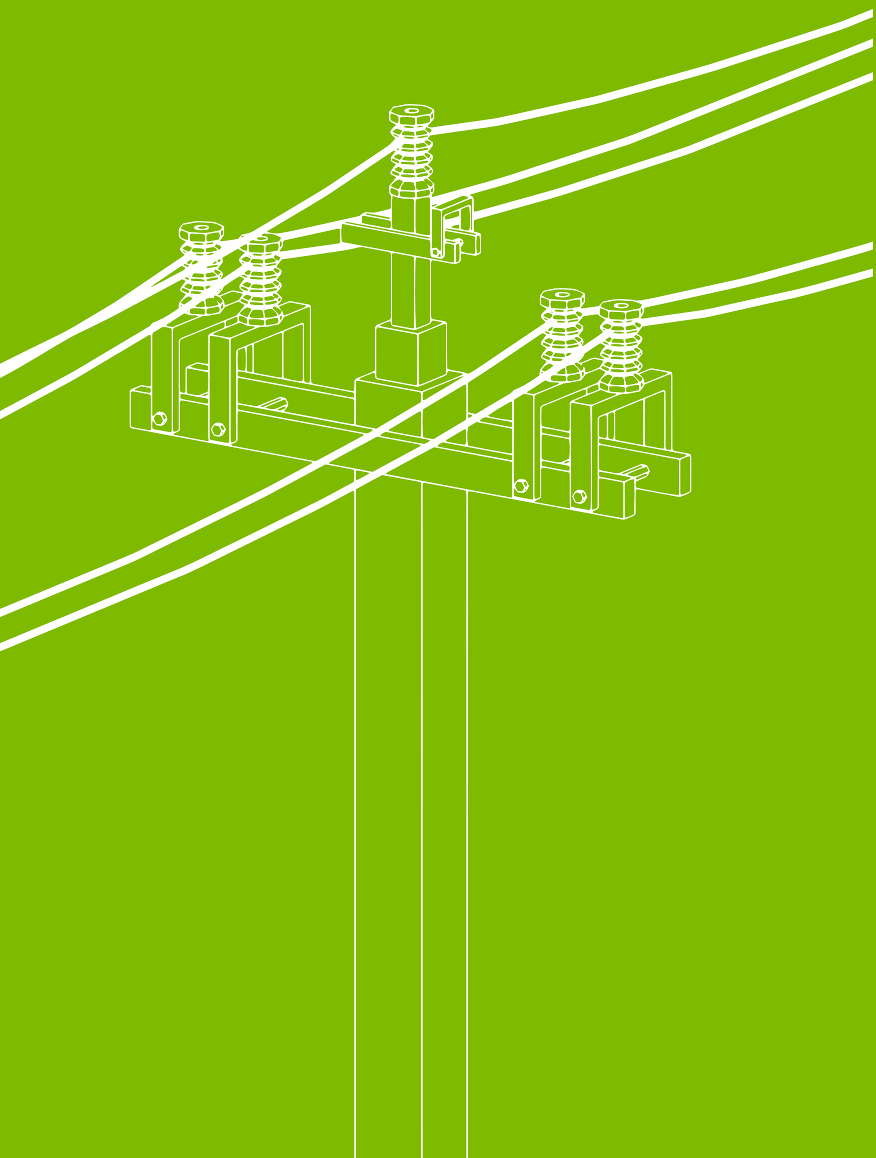
Source: AEEE's Visualization

These methods are well-established in the literature and have been mentioned in international practices. The practical examples of the High X of Y baselines used in the global market are High 10 of 10 in CAISO, High 5 of 10 in NYISO, High 15 of 20 in IESO, and High 4 of 5 in PJM [13]. Generally, a High 5 of 10 and a High 4 of 5 are among the most used methods for assessing the impact. However, due to a small sample size leading to data limitations, the effect has been estimated using other established methods (for e.g. High 2 of 5 for an optimistic baseline and Last of Y for a conservative baseline).

CHAPTER

03

Key Insights from the Pilot



To understand the impact of the ADR program, the analysis covered seven events in October across a cluster of 30 customers. AEEE's analysis, which utilizes three distinct methodologies – Spot Reduction, High X of Y (HXY), and Last of Y (LOY), reveals the following demand reduction potential:

Spot Reduction analysis demonstrated peak demand decreasing by 9% to 35% during DR events, translating to a reduction of 1 kW to 5 kW.

HXY analysis further emphasized the program's effectiveness, showing an average and maximum demand reduction ranging from 16% to 56% (equivalent to 2 kW to 10 kW).

LOY analysis also indicated demand reductions, albeit with a slightly lower range of 0.5% to 38% (equivalent to 0.05 kW to 5 kW).

These findings, summarized in Table 3, provide evidence of the effectiveness of the ADR program in curbing electricity demand during peak periods.

Table 3: Demand Reduction Potential for a Cluster of 30 Customers for October

Method	Demand reduction	
	Average	Maximum
Spot demand reduction (Peak Demand Comparison)	9 % (1 kW)	35% (5 kW)
Spot demand reduction (Average Demand Comparison)	11 % (1kW)	28 % (2 kW)
Peak demand reduction (via High X of Y method)	16 % (2kW)	56% (10 kW)
Peak demand reduction (via Last of Y method)	0.5 % (0.05 kW)	38 % (5 kW)

Source: AEEE Analysis of Data shared by Schneider

Analysis highlights that the reduction in electricity demand, as calculated using the Spot Demand Reduction method, ranges from 1 to 5 kW for the entire cluster (or an average of 0.03 to 0.16 kW per connected customer). The assessed demand reduction is minimal due to decreased/no use of air conditioning during October, and demand reduction achieved is mainly from refrigerators in operation. Therefore, a simulated case was developed to evaluate the potential benefits of an ADR program during peak summer months. With high-power-rated appliances, such as ACs in operation.

3.1 Impact of ADR During Peak Summer Months with High AC Usage

To estimate the demand reduction potential in peak summer months, a simulated case is developed by generating the demand profile of the cluster. Towards this, 30 diverse demand profiles were generated using ±10% variation at each timestamp in the modified demand profile. To estimate HXY and LOY baselines, diverse historical demand profiles for five days were generated using the cluster's demand profile, maintaining a ±10% variation at each timestamp. As all the customers at the cluster may not be operating their air conditioners during the DR event, the analysis considers AC operation to be in the range of 20 % to 50 %, respectively.

The analysis highlights that the spot demand reduction for the cluster during the ADR event ranges from 8 kW to 22 kW. The spot reduction in average demand during the event is 9 kW to 21 kW. The average per customer's spot electricity demand reduction in the case of significant ACs in operation at 20% co-incidence use is 0.3 kW. Furthermore, the electricity demand reduction estimated using the HXY method for the 20% to 50 % range of co-incidence AC use is from 10 kW to 24 kW, while the reduction assessed using the LOY method ranges from 9 kW to 23 kW. A summary of the demand reduction assessment for simulated cases of ACs operation during the peak summer months, calculated using various methods, is presented in Table 4.

Table 4: Summary of Potential Demand Reduction for a Cluster of 30 Customers with High AC Usage

Method	Peak Demand reduction (in %) & kW	
	20% AC operation	50% AC operation
Spot demand reduction -Peak assessment	53% (8 kW)	74 % (22 kW)
Spot demand reduction -Average assessment	60 % (9 kW)	78 % (21 kW)
Peak demand reduction (via High X of Y method)	57 % (10 kW)	76 % (24 kW)
Peak demand reduction (via Last of Y method)	55 % (9 kW)	75 % (23 kW)

Source: AEEE Analysis of Data shared by Schneider

3.2 Scaling the ADR Program: Estimated Impact on Peak Demand

Analysis of BYPL DISCOM's demand requirements reveals that it faced an additional electricity demand of 192 MW for just 88 hours during 2022-23. The distribution infrastructure developed to fulfill this additional demand remains underutilized 99% of the year. In this context, widespread customer participation in ADR becomes essential to effectively reducing DISCOM's peak demand. Therefore, an analysis is performed to estimate the overall number of participants required to mitigate this demand via an ADR program at 20% and 50% AC operation scenario. The results from the analysis are presented in Table 5.

Table 5: Total number of residential ACs required for a 192 MW demand reduction

Desired Demand Reduction (MW)	ACs Co-incidence Operation (in %)	Average Electricity Demand Reduction	Required ACs to Enroll in ADR Program
192	20	0.3 kW / AC (at 20% co-incidence use)	6,40,000
192	50	0.75 kW / AC (at 50% co-incidence use)	2,56,000

Source: AEEE's Analysis

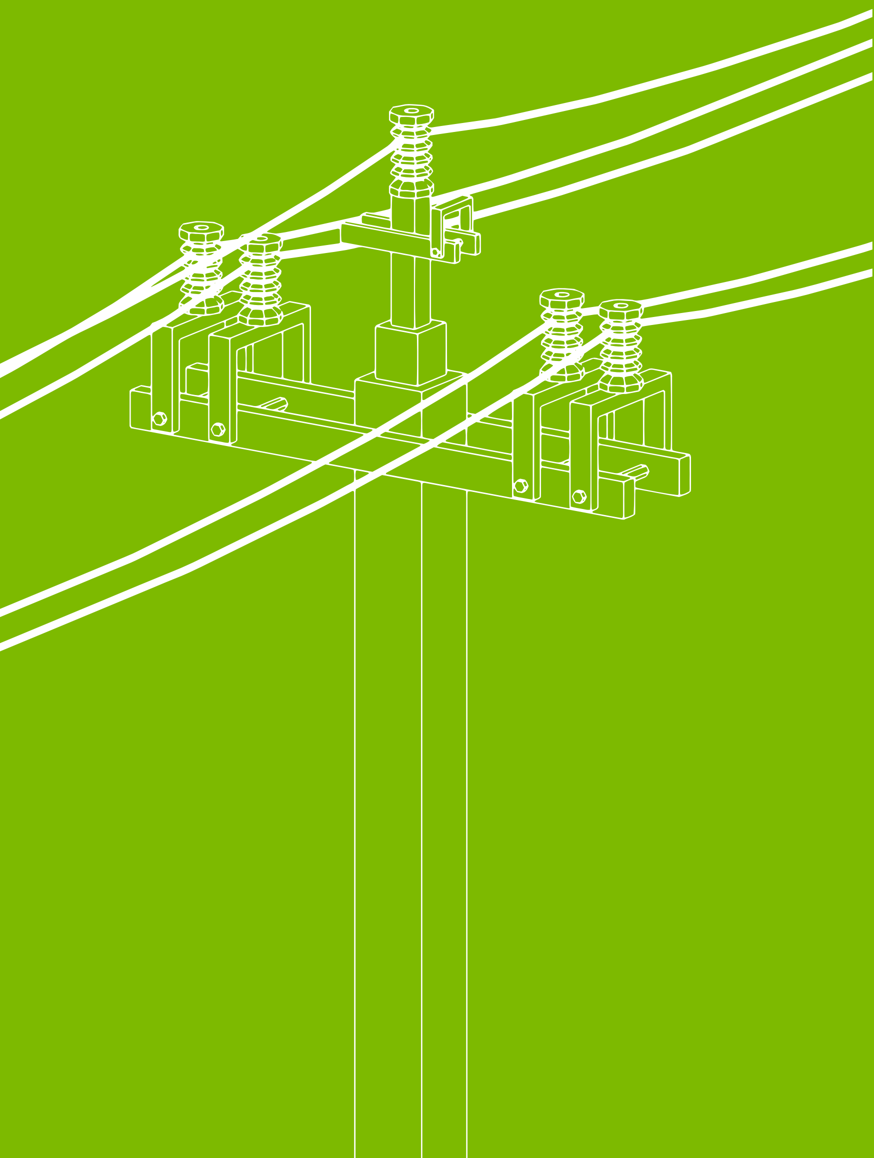
In practice, the actual number of ACs required to achieve the desired demand reduction could be less due to the high co-incidence use of ACs during peak demand hours. Moreover, targeting areas that experience high transformer overload and have high co-incidence use can further increase the effectiveness of ADR.


Customer participation for system level impact via AC

CHAPTER

04

Cost-Benefit Assessment of ADR Implementation



The recently released Maharashtra Electricity Regulatory Commission's "Demand Flexibility and Demand Side Management—Implementation Framework, Cost-effectiveness Assessment; and Evaluation, Measurement and Verification" regulation stipulates that any demand-side management activity must evaluate the Total Resource Cost (TRC) test as the primary hurdle test for implementing a demand response program [14]. The TRC test is carried out by calculating the Benefits and Costs of the program. A program is considered beneficial when the Benefit to Cost ratio exceeds 1.

The benefits of the ADR program include financial savings from reduced peak demand and lower power procurement costs. The costs associated with these programs include expenses related to program design, the acquisition of ADR hardware, and ongoing operation and maintenance, and cost of Measurement and Verification (M&V) for verifying actual demand reduction performed by customers.[4] Table 5 provides a detailed overview of the cost and benefit streams.

Table 6: Parameters of benefit and cost streams for the cost-benefit analysis

Benefit Stream	Cost Stream
Reduction in Peak Demand	Upfront capital cost on ADR hardware and software / Annualized capital cost on ADR hardware and software
Savings in Expensive Power Purchase	Annual Fixed Operation & Maintenance
Savings in Capex Deferral on additional Distribution Infrastructure	Annual Incentive/Reward payout to customers for
Savings in O&M and Breakdown Cost	Program Design Cost (Studies and Approvals)
Savings in DSM deviation Charges	Cost of Measurement and Verification

Source: AEEE's Compilation of Information

4.1 Estimation of Benefits from Large Scale ADR Program

To assess the cost incurred vis-a-vis benefits that can be achieved from a large-scale ADR program, we performed an analysis, which involves 50,000 participants households (or ACs) with an average household consumption of 305 kWh/ month, 3 kW sanction load, and AC coincidence use in the range of 20% to 50%. The analysis highlights an annualized cost of around 8.4 crores compared to a yearly benefit of INR 15.6 crore at 50 percent co-incidence use of AC[5]. The result from cost and benefit analysis at co-incidence of 20 – 50 percent is illustrated in Table 7.

Table 7: Customer enrollment and capital expenditure of ADR Program at different levels of AC's coincidence usage

No. of ACs	Co-incidence use of AC	Upfront Capital Cost (Cr.)	Annual Benefits (Cr.)	Annual Operational Cost (Cr.)	Payback Time (in years)
50,000	50	12.6	15.6	5.2	1.2
50,000	30	12.6	10.2	4.3	2.2
50,000	20	12.6	7.4	3.9	3.6

Source: AEEE's Analysis

Note: Annual operational cost includes O&M cost, Incentive payout, and revenue loss to DISCOMs due to implementation of DR

4 Analysis uses information like debt-to-equity ratio of 70:30, nominal interest rate of 9 %, and distribution infrastructure expenditure of 2.5 crore/MW. The analysis is conducted at customer participation of 50,000 at ADR device and software costs of INR 2500 per device, respectively. The additional input parameters used in the model are attached in Annexure A.

5 Coincidence Use- It refers to the simultaneous utilization of resources, such as electrical appliances, by multiple users at a given time. It is often used to evaluate the contribution of appliances (e.g., air conditioners, geysers) to peak demand.

A breakdown of the annualized benefit and cost for an ADR program at a 50% coincidence use is illustrated in Figure 6.

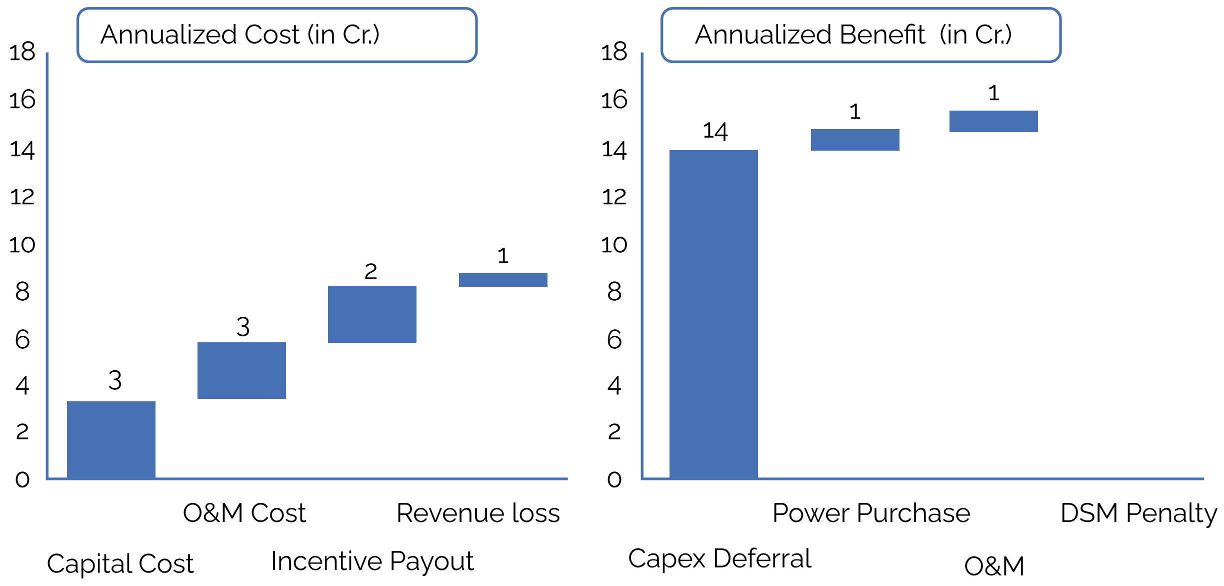


Figure 6: Annualised Cost and Benefits of an ADR Program

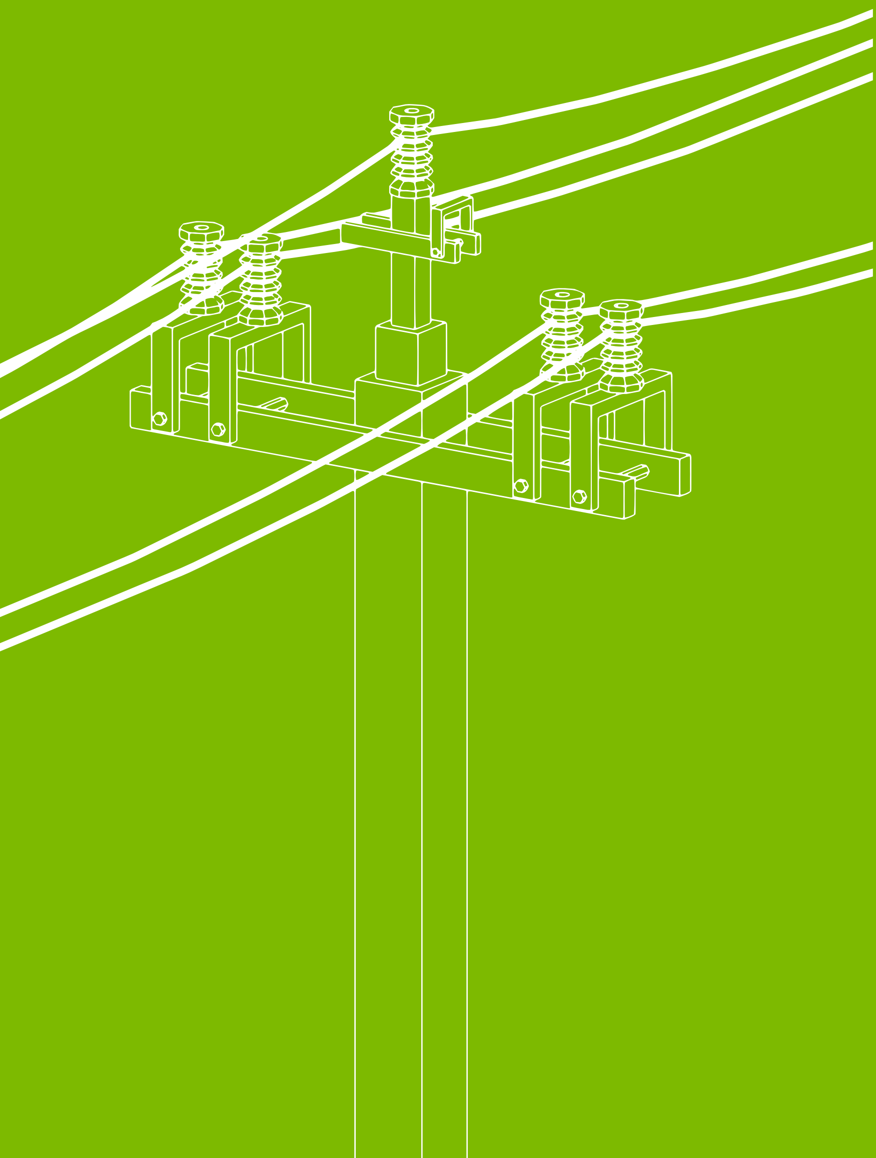
Source: AEEE's Analysis

The analysis of the various cost and benefit components further reveals that while the primary cost arises from capital expenditures on the infrastructure required to implement ADR, the deferred capital costs for distribution infrastructure contribute significantly to the benefit. The analysis shows that the project is also economically viable at a low coincident usage of 20%, with a payback period of about 3.6 years for a project life of 5 years. A more detailed breakdown of the contribution of various components in cost and benefit is attached to Annexure B.

CHAPTER

05

Stakeholder Perspectives and Insights on ADR Implementation



An effective demand response program reduces peak demand without impacting the customer's service quality. It becomes more critical, especially in the case of ADR, as it intervenes in appliance operation. Therefore, to collect participant customers' experiences, perceptions, and attitudes concerning ADR, a series of interviews and discussions with customers and utilities were conducted through one-to-one and focused group discussions. The summary of the insights from customer engagement is presented in the subsequent section.

5.1 Insights from Customer Interaction

The customers' experiences with demand response were captured through one-to-one and group interviews to better understand the barriers to broader ADR and to suggest strategies for enhancing program effectiveness and engagement. The insights gathered from these customer interactions are illustrated in the table below:

Maintaining Customer Comfort	Most of the customers reported a minimal impact on thermal comfort due to demand response, with some even failing to notice the occurrence of the ADR event itself.
A need of Awareness Creation	A few customers expressed unfamiliarity with the benefits, goals, and environmental impact of DR program. In lack of communication, customers perceive a program as merely a DISCOM-led effort to manage electricity supply and demand rather than an opportunity for households to contribute toward sustainability.
Need for Financial and Environmental Initiative	Many customers reported monetary incentives are essential to attract participation in ADR programs. However, monetary rewards alone are not compelling enough reasons for households to participate actively in these programs.
	Interlinking ADR with broader values, such as sustainability and social responsibility, can yield long-term benefits as customers mentioned their willingness to support initiatives that align with their personal values, especially related to environmental conservation and community well-being.
Multi strategy for Onboarding Customers	A multi strategy is important to implement the ADR program at a more significant level with a diverse set of customers. For instance, promoting the economic benefits of ADR to budget-conscious customers while highlighting the environmental impact on eco-minded households can make the message more relevant to diverse segments.
	Attractive financial incentives can help onboard cost-sensitive customers or customers already inclined toward participating in energy programs. It can serve as an initial hook to get customers involved, that encourages them to try out the program.
	Integrating ADR programs with local sustainability efforts or community-focused projects can appeal to socially conscious customers.
Customer Feedback is Important	Frequently seeking feedback and making adjustment based on customer experiences can help ensure that demand response programs remain relevant and effective to customers. A continuous improvement approach can foster a sense of ownership and partnership between utilities and customers.

5.2 Insights from Discussions with DISCOMs

Multiple discussions were conducted with DISCOMs to capture insights regarding the challenges and potential solutions associated with the implementation of DR programs. The conversation with DISCOM officials also shed light on why DR has not yet been fully embraced as a mainstream solution for demand management. The insight collected from the DISCOM interaction is discussed in the table below:

Regulatory Hesitation and Approval Bottlenecks	Despite numerous policy documents endorsing DR, acquiring regulatory and financial approvals for DR programs remains challenging.
	Regulatory bodies and DISCOMs often do not perceive DR as a reliable or effective means of managing electricity demand. This perception limits the willingness to approve DR-related expenditures.
Risk of Revenue Loss	DISCOMs see demand response as a threat related to revenue reduction due to lower energy consumption from customers participating in DR programs. However, higher power procurement prices during peak demand time can provide benefits to DISCOMs.
Low Awareness and Acceptance Among Customers	Awareness of DR programs is limited among the public, coupled with concerns regarding data privacy, discomfort during load reduction events, and skepticism about the tangible benefits.
	These customer concerns prevent widespread acceptance and participation in DR programs.
Narrow Assessment of DR Benefits	When evaluating the advantages of DR programs, authorities do not typically account for savings from capital expenditure (capex) deferral on infrastructure upgrades.
	This narrow assessment fails to acknowledge that DR can reduce the need for costly investments in new power infrastructure by efficiently managing existing demand.
High Initial Capital Requirements	Implementing DR requires a substantial initial investment in technology, such as automated systems and advanced metering infrastructure.
	These upfront costs are a significant barrier for DISCOMs, mainly when there is no assurance of cost recovery or revenue protection.

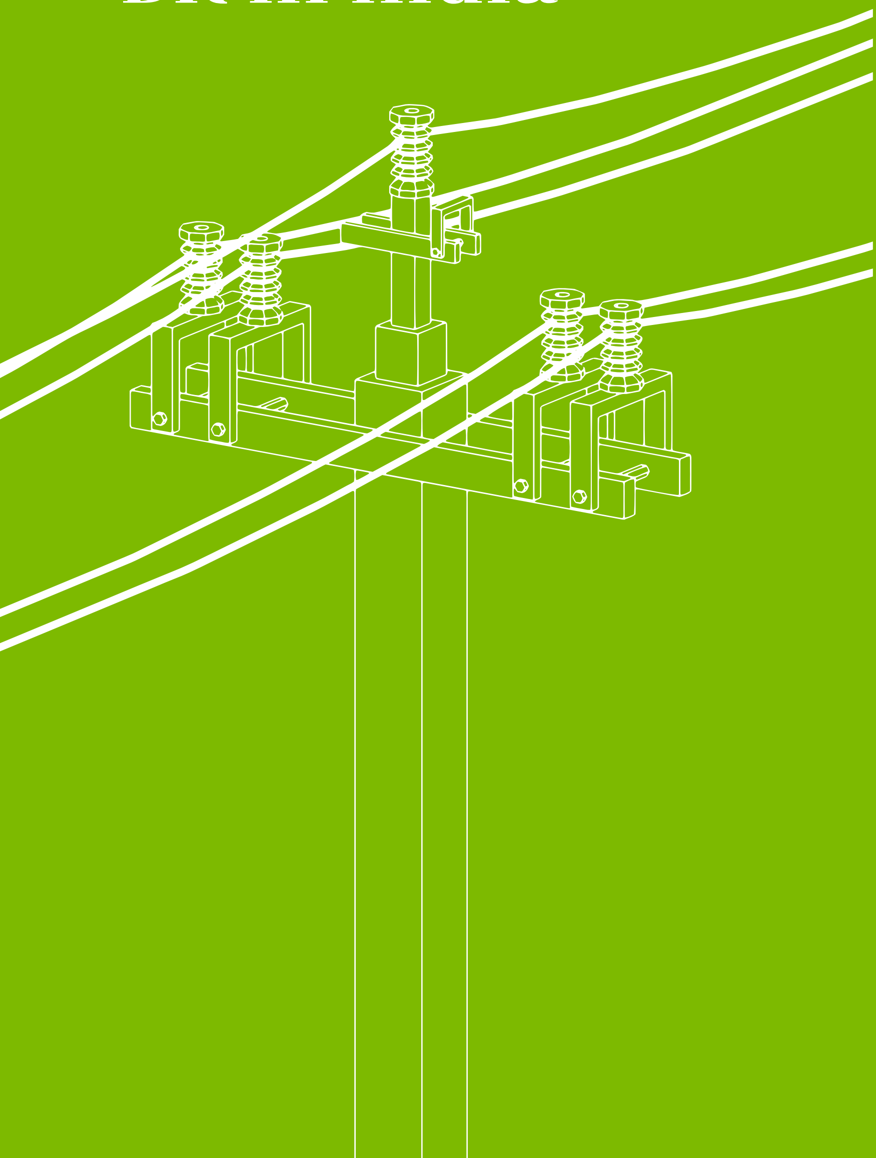
5.3 Learnings from the ADR Pilot

The pilot conducted offers multiple insights into the residential demand response. The Key learnings from this pilot include:

- **Identification of Optimal Season and Timing:** The timing and season for conducting ADR events significantly influence their effectiveness. For example, the events scheduled during periods of peak electricity demand (e.g., summer months for high air conditioner usage) can yield the most substantial demand reduction.
- **Prioritizing High-Impact Appliances:** High-power appliances (such as ACs) are major contributors to peak demand. By effectively managing the usage of these appliances during peak demand periods, DISCOMs can achieve significant load reduction.
- **Tailoring Interventions Based on Appliance Usage Patterns:** Appliance usage varies significantly by location within a household. For instance, living room ACs are used more during the daytime, while ACs in bedrooms are used more during the night. ADR strategies can be tailored to leverage these usage patterns, targeting appliances based on their location and aligning interventions with peak demand periods.
- **Local Engagement is Crucial:** The presence of local representatives is a significant factor in promoting program awareness, fostering consumer trust, and ensuring their successful onboarding. A community-focused approach can ensure that residents are well-informed, engaged, and more likely to participate in DR programs.

06

Conclusion and Strategic Recommendations for Scaling DR in India



India is facing the challenge of increasing extreme heat and rising electricity demand, particularly in urban areas, where air conditioning significantly contributes to peak electricity demand. As the country faces these challenges, Demand Response (DR) has emerged as a critical solution to mitigate the stress on the electricity grid. ADR programs have demonstrated significant capability in many pilots, showing their potential to manage demand more efficiently and reliably. However, despite these promising results, these programs have struggled to scale up to a larger level. Based on the experiences gleaned from ADR pilot, the following key recommendations can guide the effective expansion and integration of DR across India's electricity grid:

- **Mandating DR as a Resource to be Considered by Regulatory Bodies**: To effectively integrate DR into the country's energy mix, regulatory bodies, specifically at the state level, must recognize and mandate it as a resource alongside traditional power generation resources. There is a need to ensure that utilities factor in DR capabilities in long-term power planning processes.
  - **Approving Capex Deferral as a Recognized Benefit**: To promote DR, regulators should recognize the long-term savings associated with avoided capital expenditure (Capex), particularly the deferring costly grid infrastructure investments (including costs associated with generation, transmission, and distribution infrastructure development). Recognizing capex deferral will help to align the interests of multiple stakeholders for future grid development.
- **Targeted Approach to Demand Management**: A more targeted approach is necessary, tailoring DR strategies to specific local usage patterns and peak demand periods. For example, in areas where transformers are overloaded due to high air conditioning usage causing peak demand, DR initiatives could focus on shifting or reducing AC consumption during critical hours to alleviate the strain on the transformers in those specific areas/clusters.
- **Attractive Incentive Design**: To ensure that DR programs are financially attractive and scalable, specific incentives that incorporate load reduction performed by customers into account must be designed. Considering these, a good incentive amount, if identified, can motivate the customers to participate and perform load reduction actively.
- **Establishing a Market for Demand Response Aggregators Business in the Country:** Demand Response Aggregators are the entities registered with the Distribution Licensee to provide demand aggregation response services, such as assisting retail customers with strategies or technology to reduce their electric consumption and then bidding on those electric load reductions in retail or wholesale transactions. Aggregators could be crucial in balancing supply and demand by consolidating various flexibility resources, such as air conditioning, particularly during peak demand periods and grid emergencies, by dynamically adjusting consumption patterns. If schemes or programs are introduced to encourage market development of such aggregators, including ways to derisk them, various business models can emerge and operate. A few models are indicated in the Annexure C of this report.
- **Local Community Engagement**: Effective DR programs require strong customer engagement, especially at the grassroots level. Establishing local representatives to facilitate communication and customer engagement will help demystify DR and build trust.

- **Special Scheme by Ministry of Power (MOP) Focusing on DR/DF**: To accelerate the implementation and scaling of DR, the Ministry of Power (MOP) should introduce a dedicated scheme focused on DR and Demand Flexibility (DF), similar to the RDSS scheme to promote smart meter penetration. A specific scheme could provide targeted financial incentives, regulatory support, and capacity-building resources to encourage the adoption of DR technologies. Such a scheme would let DR reach its full potential, ensuring its widespread adaptation into India's energy landscape.

Overall, by mandating DR as a key resource in regulatory frameworks and integrating it with resource adequacy, designing attractive incentives for participating households, and implementing targeted schemes, India can scale up DR programs and enhance grid stability. A multi-faceted approach involving customer engagement, regulatory support, and community involvement will unlock the full potential of DR, enabling India to meet its energy needs sustainably and efficiently.

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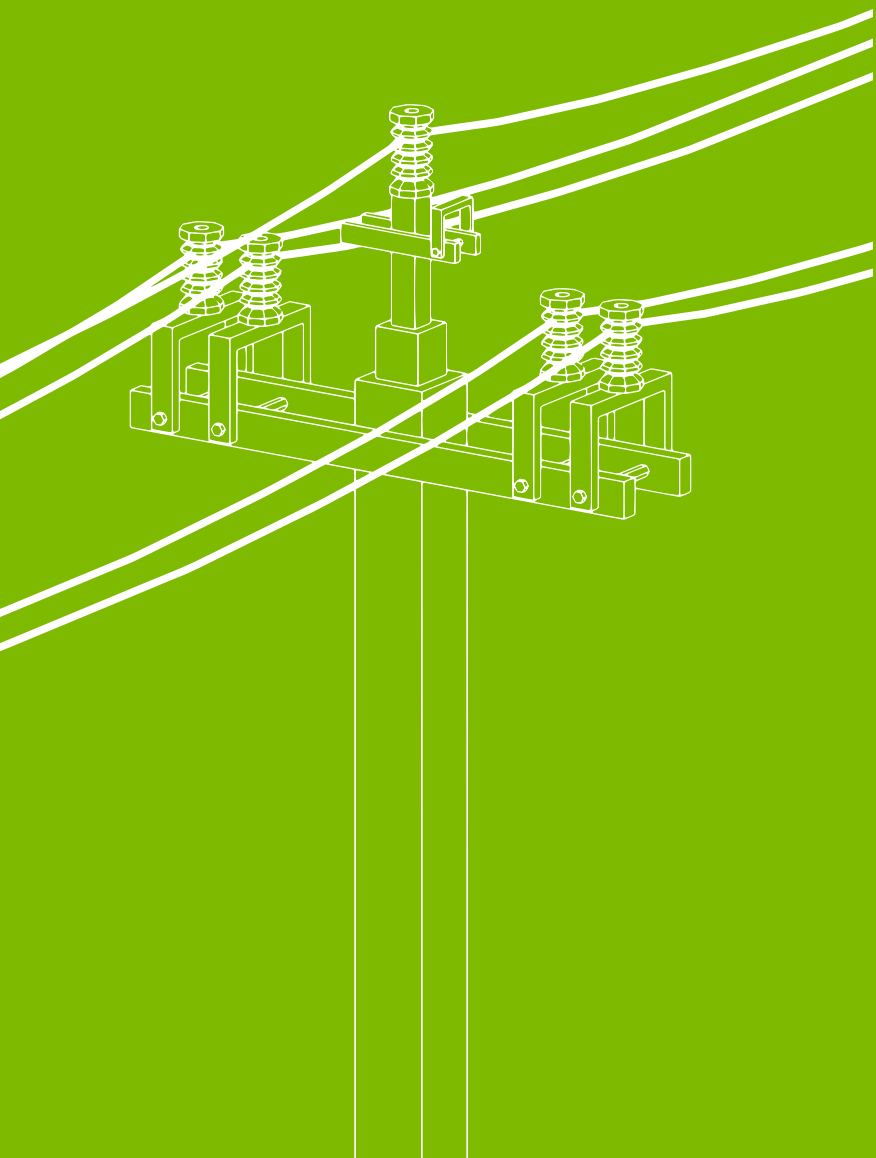

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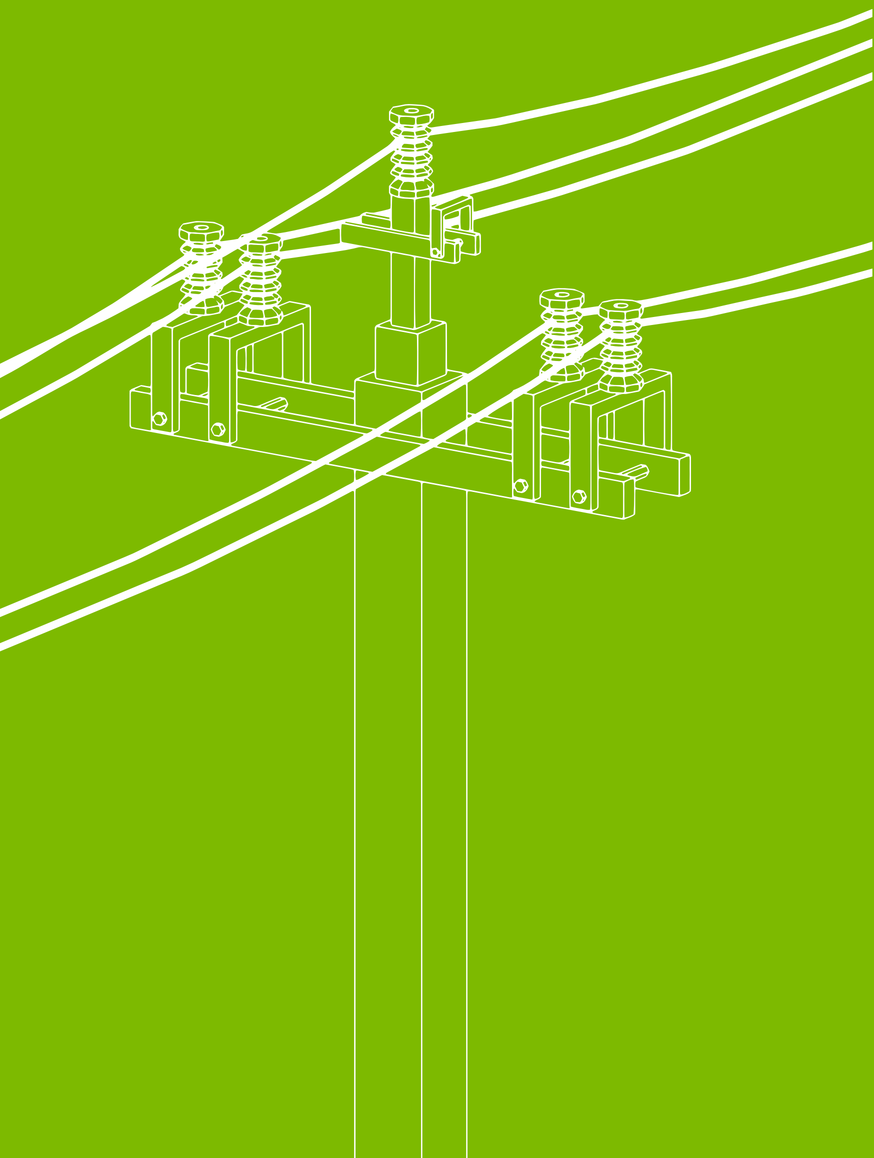
Annexures



Annexure A: Cost Assumptions for Hardware, Software, and Program Operations

Assumption	Assumption Value
Hardware & Software (Rs/customer)	2,500
Annual O&M Cost of Hardware & Software (% of total hardware and software cost)	5%
M&V (% of total software and hardware cost)	3%
Annual Operating Cost for Distribution Infrastructure (% of total distribution infrastructure cost)	5%
Annual Program Admin Cost including marketing, comms (Rs/customer)	300

Financial Assumption related to DR infrastructure

Project Life (years)	5
Return on Equity	13%
Nominal Interest Rate	9%
Equity	30%
Debt	70%
Tax Rate	30%
WACC calculated	8.3%

Annexure B: Breakdown of Costs and Benefits from the ADR Program for 50,000 Participants

Cost Components/ Benefit Component (in Crore) (INR)	AC coincidence usage 20%	AC coincidence usage 30%	AC coincidence usage 50%
Capital Cost	3.2	3.2	3.2
O&M Cost	2.5	2.5	2.5
Incentive Payout	0.9	1.4	2.3
Revenue loss	0.5	0.5	0.5
Capex Deferral Saving	5.5	8.2	13.7
Power Purchase Saving	0.9	0.9	0.9
O&M Cost Saving	1.0	1.0	1.0
DSM Cost Saving	0.1	0.1	0.1

Annexure C: Demand Response Business Models

Various stakeholders are involved in electricity distribution, including power distribution companies, load dispatch centers, and transmission companies. In many international experiences, a demand aggregator is also part of the system. It is an entity that pools and coordinates the electricity consumption or flexibility of multiple customers, typically end-users such as households, businesses, or industrial facilities, to create a consolidated demand response resource. They assist utilities in aggregating flexible loads and implementing demand response strategies to reduce peak-period grid stress.[6]

Together with utility, aggregators have developed the business model on DR. The two business models that are most prevalent in an international context and can be adopted in India are:

6 https://gridwiseac.org/pdfs/forum_papers09/thomas.pdf

- Utility-led DR Model– Investment by utility
- Fee for Services Model (or aggregator model)

C.1 Utility-led DR Model– Investment by Utility

In the utility-led model, the utility acts as the aggregator, enrolling customers to achieve the desired demand response (DR) during specific hours of interest. The utility acquires the necessary DR infrastructure from a service provider, either by paying an upfront cost or through an annual payment plan, along with an annual maintenance charge (AMC) for ongoing upkeep. This procurement process may be conducted via competitive bidding or directly by the utility.

Moreover, customers receive direct incentives from the utility based on their performance in reducing demand during DR events. To ensure an accurate assessment of demand reduction, the utility engages an independent Measurement & Verification (M&V) entity. The utility also covers the associated fees for M&V services. An example of the utility-led model is illustrated in Figure A1.

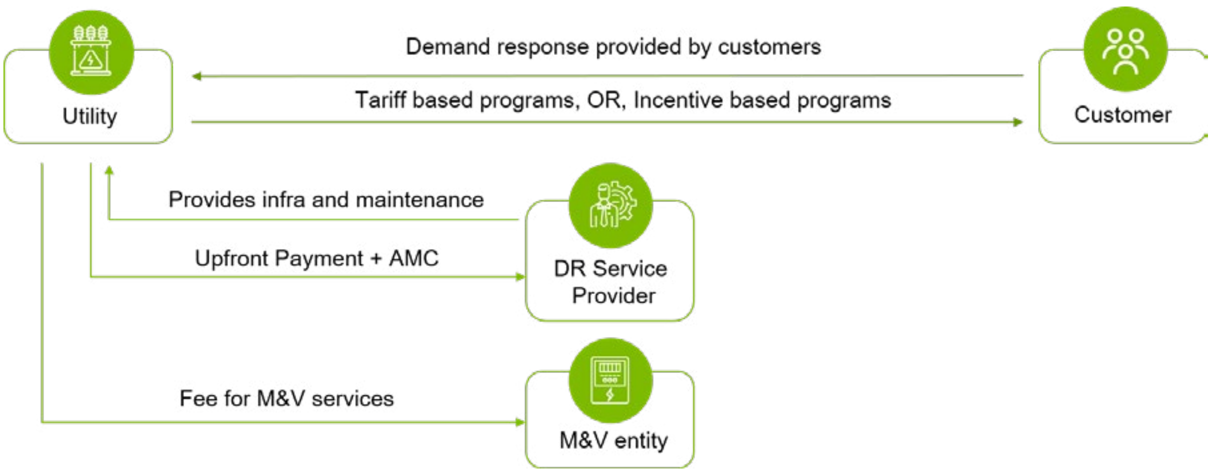


Figure A1: Utility-led DR model – Investment by utility

C.2 Fee for Services Model (or aggregator model)

In fee for Services business models, the utility does not directly procure any infrastructure from the DR service provider; instead, it takes it on lease or rent (the DR service provider works as an aggregator). Instead of an upfront cost, a fee is paid by the utility to the service provider for the services offered to the utility. The DR service providers also work as aggregators in cases where utilities have less manpower and necessary DR infrastructure to fully optimize, manage, or aggregate the DR potential from smaller residential and small commercial customers. These service providers aggregate the DR potential from small sources and make it sizable to make small participants eligible to participate in the electricity markets.

The service offered may include the DR/DF offerings, customer enrolment, providing and installing hardware, software, and other necessary infrastructure at utility's and/or customers' premises, etc. The fee for services provided can be determined either by competitive bidding or a fixed fee is provided based on the approval of regulators. Two types of fee-for-service-based business models are described below in Figure A2

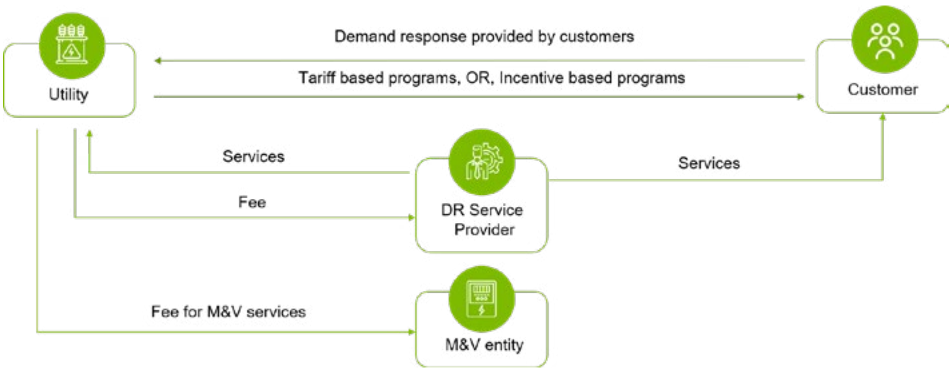
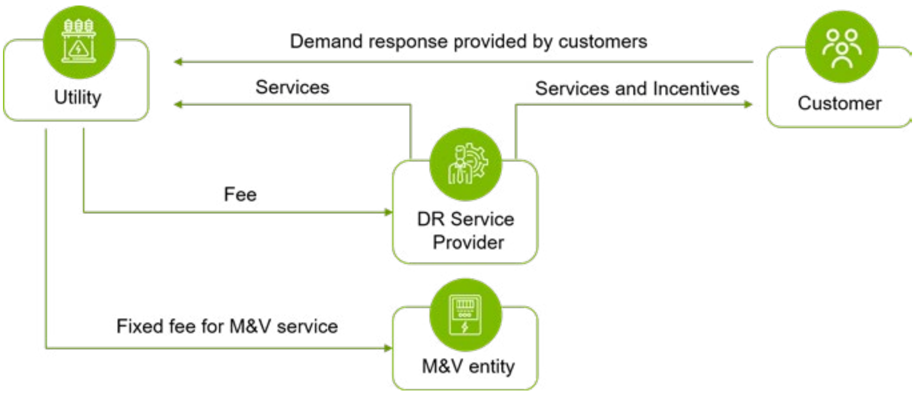
Fees for Service Model	Description
Incentive Payout by Utility (Performance fee)  	• In this business model, the utility signs a contract with the DR service provider to provide the DR services to the utility and customers. • In this case, incentives to the customers are directly paid by the utility. • Utility also hires an M&V entity to measure the demand/energy reduction for a fixed fee.
Incentive Payout by Aggregator (Performance Fee)  	• In this business model, similarly to incentive payout by the utility model, the utility signs a contract with the DR service provider (or aggregator) to provide the DR service. • In this model, DR service provider receives a fee for the services, which it shares with customers as incentives for their participation. • The utility also hires an M&V entity to measure the demand/energy reduction for a fixed fee.

Figure A2: Fee for service-based DR business model

C.3 Advantages and Disadvantages of Each Business Model

Each business model has its own advantages and disadvantages. The selection of any business model will largely depend on the technical capability and manpower availability of DISCOMs. The main advantages and disadvantages of the utility led, and fee for service-based business model are highlighted in Table A1:

Table A1: Advantages, disadvantages, and applicability of DR business models

Business Model	Advantage	Disadvantage
Utility-led DR Model	• Higher economic benefits can be achieved after recovering the initial investment cost on DR infrastructure in the long run (only a small part of the financial benefits will be given to the service provider and M & V entity on account of AMC and fee, respectively). • Utilities can maintain full control over DR operations, ensuring quick responses to grid needs. • Utilities can avoid third-party service fees by managing DR programs in-house, potentially lowering overall costs. • Better data security as customers' data remains with the utility.	• Utility needs capacity building to provide services to the mass customer (such as hardware/software installation) which results in increased capital expenditure. • Utility needs to pay huge upfront costs for procuring DR infrastructure. • Lack of technical specialized skill set for implementing DR programs can harm the effective implementation of DR program. • Utilities may struggle to engage with customers as effectively as third-party experts having more experience of customer's engagement program.
Fee for Service Based Model	• This model allows DR service providers to bring specialized skills and advanced technologies, making DR programs more efficient and effective. • Faster enrollment of diverse customer segments based on service providers' expertise, tools, and digital platforms. • The model allows utilities to avoid the upfront costs associated with developing and maintaining their own DR infrastructure. • The DR service providers can design flexible DR programs tailored to customer needs, utility requirements, and grid conditions.	• The model prohibits DISCOMs from directly controlling over customer engagement, as the service provider is responsible for interacting with customers. This can create challenges for utilities in terms of ensuring program consistency, quality of service, and customer satisfaction. • The involvement of DR service providers (or aggregator) raises concerns over the sharing and handling of customer data. • Utilities may become overly reliant on third-party technology platforms i.e., if a third-party provider experiences technical issues, DR programs could be disrupted.

C 4. Role and Responsibility of Stockholders

In each business model, different stakeholders play different roles. The role of each stakeholder is discussed in detail in Table A2:

Table A2: Role of different stakeholders in different business models

Role of Stakeholders				
Stakeholders	**Utility**	**DR service provider**	**M & V entity**	**Customers**
Utility-led DR Model	• Enroll customers, device installation and maintenance • On-board service provider and M&V entity • Decide the time and duration of DR event and financial settlement with customers • Spread awareness about the program	• Provide necessary infrastructure (hardware, software, server) to the utility to smoothly carry out DR programs	• To measure and verify the reduction in customers' demand or energy consumption	• To reduce their electricity demand or interrupt appliances (manually/ automatically) as per the signed contract with the utility
Fee for Services Model	• Signs an agreement/ contract with a service provider to provide the DR services to the utility as well as the customer for a service fee on an annual/monthly basis. • Provides the time and duration of the forthcoming DR event to the service provider. • Incentivize the customers for their reductions (in case of incentive payout by utility)	• Enrolling the customers in the DR program • Provide and install necessary infrastructure at utility's & customers' premises to carry out DR events. • Execute DR event as per the directions of the utility • Assess demand reduction elated calculation, which can be offered to the utility during the event. • Incentivize the customers for their reductions (in case of incentive payout by aggregator)	• To measure and verify the reduction in customers' demand or energy consumption	• To reduce their electricity demand or interrupt appliance (manually/ automatically) as per the signed contract with the service provider

Alliance for an Energy-Efficient Economy
37, Link Road, Ground Floor, Lajpat Nagar III,
New Delhi 110024

+91-11-4123 5600 info@aeee.in www.aeee.in