Final Report

Regulatory and Business Case for Distributed Energy Resources in India: Phase 2

Grantee:

Tata Power-Delhi Distribution Limited

Contractor:

Energy and Environmental Economics, Inc.

Point of Contact: Snuller Price
44 Montgomery Street, Suite 1500
San Francisco, California 94104
Tel: 415.391.5100
Fax: 415.391.6500
E-Mail: snuller@ethree.com

Public Version
Date: September 2022

This report was funded by the U.S. Trade and Development Agency (USTDA), an agency of the U.S. Government. The opinions, findings, conclusions or recommendations expressed in this document are those of the author(s) and do not necessarily represent the official position or policies of USTDA. USTDA makes no representation about, nor does it accept responsibility for, the accuracy or completeness of the information contained in this report.

USTDA
U.S. TRADE AND DEVELOPMENT AGENCY
1101 Wilson Boulevard
Arlington, VA 22209

Energy+Environmental Economics

U.S. TRADE AND DEVELOPMENT AGENCY

1101 Wilson Boulevard
Arlington, VA 22209

The U.S. Trade and Development Agency helps companies create American jobs and expand the export of U.S. goods and services for priority development projects in emerging economies. USTDA links U.S. businesses with export opportunities by funding project preparation and investing in relationship-building activities that develop sustainable infrastructure and foster economic growth in partner countries.

Table of Contents

1 Executive Summary

1.1 Overview

In 2014, the United States Trade and Development Agency (USTDA) provided a grant to Tata Power Delhi Distribution Limited (Tata Power-DDL) to complete a feasibility study titled "Business Models for Distributed Energy Resource Deployment." Energy and Environmental Economics (E3) was chosen to complete the study. The study focused on developing business models to facilitate distributed solar deployment in Tata Power-DDL's service territory. Since 2014, there have been many changes within the global electricity sector, as well as within India's electricity sector, that merit revisiting the role of distributed energy resources (DER) in Tata Power-DDL's service territory. Tata Power-DDL and E3 worked together in 2018 to secure a second grant from USTDA titled "Regulatory and Business Cases for Distributed Energy Resources in India: Phase 2" to explore the regulatory and business cases for a broader set of DERs including electric vehicles, demand response, storage, and energy efficiency. While the project is being conducted for Tata Power-DDL and its service territory, the tool and learnings from the project are meant to be applied to distribution companies (Discoms) across India upon project completion.

1.2 Distributed Energy Resources (DERs)

DER technologies are a class of resources that are typically installed behind a customer's meter and/or at a customer site, rather than at a central generation station. DER technologies can improve the reliability of Tata Power-DDL's electricity system, reduce its environmental footprint, and reduce its overall costs to customers. We investigated the following types of DER technologies:

+ Distributed solar
+ Distributed energy storage (batteries)
+ Electric vehicles
+ Energy efficiency
+ Demand response
+ Grid energy storage (batteries)

1.3 Project Goals

+ **Development of Integrated DER Planning Tool**: The first major goal of this project was to develop an integrated planning tool that will allow Tata Power-DDL to evaluate the economic case for large-scale DER roll-out.
+ **Evaluate DER Portfolios:** This tool was used to analyze the cost-effectiveness of various DER programs and develop a least-cost and optimized DER portfolio for Tata Power-DDL.
+ **Development of Distributed Energy Roadmap:** The DER programs evaluated for moving forward are individual programs linked as part of an overall DER portfolio and roadmap that can evolve over time. E3 supported Tata Power-DDL in articulating the roadmap and working with Tata Power-DDL management to prioritize and select specific DER program designs from among many options.

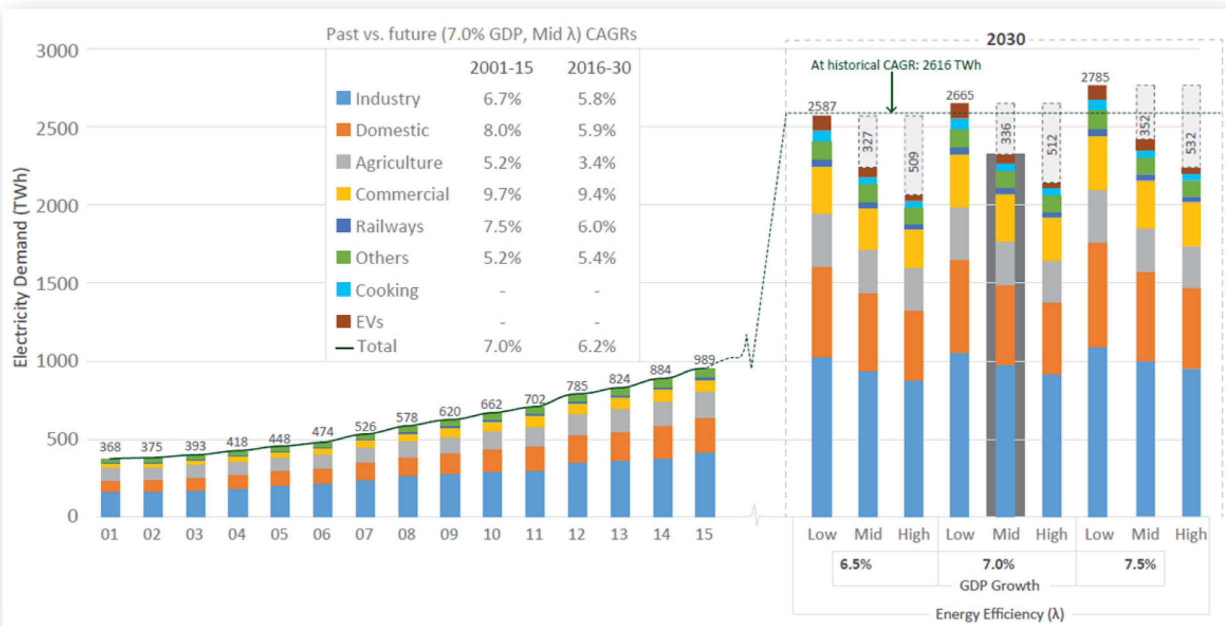
- **DER Programs Screening and Evaluation:** E3 and Tata Power-DDL developed a DER roll-out roadmap and identified an initial set of six DER technologies and programs to be evaluated. E3 then used the integrated DER planning tool developed earlier in the project to conduct a cost-benefit analysis for the six selected programs.
- **Support DER Program Designs and Regulatory Materials:** Given the evaluation results, cost-effectiveness, and value to customers and the environment, Tata Power-DDL and E3 further narrowed down the DER programs for launch to two programs: distribution hot spot demand response, and electric vehicle infrastructure. Other programs were identified for release in upcoming years. After the programs were identified, E3 supported Tata Power-DDL in finalizing key program design parameters including technology assumptions, incentive levels, retail rate offerings, and utility control strategies to guide the development of the programs, conducting benefit and cost assessment, and estimating the impact of DER programs on customers.
- **Support Regulatory Due Diligence:** During the review process preceding program launch, E3 supported Tata Power-DDL on regulatory due diligence by providing feedback, guidance, and assistance on both programs that are moving forward. As of October 2021, Tata Power-DDL is in various public processes to move ahead with both DR hot spot and electric vehicle (EV) charging infrastructure programs.

2 Overview of Indian Power

Distributed energy resource technologies can enable Discoms to adapt to the changing Indian economy and electricity grid, providing benefits for customers and utilities alike while helping India achieve long-term climate and environmental goals.

+ **Rapid Renewable Deployment in India:** The rapidly declining costs of renewables paired with a strong central government policy are driving the procurement of large amounts of renewables throughout the country. India has set a target of 175 GW of renewable energy coming online by 2022. By the end of 2018, nearly 75 GW of the 175 GW target was online. At the current rate of renewable deployment, India is expected to exceed this goal and install 225 GW by 2022. In 2018, Bloomberg New Energy Finance (BNEF) stated that India was the largest market for auctions of renewable energy in the world.[1] Indeed, rapidly declining costs of renewables, particularly solar, have resulted in very low auction prices (₹2.44/kWh for solar in 2018).
+ **India's Growing Economy:** India's growing economy is resulting in rising electricity demand. By 2030, electricity demand is forecasted to almost triple compared to 2015 levels. A report by Brookings India titled, "The Future of Indian Electricity Demand" details this demand growth, shown in the figure below:

Figure 2-1. Brookings India 2018 analysis depicting electricity demand growth in India out to 2030[2].

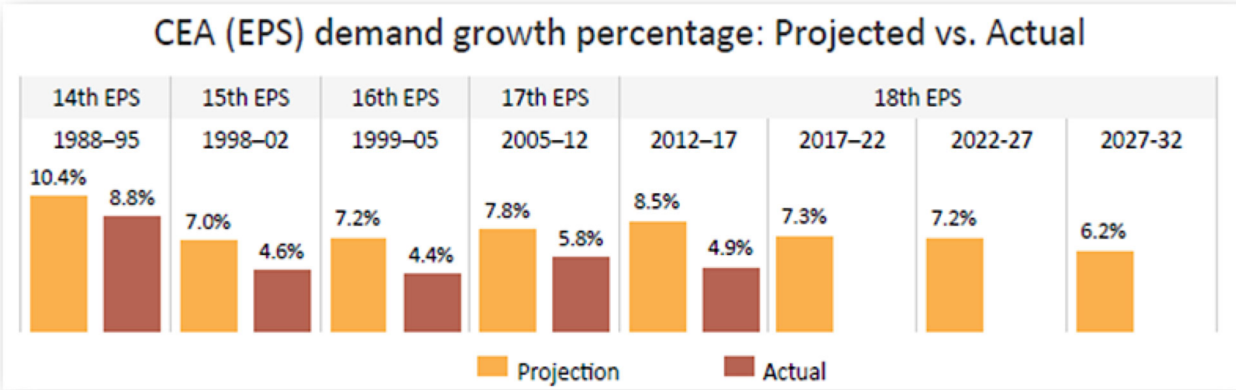


[1] BNEF Report: http://carboncopy.info/bnef-indian-renewable-auction-market-worlds-largest/

[2] Low, mid, and high scenarios correspond to different levels of energy efficiency.

- **India's Capacity Overbuild:** While population and load growth in India has been considerable in recent decades, the Central Electricity Authority (CEA) has consistently over-forecasted demand growth in five-year plans. This has led Discoms to enter long-term (20+ years) contracts for thermal capacity far exceeding customer demand levels. Higher commercial and industrial (C&I) tariffs, which typically subsidize other rate classes, are driving C&I customers to pursue open access and procure low-cost renewables to serve their loads. Due to these two reasons, there is limited demand for capacity addition in the near term, with future increases in load playing a key part in creating capacity value for new resources.

Figure 2-2. Prayas 2017 graphic depicting CEA's over-forecasted load growth in India



- **Air Pollution in India:** In 2018, 11 of the world's 12 most polluted cities were in India, according to the World Health Organization.[3] The Delhi government has taken steps to reduce pollution at critical periods of time, including (1) limiting the amount of coal generation, (2) banning entry of medium- and heavy-duty vehicles to the city, and (3) banning construction in the city. As more renewables come online to meet the national goal, power sector emissions will naturally decline. Transportation electrification will remain a key part of reducing air pollution in India.

[3] WHO, "Air pollution and child health: prescribing clean air": https://www.who.int/ceh/publications/air-pollution-child-health/en/

3 Kick-off Meetings and Information Gathering

3.1 Overview

This chapter summarizes the findings of Task 1's project kick-off meetings and information-gathering efforts. E3 and Tata Power-DDL coordinated remotely for several months before the teams were able to meet in person in October 2018. The key objectives fulfilled in Task 1 include:

+ **Develop Project Workplan and Schedule:** The E3 and Tata Power-DDL team (the Team) refined the project work plan and schedule outlined in the grant's terms of reference (ToR) based on conversations with Tata Power-DDL. Due to the delayed project start, the Team agreed to parallelize several of the project tasks in 2019 to meet the ToR's original project end date (September 30, 2019).
+ **Develop Working Groups for the Technical Assistance (TA) Tasks:** As the project required close coordination between Tata Power-DDL and E3, key members at both organizations were identified to support the various TA tasks. These working groups have coordinated via email and phone calls/webinars to ensure the tasks progressed according to schedule.
+ **Gather Data:** The E3 team coordinated with Tata Power-DDL on key data inputs required for the TA tasks, and met with relevant Tata Power-DDL teams in person during the October 2018 session to clarify any outstanding questions and requests concerning project data. Most of the data requested has been provided at this date.
+ **DER Program Scoping**: E3 met with various Tata Power-DDL teams to better understand the existing DER programs offered by Tata Power-DDL and the programs to pursue as a part of this TA, and to provide DER-relevant learnings from project experience in the United States. Tata Power-DDL demonstrated interest in distribution "hot spot" demand response, managed charging for electric vehicles, and volt-VAR optimization. The Team agreed to refine the list based on preliminary cost-effectiveness analysis (through Task 2) as well as input from customers and regulators during the second in-country trip (originally scheduled in March 2018).
+ **Information Gathering and Meetings with Key Stakeholders:** E3 met with stakeholders within Tata Power-DDL as well as outside of Tata Power-DDL to help understand the current industry environment for DERs in India. The Team met with regulators from the Central Electricity Regulatory Commission (CERC) and state Delhi Electricity Regulatory Commission (DERC), key commercial and domestic customers, government agencies that set DER policy and goals, and DER technology providers and implementors. These meetings served to inform external stakeholders of the study as well as to get their input on DER technology readiness, current and needed regulations and policies for increased DER adoption, and to hear more about previous successful DER programs in India.

3.2 Summary of Kick-Off Meetings and Information Gathering Efforts

Three members from E3 (Lakshmi Alagappan, Eric Cutter, and Jasmine Ouyang) traveled to Delhi in October 2018 to take part in the Task 1 kick-off meetings and close out information gathering efforts that had started shortly after the grant agreement was signed in May 2018. The trip was successful in achieving both objectives. In addition, the Team refined the project work plan to adjust the schedule and assign relevant E3 and Tata Power-DDL team members to the various working groups for several TA tasks. This section summarizes each of the external meetings and provides background and an update on the information and data gathering efforts that were undertaken to support the TA.

3.2.1 Kick-off Meetings

To ensure that the DER regulatory and business cases developed were feasible and rooted in a common understanding of the Indian electricity sector, the Team met with many stakeholders across the industry involved with DER regulation, policy, and deployment. The Team discussed the scope of this project with each stakeholder and solicited their feedback in their relevant areas of expertise. Specifically, the Team met with members from the following organizations:

- Regulators
  - Delhi Electricity Regulatory Commission (DERC) – the state-level electricity regulator
  - Central Electricity Regulatory Commission (CERC) – the central-level electricity regulator
- Government Agencies
  - Central Electricity Authority (CEA) – electricity sector planning agency for India
  - Ministry of Power – the government agency tasked with overseeing the development of the power sector in India
  - NITI Aayog – a government think-tank that provides directional policy guidance on several issues including energy policy; has been a leader in thinking on EVs in India
  - Solar Energy Corporation of India (SECI) – government agency meant to help facilitate solar deployment across India
- Customers
  - Delhi Integrated Multimodal Transit System (DIMTS) – government joint-venture focused on urban transport and infrastructure development; developing an electric bus depot in Tata Power-DDL's service territory
  - Unity Group – commercial and domestic customer of Tata Power-DDL that has malls and apartment buildings in Tata Power-DDL's service territory; one of the largest developers in Delhi
  - Purearth – commercial customer of Tata Power-DDL that has a large office complex in Tata Power-DDL's service territory
- Technology Developers and Implementors
  - Panasonic – global battery storage developer working in India for the last two years
  - Tata Power – large integrated power company that is exploring EV charging infrastructure in India

Detailed meeting summaries are described below:

Table 3-1. Summary of Kick-off Meetings

No	Meeting Name	Date	Meeting Goals	Meeting Duration
1	Visiting Smart Grid Lab	10/08/2018	Gather data	1 hour
2	Meeting with Regulatory Affairs	10/09/2018	DER program scoping	1 hour
3	Meeting with Mr. Sunil Singh (Chief Operation Officer)	10/09/2018	DER program scoping	1 hour
4	Meeting with Mr. Mithun Chakraborty and Dr. G Ganesh Das (Head of Strategy)	10/09/2018	DER program scoping	1 hour
5	Meeting with Tata Power-DDL's KPM Group	10/09/2018	DER program scoping	1 hour
6	Meeting with Central Electricity Authority (CEA)	10/10/2018	Information gathering and meetings with key stakeholders	1 hour
7	Meeting with Mr. Sanjay Banga (Chief Executive Officer), Mr. Puneet Munjal (Chief of Power Management, Business Development, and Contracts), and Dr. G Ganesh Das (Head of Strategy)	10/10/2018	DER program scoping	1 hour
8	Meeting with Tata Power-DDL Network Engineering Group (NEG) Team	10/10/2018	Gather data	1 hour
9	Meeting with Ministry of Power	10/11/18	Information gathering and meetings with key stakeholders	1 hour
10	Meeting with Mr. Jatindra Nath Swain (Managing Director, Solar Energy Corporation of India (SECI))	10/11/2018	Information gathering and meetings with key stakeholders	1 hour
11	Meeting with Mr. Shailesh Kumar Mishra (Director, Solar Energy Corporation of India (SECI))	10/11/2018	Information gathering and meetings with key stakeholders	1 hour
12	Meeting with Mr. Ashvini Prashar (Executive Vice President of Business Partnerships, Delhi Integrated Multimodal Transit System (DIMTS))	10/12/2018	Information gathering and meetings with key stakeholders	1 hour
13	Meeting with Rahul Shal from Tata Power-DDL	10/12/2018	DER program scoping	1 hour
14	Meeting with Tata Mumbai	10/12/2018	Information gathering and meetings with key stakeholders	1 hour
15	Meeting with commercial customer representatives	10/12/2018	Information gathering and meetings with key stakeholders	1 hour
16	Meeting with Unity Group	10/12/2018	Information gathering and meetings with key stakeholders	1 hour
17	Meeting with Delhi Electricity Regulatory Commission (DERC)	10/15/2018	Information gathering and meetings with key stakeholders	1 hour
18	Meeting with Central Electricity Regulatory Commission (CERC)	10/15/2018	Information gathering and meetings with key stakeholders	1 hour
19	Meeting with NITI Aayog	10/16/2018	Information gathering and meetings with key stakeholders	1 hour

3.2.2 Information and Data Gathering

A large number of inputs from Tata Power-DDL were required to populate the Toolkit, which developed the least-cost DER portfolios for Tata Power-DDL's service territory. E3 has been working with Tata Power-DDL since June 2018 to gather the relevant pieces of data. Inputs include technology specifications, customer adoption functions, customer end-use loads, utility local and system loads, avoided cost estimates, utility rates, utility capital investment plans, customer determinants such as numbers and sizes by class, existing penetration of DER, and scenario-specific inputs such as program design and portfolio selection criteria.

E3 met with several internal Tata Power-DDL teams including the Network Engineering Group (NEG) for capital investment plans (also known as distribution schemes), the Power Management Group (PMG) for system-level data, and the customer team for customer load shapes and tariff data. The table below lists each category of data requested and the status of the data delivery. E3 has reviewed all data provided by Tata Power-DDL for the Toolkit to ensure it produces reasonable results.

Throughout the project, the E3 and TPDDL teams were in close communication. In some stretches of time, the communication was multiple times per day as necessary to develop a high-quality project. Even in times with less intense work, both teams were well-coordinated and well aware of the next steps and milestones. Communication included email, phone, video conference, and less formal WhatsApp messages.

Table 3-2. *Data Requests and Delivery Status*

Data Category	Input	Status
System Information	System historic hourly load and future load forecasts	Received
	Existing and planned PPAs	Received
	System losses and planning criteria	Received
	Distribution schemes for Capex FY16-17, FY17-18, and FY18-19	Received
Distribution Schemes	Zone, feeder, and transformer level peak growth forecasts	Received
	Feeder and transformer capacity limits	Received
	Three representative load shapes	Received
Retail Tariffs	DERC approved tariff FY18-19	Received
Customer	Representative customer load shapes	Received
	Customer account number to rates, distribution locations, and customer industrial type categories	Received
DER Measure Characterization	PV technical potential & current adoption level	Received
	DSM technical potential & current adoption level	Received
	DSM energy savings & appliance costs	Received
	DR load shedding potentials	Received
	EV preferences	Received
	Program admin and marketing costs	Partially Received[4]

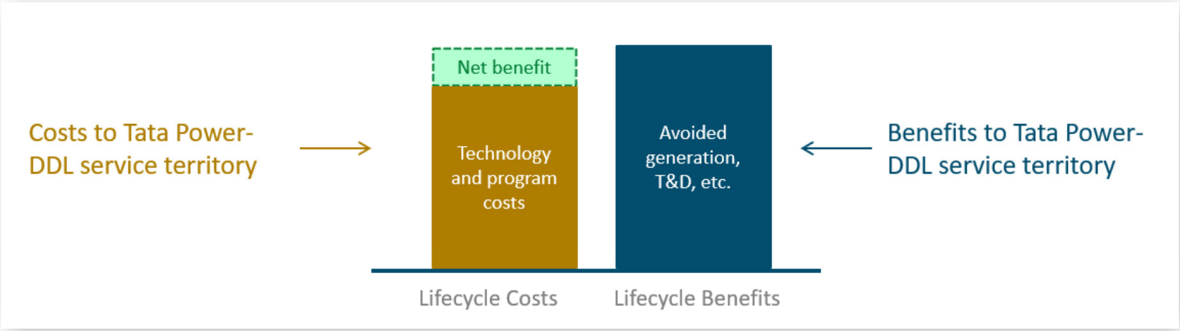
[4] E3 pre-populated the Toolkit with best available, publicly sourced proxy data. This can be substituted later by Tata Power-DDL if better data becomes available.

4 Analytical Approach

4.1 Valuation Framework

The foundation of DER valuation is comparing the cost of DERs against the avoided costs of procuring equivalent amounts of energy and capacity from grid-scale coal or gas resources. A regulatory valuation framework is necessary to estimate net costs to all customers from a DER program. This framework will help Tata Power-DDL and regulators determine whether the overall cost of energy supply in the Tata Power-DDL territory will increase or decrease with a particular DER program. Ultimately, the Delhi Electricity Regulatory Commission (DERC) has requested that DER programs remain tariff-neutral, meaning costs must be lower than benefits. In general, sustained high energy and capacity values can make DER programs cost-effective. This framework is generalized in the figure below:

Figure 4-1. Valuation Framework for DER Programs



To estimate the procurement and operating costs that can be avoided by installing DER, we developed a series of avoided costs for the Tata Power-DDL system to represent the marginal costs that can be avoided by reducing the load at each hour. The avoided costs represent the costs of avoiding system marginal generation, transmission charges, losses, and generation capacity contracts due to DER generation. The study includes five avoided cost components as summarized in the table below.

Table 4-1. Avoided Cost Components

Component	Description
Generation Energy	Estimate of the hourly marginal cost of generation (e.g., PPA variable cost or wholesale energy price in Indian Energy Exchange (IEX)
Generation Capacity	The costs of building new generation capacity to meet system peak loads (e.g. PPA fixed cost)
Avoided Losses	Avoided transmission and distribution losses
Avoided Transmission Charges	Avoided transmission charges for Delhi Transco and Central Transmission Utility (CTU)
Avoided Distribution	The costs associated with expanding distribution capacity to meet peak loads

The valuation framework is designed to answer the following main questions about a given DER program:

- Will the DER program be cost-effective for participating Tata Power-DDL customers?
- What will the tariff impact of the DER program be on non-participating customers?
- What are the net benefits of the DER program for Tata Power-DDL?

These questions are important components of the regulatory case for DER programs, especially the impact of DER adoption on a utility's overall cost of supply. Traditionally, Tata Power-DDL's and most utilities' cost of supply is dominated by conventional resources, and in India, particularly coal. If solar or DER technologies are more cost-effective than conventional energy resources, they have the potential to reduce energy bills for Tata Power-DDL customers. The above questions can be answered by the results of four different cost tests, which are the Total Resource Cost Test (TRC), Non-Participant Cost Test (N-PCT), Participant Cost Test (PCT), and Program Administrator Cost Test (PAC). The tool also includes the Societal Cost Test (SCT), which goes beyond TRC to include externalities and uses a societal discount rate. Table 4-2 shows how program economic impacts are considered from different cost test perspectives. A green cell with a plus sign indicates that the component is considered as a benefit, while a brown cell with a minus sign indicates that the component is a cost.

Table 4-2. Costs and Benefits from Each Cost Test Perspective

Benefit and Cost Component	TRC	N-PCT	PCT	PAC
Customer Bill Savings		-	+	
Reliability Value	+		+	
Total System Cost	-		-	
Utility Incentives		-	+	-
Utility Admin Cost		-		-
Avoided Generation Energy	+	+		+
Avoided Generation Capacity	+	+		+
Avoided Ancillary Services	+	+		+
Avoided Transmission Charges	+	+		+
Avoided Distribution Upgrade	+	+		+
Avoided Losses	+	+		+

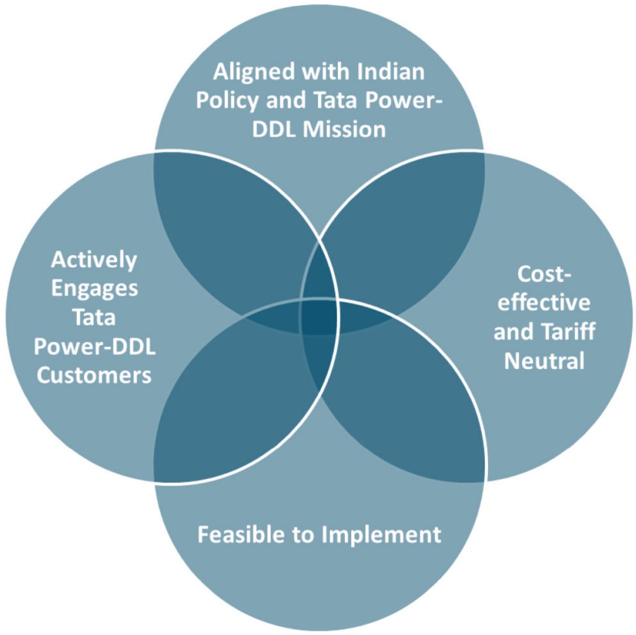
- **Total Resource Cost Test (TRC):** The TRC assesses the monetized costs and benefits to the Tata Power-DDL system. The costs are the installed cost of the DER system, while the benefits are the avoided costs of supplying energy. Costs of supplying energy are avoided when the load is reduced or shifted from times when resources are expensive or limited to times when they are less expensive. The avoided costs of supplying energy include avoided ancillary services purchases, avoided resistive transmission and distribution losses, avoided generation capacity costs, avoided energy purchase or generation costs.

- **Non-Participant Cost Test (N-PCT)**: The N-PCT quantifies the effect of a program on the non-participant customers, comparing the avoided cost savings to the utility to the lost revenue from customer bill reductions. The costs of the N-PCT are the bill savings from the customers. The benefits of the N-PCT include all the avoided costs of the TRC. A negative N-PCT represents a cost-shift that is borne by non-participating customers. Most DER measures and programs in the world have a negative N-PCT but are nevertheless promoted to achieve broader policy goals. The N-PCT is provided here as a measure of the benefits to Tata Power-DDL non-participating customers for DER projects and an indication of the viability of the economic and business model for DER projects. A DER business model that imposes large cost-shifts to non-participating customers will not be viable at a large scale until the cost-shift is addressed.
- **Participant Cost Test (PCT)**: The PCT is designed to assess if a demand-side program is cost-effective from the perspective of the customer who chooses to participate in a DER program. The costs to the participants are the purchase costs of the DER system. The benefits to the participants are the retail electricity bill savings and reliability value from the DER system providing an uninterruptible power supply (if applicable).
- **Program Administrator Cost (PAC) Test**: The PAC Test measures the impact of the program based on the costs incurred by the program administrator. Here, benefits include the same avoided costs as the TRC and N-PCT tests, while costs include only incentive costs. As the result, bill reduction from participants doesn't count as the cost in the PAC test. Positive PAC test results translate to reductions in average customer bills, although bills may not decline for all customers. A measure may not be cost-effective from a societal perspective and lead to large cost-shifts, yet reduce average bills.

Including both this analytical framework and other important non-economic factors, E3 has identified the following core elements of a successful DER program for Tata Power-DDL:

- **Tariff-neutral:** The first element is whether the program is cost-effective and tariff-neutral. The valuation framework determines if the DER program benefits are higher than the costs.
- **Implementation Feasibility:** Here, we ask if the DER technology in question is available and affordable today, or when it might become available and affordable.
- **Robust Customer Engagement:** Successful DER programs must have the support of Tata Power-DDL customers.
- **Alignment with Environmental Goals:** The program must help integrate higher renewable energy penetration levels and aids in mitigating local environmental issues.

Figure 4-2. Core Elements of a Successful DER Program



4.2 Tool Overview

The DER Valuation and Analysis Toolkit (the tool) developed in this project evaluates the cost-effectiveness of DERs from different cost-benefit perspectives by simulating their optimal dispatch behaviors against corresponding price signals, then simulates economic-driven customer adoption behaviors, and generates an optimized DER portfolio for the modeled area based on the utility need. As shown in Figure 4-3, the tool can model a wide range of DER technologies including energy storage, solar, electric vehicles (EVs), demand response (DR), and energy efficiency (EE) measures, and is designed to evaluate several use-cases. It provides a wide range of revenue streams for users to select from and has a flexible program design framework to test program and incentive ideas. The tool's use cases are grouped into two categories as summarized in Figure 4-4:

Figure 4-3. Technologies modeled by the DER Toolkit

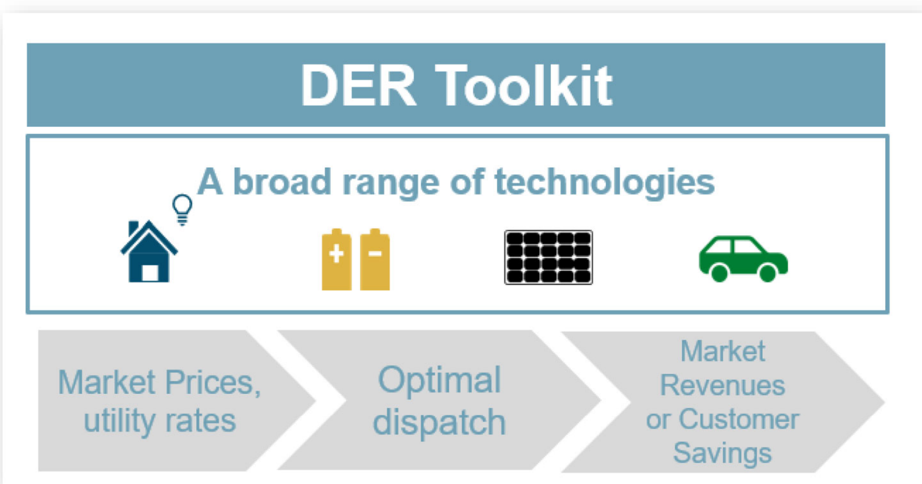
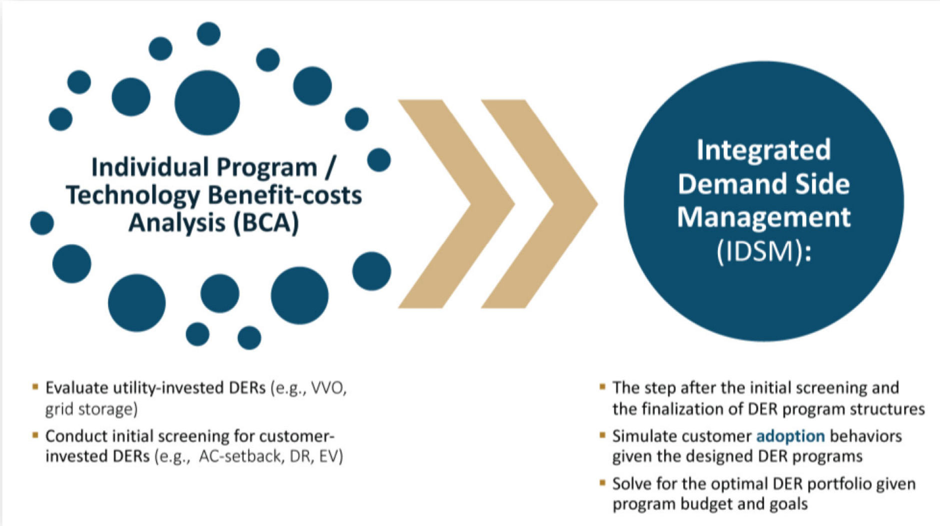


Figure 4-4. Two use case categories for the tool



- Individual Program/Technology Benefit-Cost Analysis (BCA)

  This use case category focuses on the BCA for individual programs and technologies without considering customers' adoption behaviors. For example, the BCA analysis for utility DER investments (e.g., grid storage, VVO) falls into this category. These types of investment decisions can be made without considering customers' adoption behavior. Incentive and rate analysis, which evaluate the impact of rates and incentives on DER's cost-effectiveness for customers, also fall into this category. This use case category doesn't consider the impact of a customer's adoption behavior on the program outcome.

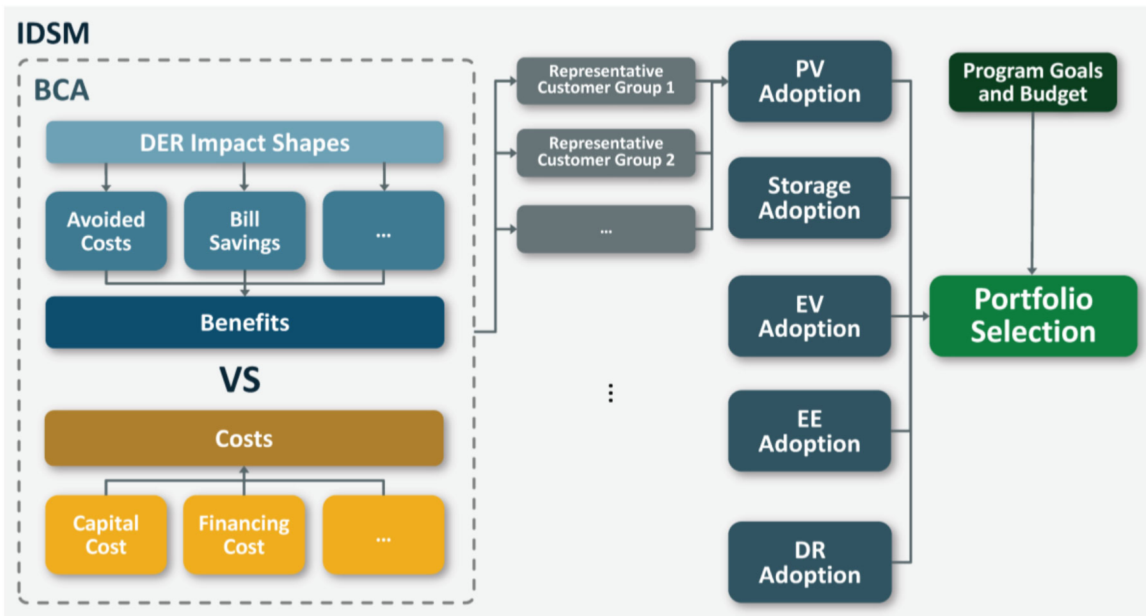
- Integrated Demand Side Management (IDSM)

  The IDSM module of this tool uses the BCA framework described above to create an optimal DER portfolio, incorporating customer adoption behavior from several representative customer groups and system constraints such as utility peak reduction goals and program budgets. Based on cost-effectiveness results and subsequent customer adoption behavior simulations, the tool constructs an optimal incentive spending strategy and DER portfolio. Customers are grouped into representative customer groups based on their rates, load level, and types. The DER cost-effectiveness for each representative customer group is calculated separately and then combined to get the aggregate impact on the system. A single iteration of the IDSM module consists of BCA analyses for each DER technology and representative customers group for a system scope of the utility's service territory or a single distribution planning area, culminating in an optimized, least-cost DER portfolio subject to the inputted model constraints. Please check section 4.3 and 4.4 for details on methodology.

These two use cases are closely related as they share the same analytical framework, codebase, and data folders; however, this tool has two separate UIs in Excel for each use case to provide targeted case configuration and results viewing.The DER Toolkit can evaluate a number of scenarios,can be adapted by using appropriate input data for modeling efforts by other Indian utilities, and users of the tool can specify the values of different macro driver assumptions and create their own scenarios. The tool calculation flow is summarized in Figure 4-5 below. As shown in the figure, the BCA calculation is shared by both the BCA and IDSM use cases:

- First, the DER technology's impact shape is obtained. Depending on the technology, it can be a generator (e.g., DG PV), load (e.g., EV), both (e.g., energy storage). The impact shapes are either fixed shapes provided by users or determined by the tool's dispatch algorithm.
- Benefits are then calculated based on the DER impact shapes and the available benefit streams. Depending on the use cases, benefits may include bulk system avoided costs, customer bill savings, and utility incentives (which are counted as costs from the utility's perspective).
- DER costs, including capital cost, O&M cost, and financing costs, are calculated.
- Lastly, DER's benefits and costs are compared from different perspectives in the framework of structured cost tests.

Figure 4-5. DER Valuation and Analysis Toolkit Logic Flow



If users are only interested in the BCA use case (to understand cost-effectiveness of a DER program), this is the end of the analysis. Users can evaluate a single DER technology or a DER portfolio (e.g., PV paired with storage) or run this analysis in batch to screen many site host candidates and DER technologies.

If users are interested in the IDSM use case (to understand a portfolio of DER programs), additional information regarding the studied customers is needed. First, users are asked to identify the study territory and group customers into representative customer groups. The representative customer group is the group of customers who are similar in making DER adoption decisions. They will see similar costs and benefits from DERs because they are likely to have the same rate structure and similar load patterns (e.g., load factor, peak load timing). Customers who have similar financing capabilities (e.g., good credit score, access to low-cost debt) see similar DER purchase costs. Based on these parameters, the study allocates customers into representative groups using rate schedules and customer types because they are similar in bill savings, financing, and risk tolerance. After the representative group assignment is complete, the user is asked to input information for one representative customer for that group. The final goal of the IDSM model is to solve for the optimal incentive distribution strategy among customers to achieve the specified program goal and budget. Before running the cases, the user also needs to select the DER technologies that they want to include in the portfolio, the corresponding incentive structures, as well as the program goal and budget if applicable. These inputs are used later in the portfolio selection module.

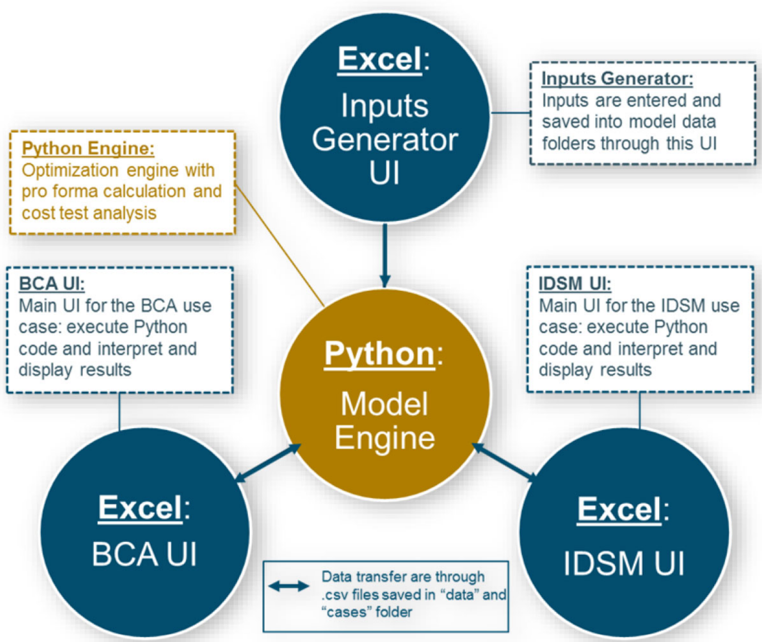
The tool is used as follows in the IDSM use cases:

+ Two sets of BCAs are calculated for the representative customer in each group. One set of BCAs is calculated with the user-specified incentives and the other set without.
+ Two sets of the adoption results are then simulated based on the BCA results. The adopted DER with incentives feeds into the next step as the available candidates for portfolio selection. The simulated DER adoption without incentives is the natural adoption case used as a benchmark.
+ Finally, the portfolio selection is conducted based on the user-specified program goal and budget.

4.2.1 Model Structure

The tool is built in Python but has Microsoft Excel user interfaces that provide intuitive platforms for generating inputs, setting up cases, and viewing results. The users don't need to have Python knowledge to use the tool. As shown in the diagram below, the core optimization and calculation engine are built in Python, an open-source and increasingly popular programming language. Inputs and outputs that are directly coming in and out of Python are in .csv formats and are saved in the cases and data folders. Three UIs are interacting with .csv files by saving them from the UI and reading in .csv files. The Input Generator UI is used to save inputs. The BCA UI and the IDSM UI are used as the main interfaces for setting up cases, executing Python code, and interpreting results for BCA and IDSM use cases respectfully. As mentioned above, this tool is set up to handle a flexible number of scenarios for modeling efforts by other Indian utilities, and users of the tool can specify the values of different macro driver assumptions and create their own scenarios.

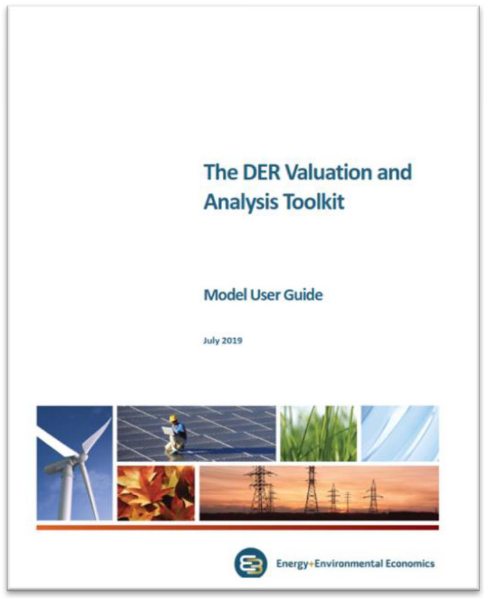
Figure 4-6. Model Structure Overview



4.2.2 User Guide

A more detailed overview of the tool can be found in the User Guide[5] document sent along with the tool package, which includes step-by-step instructions for setting up and running the cases, as well as clear documentation on the tool user interfaces. Methodology, assumptions, and results for the study are covered separately in the Task 2 report. The user guide document is organized in the following way: First, a quick-start guide is provided for walking through how to set up a case and make your first model run in both BCA and IDSM use cases. Then, Chapters 3 to Chapter 5 provide in-depth descriptions for the three Excel interfaces. In addition, many useful screenshots of the user interfaces are included in this document to provide an intuitive learning experience.

Figure 4-7. *DER Toolkit's Model User Guide*

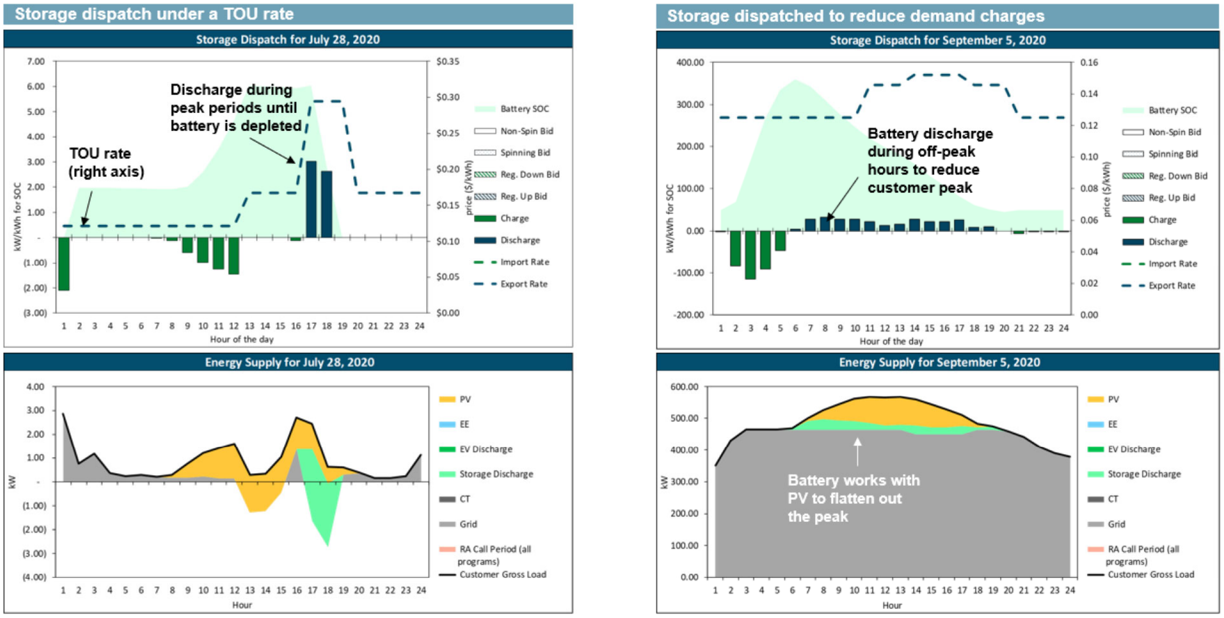


4.2.3 Example Dispatch Results

Example results below illustrate the tool's capability to simulate the optimal dispatch for a behind-the-meter (BTM) solar + storage system to respond to a residential or commercial time-of-use (TOU) retail rate (with or without demand charges) and then minimize the electricity bill for customers. Under different customer retail rate schedules or price signals, DERs would be dispatched differently to minimize customer electricity bills with perfect foresight, which means the model assumes the DERs have the perfect forecast on future customer load and price signals. In a BTM case, price signals are usually utility retail rates that are consistent and stable, whereas in a front-the-meter (FTM) case the wholesale energy market prices are more volatile and harder to predict. Under a TOU rate schedule with a volumetric rate only, the tool would charge the battery during the off-peak hours when the solar is more likely to generate excess electricity, and discharge during the peak hours to reduce and offset customer load. With a demand charge on top of the volumetric energy charge, in this specific example, the tool will instead prioritize flattening out the customer peak to avoid demand charges as a result of the co-optimization.

[5] Please note that potential mismatches exist between the User Guide and the tool, as the Guide might cover some data inputs, outputs, model features, model settings that are not accessible in the tool, which is tailored to India power system specifically and focus on specific modeling capabilities.

Figure 4-8. Example BTM Solar + Storage System Dispatch under TOU Rate Schedule



4.3 Adoption Forecast

After simulating the DER technologies' behavior and analyzing the cost-effectiveness, the model estimates the future adoption of DER technologies to understand customers' decision-making for more effective program design and the impact of those decisions on Tata Power-DDL's system.

As with every other type of adoption forecast, estimates are made using experience, the present moment, and predicted changes in future conditions. This tool uses a two-stage model based on the Bass Diffusion Model[6] and associated willingness-to-pay literature[7] to forecast adoption. This method is also used in the Distributed Generation Market Demand (dGen)[8] model developed by National Renewable Energy Laboratory (NREL) in the U.S.

The first stage is quantifying the achievable market potential for the technology based on the technology's payback period or benefit/cost (B/C) ratio and its technical potential. The achievable market potential defines the ultimate achievable level of adoption at a given payback period or B/C ratio level, and it can be viewed as the maximum adoption after all the other market barriers have been removed (e.g., market matureness, customers' knowledge about the technology, etc.). This relationship is the same for all DER technologies given this is a pure economic preference, however, residential customers might have a different preference than commercial customers as companies might be savvier and more sensitive to the payback period of an investment. This relationship is empirically derived from past experience of technological adoptions and informs the final number of adoptions if time were not a constraint.

The second stage is simulating the adoption year by year by addressing the time element: how many adoptions are expected every year given a particular achievable market potential? The process of getting to the market saturation

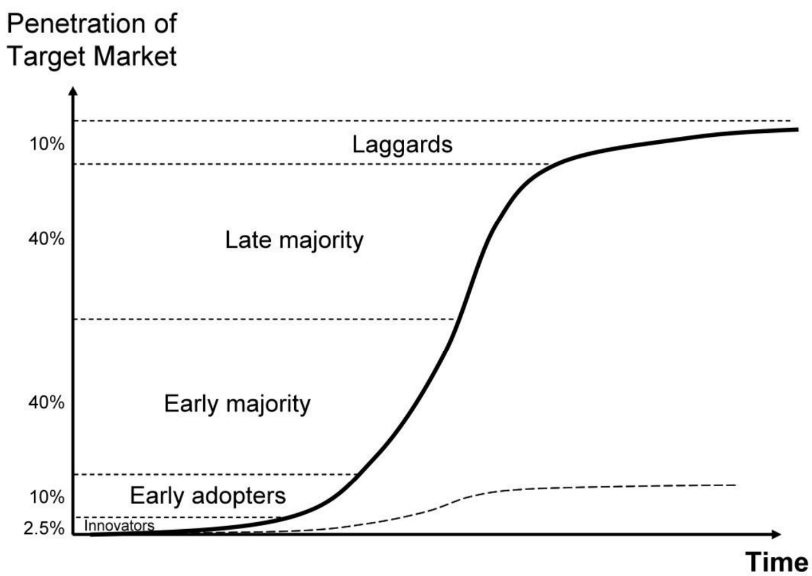
[6] Bass, F.M., 1969. A new product growth for model consumer durables. Manag. Sci. 15 (5): 215–227. http://dx.doi.org/10.1287/mnsc.15.5.215 .

[7] Sigrin, B., Drury, E., 2014. Diffusion into New Markets: Economic Returns Required by Households to Adopt Rooftop Photovoltaics. AAAI Energy Market Prediction Symposium. Washington, November 13-15, 2014.

[8] https://www.nrel.gov/analysis/dgen/

is based on the Bass Diffusion Curve (or S curve). This curve is also determined through empirical observation and is parameterized by two coefficients: the innovation parameter (p) and the imitation parameter (q). This curve describes the increasing rate of change as a new market takes off, followed by decreasing rate of change as the market becomes saturated, reaching a maximum adoption equal to the achievable market potential. Figure 4-9[9] below shows an example of the Bass Diffusion Curve. Bass Diffusion Curves reflect the rate of market adoption changes for a certain product in a certain region. The future forecast is more accurate if p, q parameters are chosen based on the study and historical data for the particular region. Unfortunately, the empirical data used to calibrate the two components described above are rarely collected and relevant studies for India were not available. Both parameters for achievable market and Bass Diffusion Curves used in this study are based on analysis done worldwide.

Figure 4-9. *Illustration of the Bass Diffusion Curve*



4.4 Optimized Portfolio Selection

The underpinning assumption for a utility's DER portfolio optimization is that incentive programs can induce customers to adopt different combinations of DERs that are valuable to meeting system and local needs. The optimized portfolio selection works in two stages:

+ Based on user settings, potential incentives and subsequent adoption rates (economically achievable potential) are calculated.
+ Given the potential incentives, the tool optimally selects measures each year up to their achievable potentials and up to a total incentive budget to achieve the T&D deferral targets specified.

For optimal portfolio selection, the tool provides three options for the optimization objective, depending on the perspective that the planner takes. The portfolio objective can be set by the user during the case setup process.

[9] http://www.business-planning-for-managers.com/main-courses/forecasting/the-diffusion-of-innovation/

- **Maximize net benefits by cost test perspective:** This objective maximizes estimated net benefits based on a specified cost test perspective. For example, it can maximize net benefits for the entire system (TRC), the utility/program administrator (PAC), or participating customers (PCT).
- **Maximize peak deferral value:** This objective maximizes the total kW of peak deferral achieved or the value of distribution deferrals (when the upgrade project information is available and the detailed T&D deferral feature is enabled).
- **Minimize total incentive spent:** This objective minimizes the total incentives needed to achieve peak deferral. Note that the incentive calculation occurs before the portfolio selection, and adoption rates are determined based on pre-calculated incentive levels. Thus, portfolio selection is an allocation of incentives among economically achievable measure adoptions.

The tool will use cost-effectiveness and adoption calculations to develop portfolios of DERs that meet the T&D deferral needs defined by the user. To help constrain the portfolio, the tool provides several types of portfolio constraints and the user can choose at least one of the following constraints to pose on the portfolio:

- **Annual peak kW reductions:** This is the principal portfolio constraint, defined by the T&D deferral need for the distribution location. The portfolio will be designed to meet the annual peak kW reductions needed to achieve T&D deferral.
- **Annual incentive budgets:** This is the total amount of incentives that the utility has available to spend on DER programs.

This framework allows utility planners to adjust incentive programs to incentivize customers to adopt different combinations of DERs that the model estimates to be more valuable to meeting system and local needs. To change the incentive approach, users must adjust the case adoption settings.

- **Fraction of incremental measure cost:** This option reflects when a utility provides a flat incentive, which may be preferable to simplify program administration and communication with customers.
- **Target PCT:** This incentive attempts to target a specific PCT value for customers (e.g., lifetime benefit-cost ratio of 1.0) such that the utility makes adoption cost-effective for the customer.
- **Align PCT and TRC B/C ratio:** This incentive attempts to align the benefits that customers see with the overall value of the measure to the system.

5 DER Portfolio Results

E3 analyzed Tata Power-DDL's system to understand 1) the cost-effectiveness of DER technologies from the PCT and the TRC perspective; 2) the optimal DER portfolio that maximizes the TRC benefits, and 3) what can be done to realize the optimal portfolio.

The study first investigates a business-as-usual (BAU) portfolio that represents expected DER adoptions in Tata Power-DDL's service territory without any additional Tata Power-DDL sponsored DER programs. The BAU portfolio is used to provide a lower bound on the net benefits that DERs can provide. It also shows the cost-effectiveness for each DER technology from the customer's perspective and the corresponding adoptions when no additional DER program is implemented.

Then, the study develops an optimized TRC-maximizing DER portfolio that determines the ideal investment and incentives for DER programs. The study assumes no budget limit for the investment, which means that the optimized portfolio establishes the upper bound on the benefits that DER can provide. The incentive is designed so that the original customer compensation plus incentives equal the benefits that the particular DER brings to the system. For example, if installing a PV system can save ₹700 each month for the customer in its electricity bill, and system benefits provided by the PV system are worth ₹800, then customers will get an additional ₹100/month as an incentive for them to install PV systems. Designing the incentives in this manner ensures customers are compensated with the amount of benefits they provide to the system. This design can help promote the DERs that are beneficial to the system and reduce the potential cost shift within a utility's customer base.

This analysis focuses on the customer-adopted DER; investment decisions for utility-owned DERs are analyzed in Task 3, which seek regulatory approval. The BAU and optimized portfolios are developed for three future scenarios which represent low, mid, and high conditions for DER deployment. Tata Power-DDL is interested in DER strategy in the near term, thus the years 2020, 2021, and 2022 were analyzed.

The remainder of this section describes the three future scenarios and the BAU and optimized portfolio for each of the three scenarios.

5.1 Scenarios

E3 created three scenarios to represent low, mid, and high scenarios for DER adoption. Table 5-1 below summarizes the key drivers in the three scenarios.

+ The low scenario represents current load forecast and policy with less aggressive distribution deferral values and technology cost decline assumptions for PV and storage. This is the least favorable scenario for DER deployment.
+ The mid scenario assumes Tata Power-DDL can renegotiate or resell its existing PPA contracts, and as a result, DER technologies can avoid fixed cost payments. In addition, this scenario assumes more aggressive distribution deferral values and technology price declines than the low scenario.

- The high scenario describes a future world with high electrification and renewables. Load growth is assumed to be 1% faster than the current Tata Power-DDL forecast due to increasing EV adoption and building electrification. Future energy and capacity need is met by solar paired with batteries. The highest distribution deferral values and the most aggressive technology price declines are also used in this scenario.

Table 5-1. Scenario Inputs Summary

Key Driver in Scenario/Name	Low	Mid	High
Load growth	BAU	0.5% faster than the current forecast	1% faster than the current forecast
Existing and new PPA	**Existing PPAs**: able to resell the VC component for surplus PPAs **New PPAs:** coal PPAs from the market	**Existing PPAs**: Able to resell surplus PPAs for both the VC and FC components **New PPAs**: coal PPAs from the market[10]	**Existing PPAs**: Retire 200 MW of the least efficient coal plants in 2019 - 2021 **New PPAs**: PV + storage as new capacity
Distribution system	Less constrained (10th percentile: 187 ₹/kW)	Moderately constrained (50th percentile: 457 ₹/kW)	Highly constrained (90th percentile: 1096 ₹/kW)
Customer retail rates	Existing Tata Power-DDL tariffs	Existing Tata Power-DDL tariffs	Existing Tata Power-DDL tariffs
DER technology costs	**PV**: 60,000 INR/kW ($882/kW) with 3% price decline per year **Storage**: 40,000 INR/kWh ($588/kWh) with a 4% price decline per year **EE**: current price, 0% price decline **EV**: 4 wheelers - start at showroom price in 2018, reach cost parity with internal combustion engine (ICE) vehicles in 2030; 2 wheelers: the show room price	**PV**: 50,000 INR/kW ($735/kW) with 6% price decline per year **Storage**: 30,000 INR/kWh ($441/kWh) with an 8% price decline per year **EE**: current price, 0% price decline **EV**: 4 wheelers - start at showroom price in 2018, reach cost parity with ICE in 2027; 2 wheelers: the show room price	**PV**: 40,000 INR/kW ($588/kW) with 9% price decline per year **Storage**: 20,000 INR/kWh ($294/kWh) with a 12% price decline per year **EE**: current price, 0% price decline **EV**: 4 wheelers - start at showroom price in 2018, reach cost parity with ICE in 2025; 2 wheelers: the show room price
Customer adoption parameters	Base	Base	Base

[10] assumes coal PPAs are domestic coal PPAs, remain real price in the future (7191 INR/kW-yr calculated based on domestic coal PPA contract price, assume in 2016 INR)

5.2 Optimal DER Portfolio

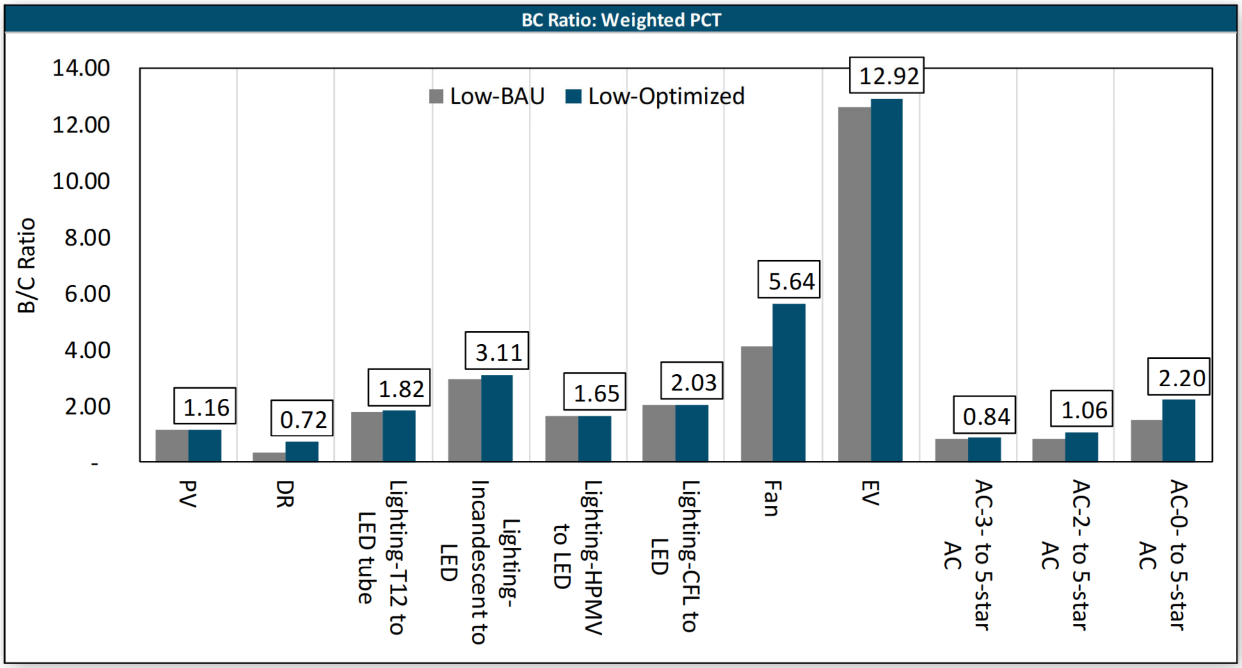
5.2.1 Low Scenario

In the optimized scenario, the model decides to provide incentives to mostly EE measures to promote adoption. The incentives for Fan and Air Conditioning (AC) EE measures make up around 95% of the total incentives due to the overlap of cooling device operating hours and the system peak. The PCT B/C ratio increases for DER technologies that receive incentives in the optimized scenario, which include DR, EE measures, and EVs. The PCT B/C ratios for the BAU and the optimized portfolio are shown side by side in Figure 5-1 below.

Table 5-2. Low – Optimized Portfolio: Incentive Spent by DER Categories

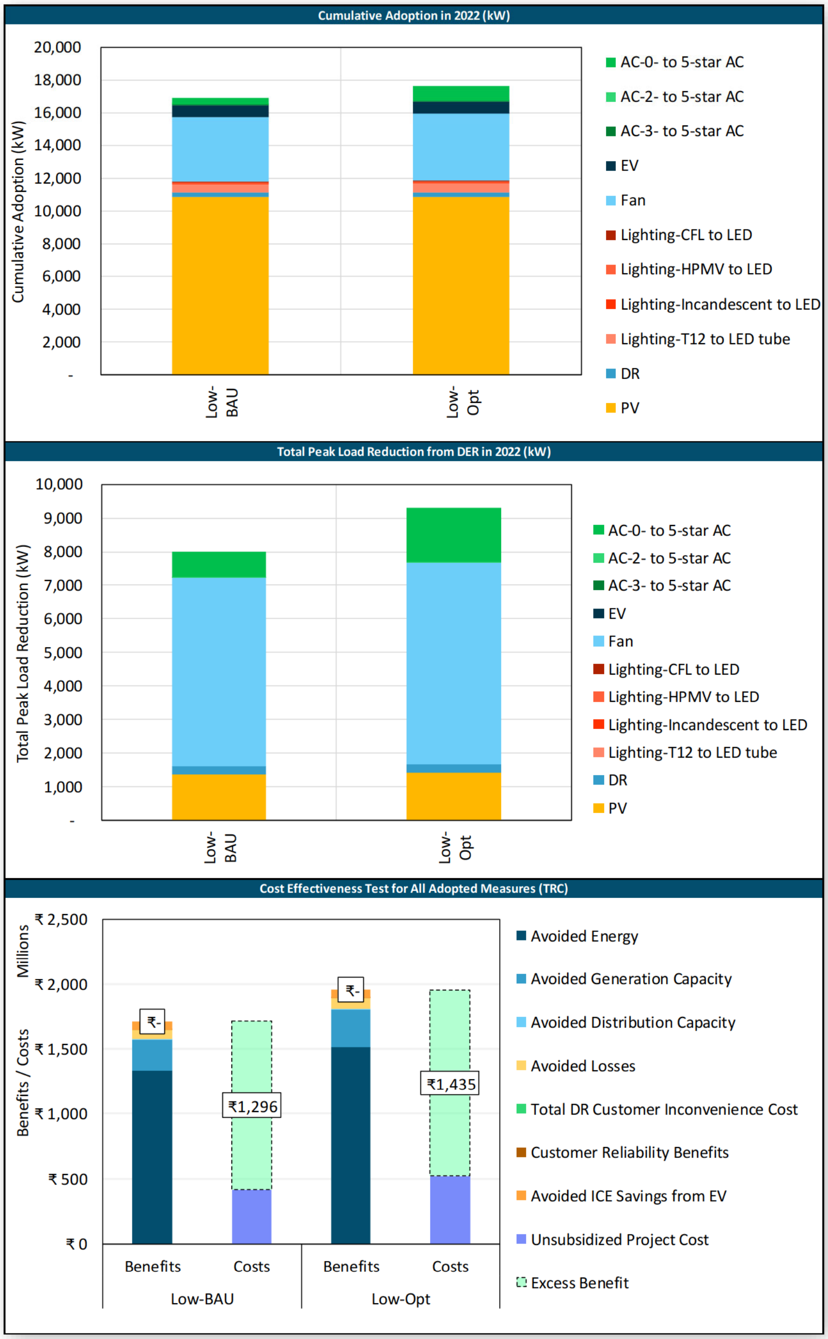
DER Technologies	Incentive Spent (2019₹ lakh)	Percentage (%)
Storage	₹ 0.00	0.0%
PV	₹ 6.42	0.1%
DR	₹ 4.46	0.1%
Lighting-T12 to LED tube	₹ 133.21	2.4%
Lighting-Incandescent to LED	₹ 22.33	0.4%
Lighting-HPMV to LED	₹ 0.00	0.0%
Lighting-CFL to LED	₹ 1.05	0.0%
Fan	₹ 3,880.93	69.4%
EV	₹ 24.42	0.4%
AC-3- to 5-star AC	₹ 1.78	0.0%
AC-2- to 5-star AC	₹ 49.81	0.9%
AC-0- to 5-star AC	₹ 1,470.34	26.3%
Total	₹ 5,594.74	100.0%

Figure 5-1. Low – Optimized Portfolio: Weighted PCT B/C Ratio by DER Technologies



The figure below shows the comparison between the BAU and the optimized portfolio on cumulative adoption, peak load reduction, and TRC net benefits in each portfolio.

Figure 5-2. Low – Optimized Portfolio: Comparison



As shown in the figures, cumulative adoption in the optimized case has increased slightly by 681 kW in 2022. Most of the increase comes from AC EE measures, which increase by 462 kW, followed by Fan EE measures, which increase by 161 kW due to incentives. The optimized portfolio reduces peak load by an additional 1,312 kW as compared to the BAU portfolio, which largely comes from AC and Fan EE measures, which increase by 1,264 kW collectively. The net benefits provided by the DERs from the TRC system perspective increase by 139 Million INR in the optimized scenario.

5.2.2 Mid Scenario

In the optimized mid scenario portfolio, similar to the optimized portfolio in the low scenario, the model still chooses to provide incentives for Fan and AC EE. In addition, the model also provides incentives to the DR program to promote adoption. This is due to the higher distribution avoided costs assumed in the mid scenario.

The following figure shows the PCT B/C ratios by DER technology for the BAU portfolio and the optimized portfolio. Comparing the B/C ratios in the two portfolios, DR and Fan EE have the biggest change because of the additional incentives provided in the optimized portfolio.

Table 5-3. Mid – Optimized Portfolio: Incentive Spent by DER Categories

DER Technologies	Incentive Spent (2019₹ lakh)	Percentage (%)
Storage	₹ 0.00	0.0%
PV	₹ 38.79	0.3%
DR	₹ 1,371.60	10.9%
Lighting-T12 to LED tube	₹ 209.63	1.7%
Lighting-Incandescent to LED	₹ 34.71	0.3%
Lighting-HPMV to LED	₹ 0.00	0.0%
Lighting-CFL to LED	₹ 1.73	0.0%
Fan	₹ 7,760.14	61.9%
EV	₹ 24.55	0.2%
AC-3- to 5-star AC	₹ 4.75	0.0%
AC-2- to 5-star AC	₹ 185.68	1.5%
AC-0- to 5-star AC	₹ 2,912.19	23.2%
Total	₹ 12,543.77	100.0%

Figure 5-3. Mid – Optimized Portfolio: Weighted PCT by DER Categories

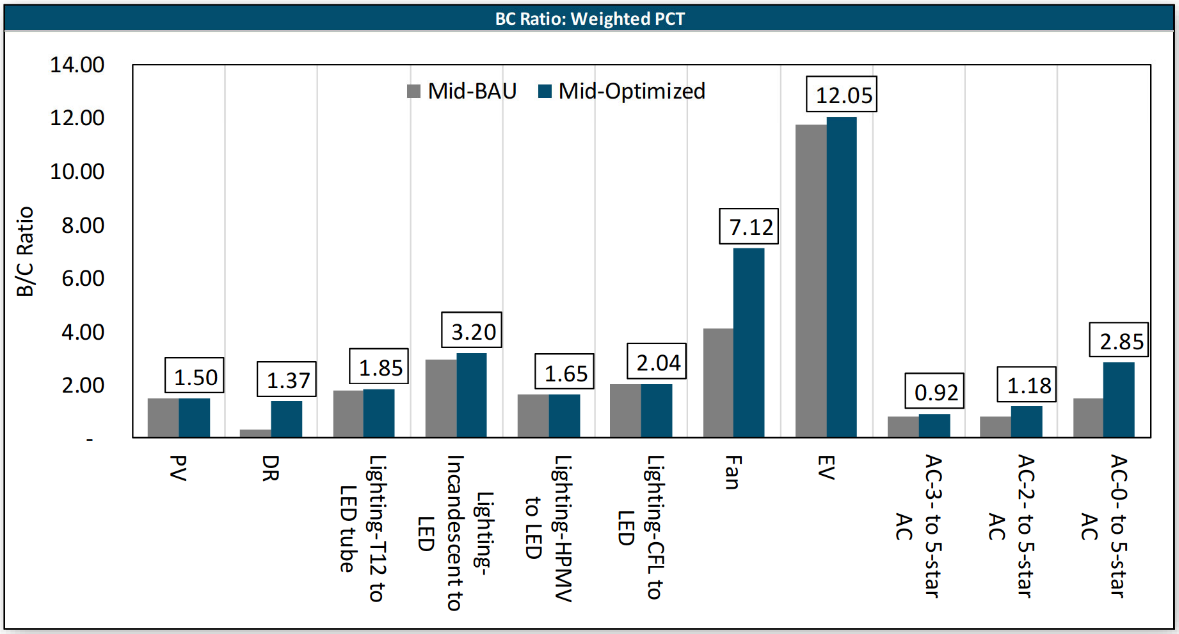
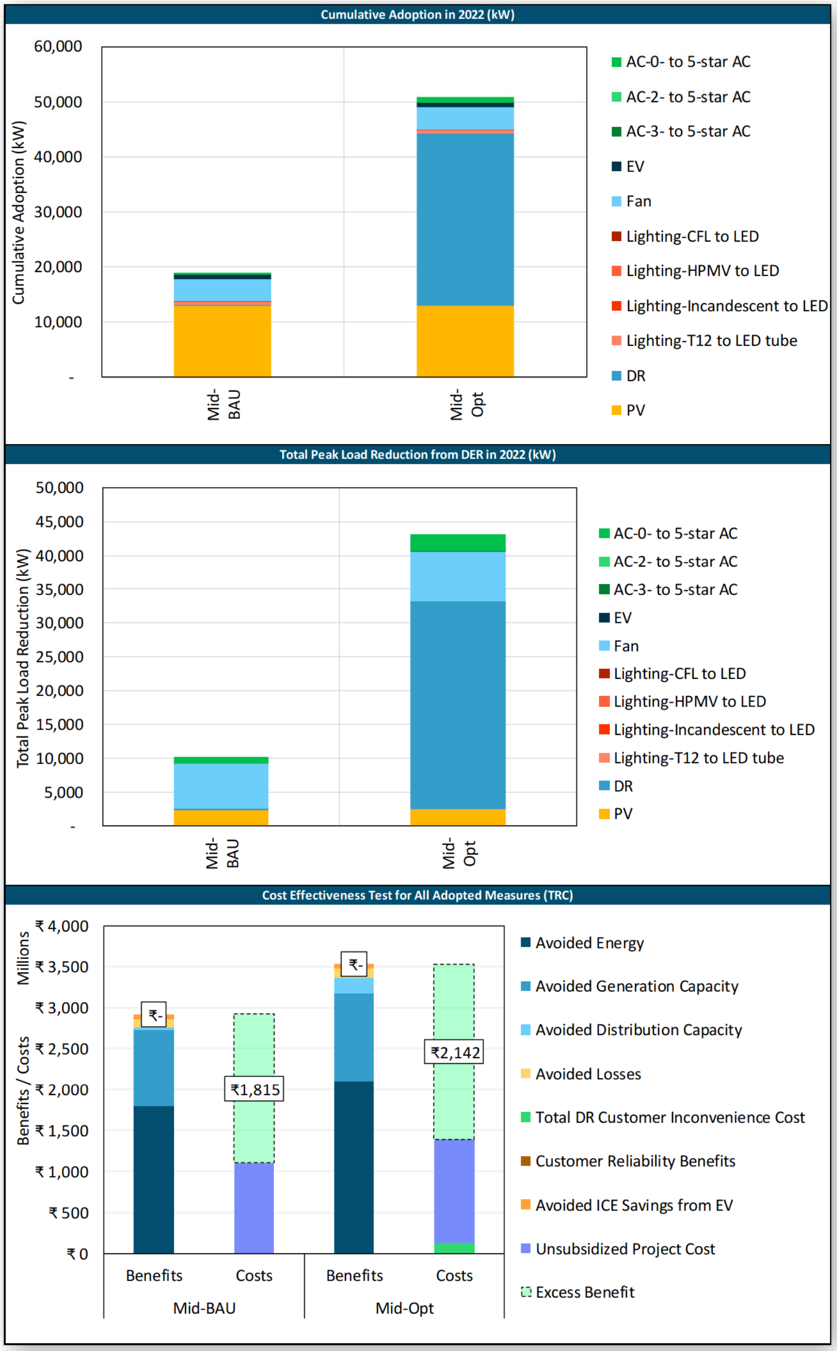


Figure 5-4 below shows the comparison between the BAU and the optimized portfolio on cumulative adoption, peak load reduction, and the TRC net benefits.

Figure 5-4. Mid – Optimized Portfolio: Comparison



The first chart shows the comparison of cumulative DER adoption. Because of the incentives in the optimized scenario, we see a large increase in DR adoption. The cumulative DR adoption increases from 286 kW in the base scenario to 31,256 kW in the optimized portfolio. Fan and AC EE measures also have a slight increase in adoption due to the incentives. Because they are already cost-effective without the incentives, the increase in adoption for EE measures is not as significant as DR adoption. The increase in adoption leads to the increase in peak load reduction as shown in the second chart. In the optimized portfolio, the peak load reduction in 2022 increases by 32,899 kW, of which 30,540 kW comes from DR programs. As shown in the third chart, the net TRC benefit of the whole portfolio has increased to 2,142 million INR. This is 327 million INR more than the 1,815 million INR net benefits in the BAU portfolio.

5.2.3 High Scenario

As shown in the figure below, AC and Fan EE measures still make up a large share of total incentives in the high scenario. The incentive share for DR programs also increases because DR programs provide a significant reduction to the distribution peak, which is highly valuable in the high scenario with its high distribution avoided costs.

The weighted PCT B/C ratio for DR programs increases from 0.33 in the BAU portfolio to 2.92 in the optimized portfolio, as shown in Figure 5-5. Each customer is given ₹ 1357/kW-yr on average for participating in the DR programs. The incentives increase the expected DR adoption by 62,907 kW, which contributes to 61,554 kW of peak load reduction as shown in Figure 5-6.

Table 5-4. High – Optimized Portfolio: Incentive Spent by DER Categories

DER Technologies	Incentive Spent (2019₹ lakh)	Percentage (%)
Storage	₹ 0.00	0.0%
PV	₹ 2,005.23	6.5%
DR	₹ 6,672.67	21.6%
Lighting-T12 to LED tube	₹ 536.45	1.7%
Lighting-Incandescent to LED	₹ 87.44	0.3%
Lighting-HPMV to LED	₹ 0.00	0.0%
Lighting-CFL to LED	₹ 6.70	0.0%
Fan	₹ 14,807.64	48.0%
EV	₹ 24.76	0.1%
AC-3- to 5-star AC	₹ 670.86	2.2%
AC-2- to 5-star AC	₹ 478.34	1.6%
AC-0- to 5-star AC	₹ 5,538.81	18.0%
Total	₹ 30,828.89	100.0%

Figure 5-5. High – Optimized Portfolio: Weighted PCT by DER

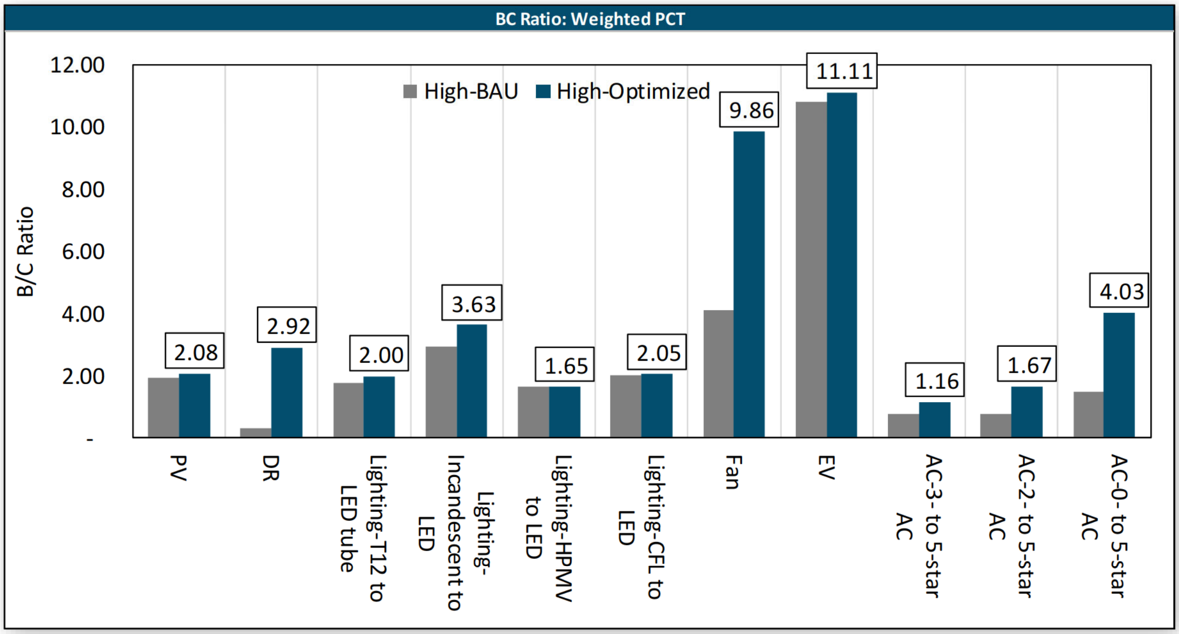


Figure 5-6 below shows the comparison between the BAU and the optimized portfolio on cumulative adoption, peak load reduction, and the TRC net benefits. The TRC net benefit for the optimized portfolio is 1,039 million INR higher than the net benefits in the BAU portfolio

Figure 5-6. High – Optimized Portfolio: Comparison

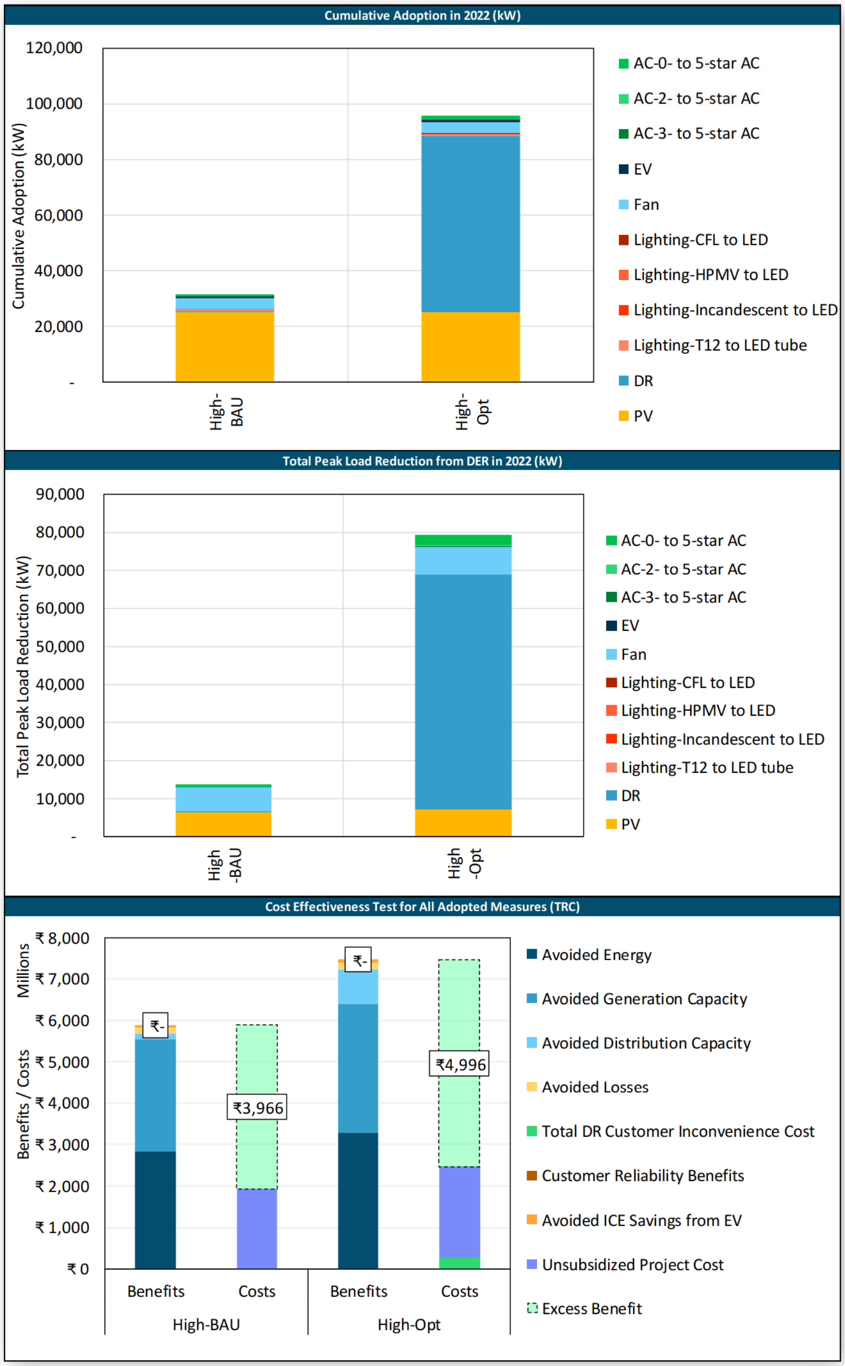
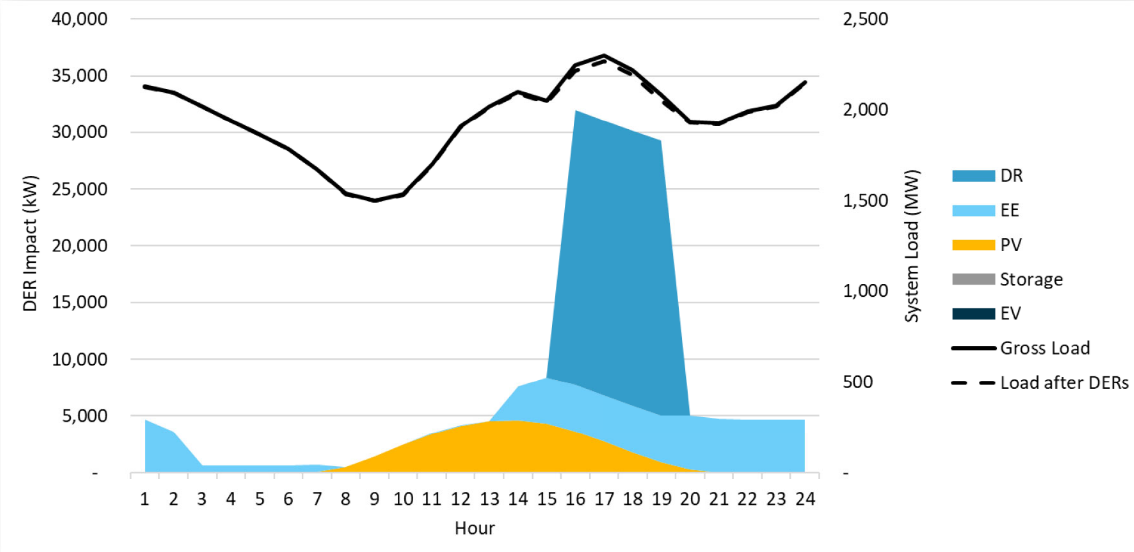


Figure 5-7 below shows the DER impact on the system peak day with the optimized portfolio in the high scenario. The load reduction from PV and EE remains similar to the BAU portfolio in the low scenario, however, the contribution from DR programs increases significantly. Because DR programs can be called specifically for peak hours, they provide a targeted solution for both system and distribution peaks.

Figure 5-7. High – Optimized Portfolio: Peak Day Snapshot



5.3 DER Portfolio Conclusion

The conclusions from the analysis are summarized below:

BAU Scenario Conclusions

+ In the BAU scenarios, when no additional DER programs are implemented, the tool forecasts that customers will adopt EE measures, especially efficient fans and ACs, as well as PV and electric 2-wheelers. If PV technology costs decline aggressively, as shown in the high scenario, PV adoption is expected to increase by 14,478 kW compared to the low scenario without additional utility incentives.
+ Electric 2-wheelers are already cheaper than the equivalent ICE 2-wheelers in the current market. The electric 2-wheelers' upfront capital cost is ₹10,875/vehicle less than the equivalent ICE 2-wheelers. It also saves customers ₹350/vehicle-year in the O&M costs and ₹19,604/vehicle-year in the fuel costs on average due to the price differential between electricity and gasoline. Electric 2-wheelers are expected to be adopted widely in Tata Power-DDL's territory.
+ Electric 4-wheelers are not cost-effective in the near term due to the expensive vehicle and charger costs. Electric 4-wheelers become cost-effective in 2022 and then reach cost parity with the equivalent ICEs in 2025. In the situation where customers don't pay for chargers, either having access to public or workplace charging, electric 4-wheelers will be cost-effective earlier.
+ The fan and AC EE measures contribute significantly to peak load reduction. These measures are cost-effective from both the customers' and the system's perspectives in all scenarios. Because the operating hours of those devices overlap with TOU peak periods and system peak hours, they provide high bill savings and system cost savings.
+ PV is cost-effective for customers in all scenarios due to the generous net energy metering (NEM) policy. From the TRC perspective, PV is cost-effective only in the mid and the high scenarios when the average energy prices are higher.

Optimized Scenario Conclusions

- In the optimized portfolios, it is beneficial in all three scenarios to incentivize customers to adopt as many AC and fan EE measures as possible. These measures are relatively cheap to purchase but provide significant energy consumption reduction in system peak hours.
- Very little DR will be adopted if utilities don't provide additional incentives. Customers experience bill savings by conserving energy during the DR hours, but these bill savings alone are not high enough to overcome the inconvenience customers face when responding to the DR calls.
- When there are capacity constraints in either the bulk system or distribution system, providing incentives for customers to participate in DR programs is a targeted and cost-effective solution.
- Incentives are not allocated to EVs in the optimized portfolio when the portfolio is designed to maximize TRC benefits. Electric 2-wheelers don't need additional utility incentives as they are already cost-effective. Due to the high vehicle cost, electric 4-wheelers are not cost-effective from the TRC perspective in the near term. This results in no adoption of electric 4-wheelers in the optimized scenarios.
- The environmental benefits provided by EVs, such as emission reductions, air quality improvement, and health benefits, are not included in the TRC. Even though TRCs are shown as negative in the near term, they can turn positive if environmental benefits are included, which would be in the government's interest due to public health interests. EV adoption can significantly increase the utility's revenue in the future. There are strong reasons and viable business development opportunities for EV promotion even though the TRC is negative in the study.
- Personally-owned light-duty electric vehicles can have a minor impact on the system peak if the correct rate signal is sent. Tata Power-DDL's system peak happens during the summer afternoon (2-5 PM) and at midnight. If customers are conscious about peak TOU periods or the vehicle is programmed to charge during cheap hours, it is easy to avoid charging during peak hours and meet customers' driving needs at the same time. Customers who charge at home can avoid peak hours by charging in the early evening or after midnight or charging at work or public places.

6 Implementation

6.1 Distributed Energy Transition Roadmap for Tata Power-DDL

Based on the Task 2 results, emerging opportunities for improved technology in the future, and Tata Power-DDL's future supply conditions, E3 worked with the Tata Power-DDL team to develop a Distributed Energy Transition Roadmap to plan how DER deployment could evolve as Tata Power-DDL's system changes and new technology makes additional cost-effective programs possible. The Distributed Energy Transition Roadmap for Tata Power-DDL is intended to provide guidance for assessing the feasibility of implementing a variety of DER programs. The roadmap suggested for Tata Power-DDL outlines the following sequential steps:

1. First, assess cost-effective DER opportunities against the backdrop of the Tata Power-DDL portfolio of supply resources, distribution, and system capacity needs within the two-to-three-year timeframe, and conditions for Tata Power-DDL such as financial impacts of COVID19. Then screen the DER technologies and identify potential high-value DER programs (from Task 2).

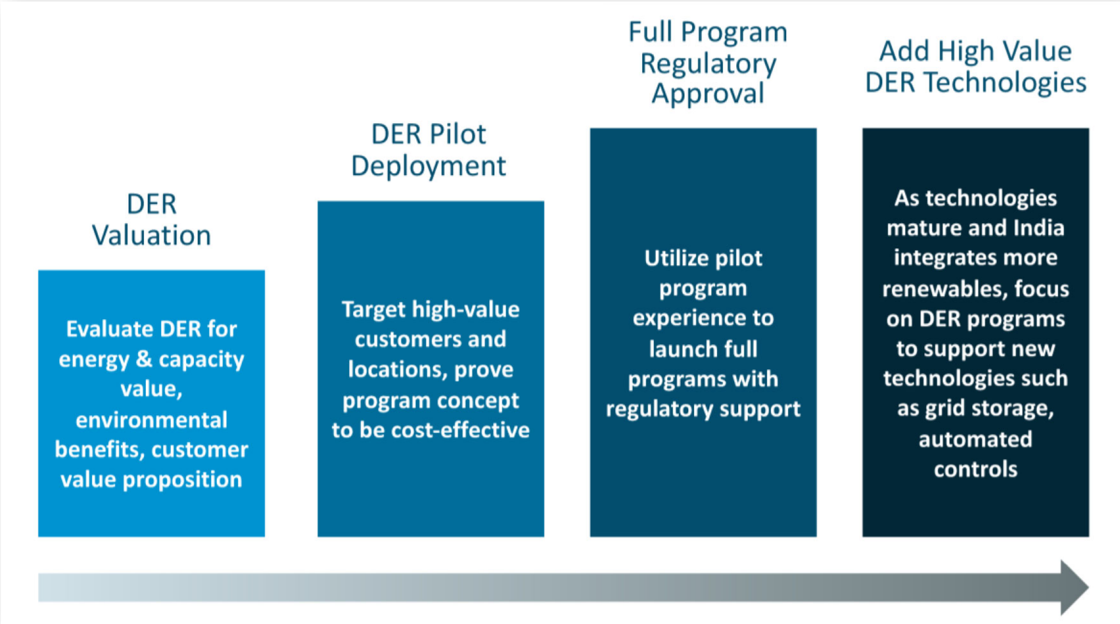
2. Identify the strategy to pilot programs in the initial DER portfolio for implementation and offer select pilot DER programs to customers while engaging the regulator (DERC) and other government authorities and regulatory agencies to improve and consider additional programs.

3. In the longer term, continue to evolve DER pilots to full programs that can benefit customers and support local and national energy policies with programs that have regulatory support.

4. Establish a process that can continue to look for new opportunities to deploy cost-effective DER when and where beneficial.

This process of identifying and cultivating programs into a roadmap is illustrated in the figure below:

Figure 6-1. DER Program Development Approach



In order to develop DER initiatives that ensure customer value, E3 conducted an initial evaluation for six DER programs in Task 3 and calculated their benefits and costs given Tata Power-DDL's system condition and technology costs. This shorter list is reduced from the list of nine or ten potential programs evaluated in Task 2. The selection of the initial six programs is based on the developed roadmap and early conversations with Tata Power-DDL. The initial six programs and their short descriptions are listed below:

- **Energy Transition Tariff Option**: This program creates an additional option for large customers currently eligible for open access. Participating customers would receive 100% renewable energy in return for a commitment to remain on Tata Power-DDL energy service. The intent is to remove one of the reasons that large customers may take direct access (ability to purchase renewable energy) and at the same time recruit industry as partners in support of India's clean energy transition. The commitment to maintain renewable service would be five years or longer, which allows Tata Power-DDL to enter new renewable power purchase agreements ("tie-ups") on behalf of participating customer load without risk of the load departing and shifting costs to others. The program benefits all customers by retaining or adding industrial customers and continuing to sell them contracted generation capacity rather than shifting costs of excess generation capacity to other customer classes as they choose to take open access. As Tata Power-DDL looks to increase the share of renewables on its grid, these large customers would become the 'anchor tenant' and be recognized as leaders in support of India's clean energy transition.
- **Air Conditioning (A/C) Setback**: This program saves both capacity and energy by encouraging customers to keep their cooling setpoint at a higher temperature throughout the summer months. The goal of the program is behavioral with an encouragement to regularly use a setpoint in the range of 25 deg Celsius (78 deg F) during months that require cooling. The program targets are offices, other workspaces, and large buildings (not residential). This program is not designed as a dynamic demand response (which is evaluated separately) but as a routine change in behavior. Program participation will be monitored through WiFi-enabled thermostats allowing Tata Power-DDL program managers to monitor the temperature inside the

participating buildings, as well as visits, and the honor system with customers recognized for their environmental and economic contributions of establishing a 'new normal'.

+ **Distribution 'Hot Spot' Demand Response**: One of the challenges in planning and operating a distribution utility in New Delhi is the high cost of adding capacity in areas where economic and population growth is increasing loads beyond local service capacity ratings. Finding available land to expand service can be impossible or extremely costly. This program would add an additional strategy to distribution planners and allow Tata Power-DDL to contract for local capacity with customers through load reduction in targeted areas. It operates as a demand-response program that reduces capital expenditures and other customer costs relative to the traditional approach of building distribution upgrades through capital projects.
+ **Volt-VAR Optimization**: In this program, the Volt/VAR optimization (VVO) use case is designed to save energy. VVO would be used to maintain optimal voltage throughout the distribution circuits. This would not be a conservation voltage reduction (CVR) approach designed for demand response. By delivering electricity at the optimal voltage at all times, customer energy usage will be reduced in the Tata Power-DDL service territory. In addition, VVO control equipment and systems could provide greater visibility into power along the distribution network to help identify problems (and potentially power theft), which could both supplement other anti-theft initiatives underway and identify new investment/operations in grid infrastructure.
+ **Electric Vehicle Infrastructure**: Tata Power-DDL is actively supporting all types of electric vehicles in support of state and national policy. This support includes designing and building interconnections for mass transit including electric buses, charge-swapping stations for small vehicle categories, and metering and billing at the preferential EV retail rates. These elements are underway. The next step in the program is designed to accelerate electric four-wheeler adoption by filling the business model gap for high amperage and DC charging. Tata Power-DDL can use its financial strength, knowledge of local distribution capacity, and available land (in some cases) to build (and potentially operate) charging infrastructure. Utility-owned charging allows a way to quickly ramp EV deployment. Tata Power-DDL would collect the costs of charging infrastructure as a utility asset. This would allow charging to be built out ahead of the number of vehicles needed to maintain the high utilization for third-party businesses to invest. Infrastructure for charging would in turn encourage more businesses and private citizens to purchase electric vehicles. A range of options has been considered from fully-owned and operated utility charging to business models that use for-profit 3rd party companies to host and maintain Electric Vehicle Supply Equipment (EVSE).
+ **Small-Scale Storage**: This program establishes pilots to deploy small-scale battery storage where it can address and capture a broad range of value streams including distribution capacity (distribution transformers), system capacity, energy, imbalance penalty, and reliability. The smaller scale batteries allow for pole-mounted storage in many locations, which allows the capture of local benefits. Because smaller scale batteries are more costly per kWh, however, the ability to address greater value also comes at additional cost.
+ **Grid-Scale Storage**: Tata Power-DDL has a large grid-scale battery under testing in its research center. This program would look for a larger deployment of grid-scale batteries. The value streams can stack much like small-scale storage, but since they are not located on a distribution system they cannot address the distribution value. On the other hand, larger battery storage systems are lower cost. Value streams available include reduced system capacity costs, renewable integration through reduction of Deviation Settlement Mechanism (DSM) penalties, and energy.

6.2 DER Programs Evaluated for Filing

6.2.1 Energy Transition Tariff (ETT)

This program involves proposing a new large industrial tariff aimed at retaining and adding load in the Tata Power-DDL system and accelerating the achievement of renewable energy goals. Large Tata Power-DDL customers (greater than 1MW) currently have a choice in energy suppliers and do not have to take energy service from Tata Power-DDL. This program would create an additional option for customers eligible for direct access that would provide 100% renewable energy in return for a commitment to remain on Tata Power-DDL energy service. The intent is to remove one of the reasons that large customers may take direct access and at the same time recruit industry as partners in support of India's clean energy transition.

The program benefits all customers by retaining or adding industrial customers and continuing to sell them contracted generation capacity rather than shifting costs of excess generation capacity to other customer classes. As Tata Power-DDL looks to increase the share of renewables on its grid, these large customers would become the 'anchor tenant' and leaders in support of India's clean energy transition. Under the rate, the industrial customer would commit to being transitioned from the existing generation mix (mostly coal power) to renewable energy over a scheduled timeline of five years or greater. By virtue of participating, customers would commit to purchasing energy from Tata Power-DDL over the transition period.

With a portfolio of committed large industrial load as the 'anchor tenant', Tata Power-DDL is at an advantage on several fronts. For instance, with large and committed load, Tata Power-DDL has a better argument to negotiate away from legacy coal contracts. Additionally, by providing renewable energy to customers to those who prioritize it, this program would remove one reason that customers might pursue open access. Finally, this program would allow Tata Power-DDL to attract new load sources (e.g., particularly large data centers) that are also interested in the energy transition and a move towards renewables (e.g., Google, Amazon).

Examples of programs in other jurisdictions

Offering large commercial and industrial customers an optional renewable energy rate option is relatively common. This section provides some example structures and designs.

+ Puget Sound Energy (PSE), Green Direct Tariff[11]

  Green Direct Tariff is offered to PSE corporate and governmental customers to provide them the ability to purchase 100 percent of their energy from renewable energy resources. Participating customers pay effectively a 0.15 cents/kWh premium for subscription to the program today. In order to participate in the program, customers must contract for 100% of their load for 10, 15, or 20 years. There is a fee for the early exit. To meet the program demand, PSE signs 15-20 years of Power Purchase Agreements (PPAs) with renewable facilities. The first project developed for the Green Direct program is the Skookumchuck Wind Facility. Construction began in 2019 and the project went into operation in November 2020. A second project for Green Direct, the 150 MW Lund Hill Solar Project, is under development. Phase I of the program is capped at 75 average MW and is fully subscribed. Initial customers include Target, REI, Starbucks, Western Washington University, Sound Transit, and five municipal government entities.

[11] PSE Green Direct: https://www.pse.com/green-options/Renewable-Energy-Programs/green-direct

- **Rocky Mountain Power (RMP), Service from Renewable Energy Facilities (Schedules 32[12] and 34[13])**
  - In Schedule 32, the customer chooses a renewable facility, and RMP signs a PPA as an intermediary with both sides. The contract price and duration are the same. RMP acts as a passthrough for energy that serves customer load, takes the delivery role, and pays for excess generation. There is a 300 MW cap for the initial program participation.
  - In Schedule 34, RMP signs a PPA with renewable facilities. The customer then contracts with RMP for either the difference between renewable cost and avoided cost of energy or a custom method approved by the commission. Customers still pay for distribution and delivery charges as well as demand charges. There is no customer cap for this program.
- **Xcel Energy – Colorado, Renewable*Connect[14]**

  In this program, Xcel procures 20-year PPAs with solar facilities (total 50 MW) at the price of $33.95/MWh. Customers then pay Xcel Energy a Renewable Connect charge and receive bill credits for the avoided energy and capacity provided by the solar facilities. Customers can sign up for month-to-month, 5-year, or 10-year service.
- **NV Energy, GreenEnergy Rider Tariff (Schedule NGR)[15]**

  Customers can choose to contract for 50% or 100% of their load with a minimum of two years contract term. There is a 250 GWh cap for the standard offering, but NV Energy can also sign customized contracts and there is no limit on specially negotiated prices. Apple (200 MW) and Switch (128 MW) were the biggest subscribers, however, Switch eventually paid $27M to exit in favor of direct access.

Example Rate Design

To ensure that the energy transition rate is competitive, and at the same time recovers enough costs to support fixed costs of the grid without shifting additional costs to Tata Power-DDL's other customers, some key components must be considered while designing the rates:

- The tariff should have energy prices that reflect renewable energy prices and a capacity reservation or annual subscription fee to collect capacity and other fixed costs.
- There should also be a minimum subscription requirement (e.g., 10 or 20MW) and a minimum participation period for customers to ensure steady cost recovery. This reduces transaction costs and results in meaningful renewable procurement sizes when aggregated together.

---

[12] RMP Schedule 32: https://www.rockymountainpower.net/content/dam/rocky_mountain_power/doc/About_Us/Rates_and_Regulation/Utah/Approved_Tariffs/Rate_Schedules/Service_From_Renewable_Energy_Facilities.pdf

[13] RMP Schedule 34: https://www.rockymountainpower.net/content/dam/rocky_mountain_power/doc/About_Us/Rates_and_Regulation/Utah/Approved_Tariffs/Rate_Schedules/Renewable_Energy_Purchases_for_Qualified_Customers_5000kW_and_Over.pdf

[14] Xcel Energy Renewable*Connect: https://www.xcelenergy.com/programs_and_rebates/residential_programs_and_rebates/renewable_energy_options_residential/renewable_connect_for_residences

[15] NVEnergy GreenEnergy Rider: https://www.nvenergy.com/account-services/energy-pricing-plans/green-energy

- There should be a transition period that reflects Tata Power-DDLs supply balance as it transitions towards greater renewable share. Therefore, the tariff might start with a certain % of renewables blend in their supply and transition to 100% incremental renewable energy by a certain date.
- Renewable supply will include solar, wind, and/or other in-country firm PPA contracted by Tata Power-DDL.
- Energy transition tariffs provided by Tata Power-DDL should be at the same cost or less expensive than the current large industrial rates to attract customers but should be high enough to cover current PPA costs and future renewable PPA costs plus the cross-subsidy provided to domestic customers.

Given these considerations, E3 designed a potential rate for Tata Power-DDL as an illustration. The example proposed rate has a 5.5 INR/kWh variable charge and a 500 INR/kW/month fixed charge. The table below shows the proposed rate along with the large industrial customer rate offered by Tata Power-DDL.

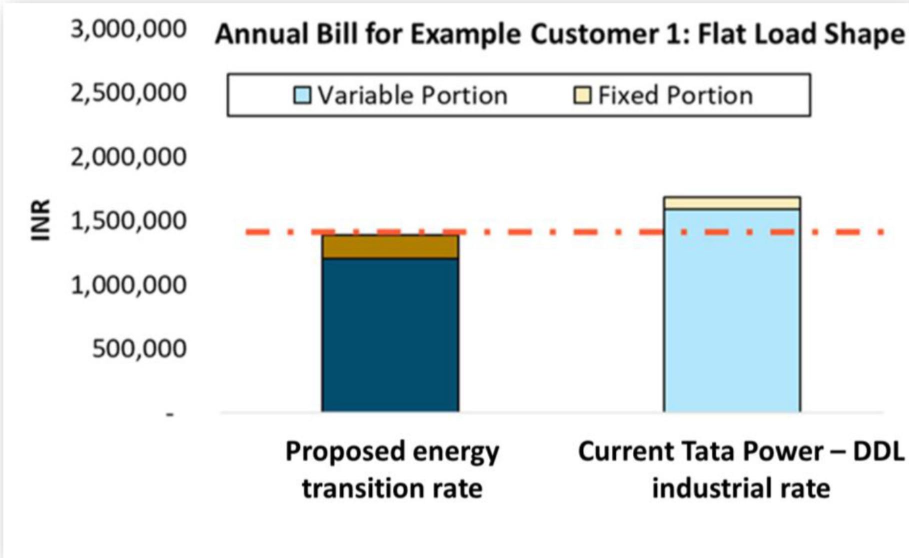
Table 6-1. Proposed ETT Rate and other Industrial Customer Rates

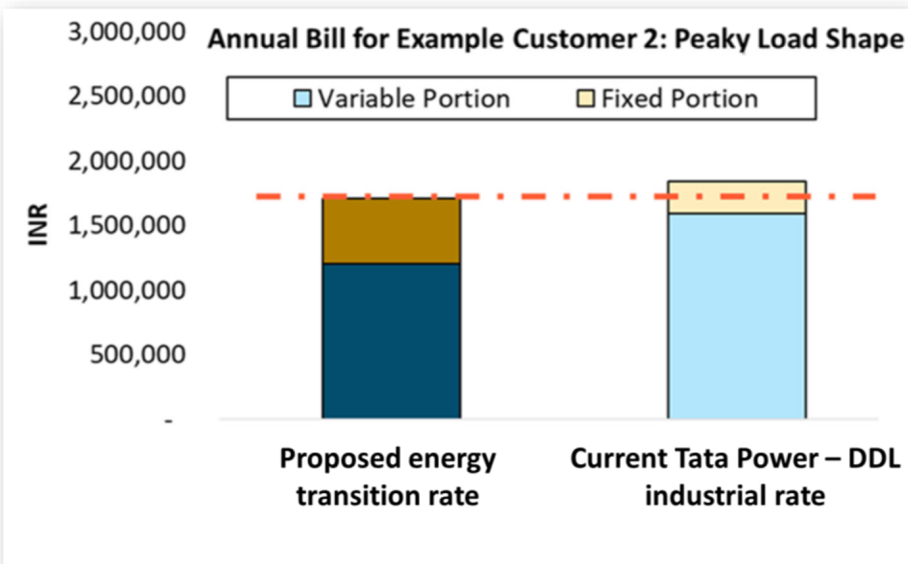
Rates	Variable Charge (INR/kWh)	Fixed Charge (INR/kW/month)
Proposed ETT Rate	5.50	500
Tata Power-DDL Industrial Rate	7.75[16]	250

To ensure that the proposed ETT rate is competitive, we created two example customers and compared the customer bills under the rates listed above. The first example customer has a flat usage shape with annual consumption of 219 GWh and an 80% load factor. The second example customer has a much peakier load shape with the same 219 GWh annual consumption but a much lower 30% load factor. For both examples, the proposed ETT rate is the cheaper option. The annual bill comparison for the two rates is shown in the figure below.

[16] The industrial rates shown for Tata Power-DDL came into effect on September 1, 2020

Figure 6-2. Annual Bills for Example Customers[17]





Example Non-Participant Cost Test (N-PCT) and Margin Calculation

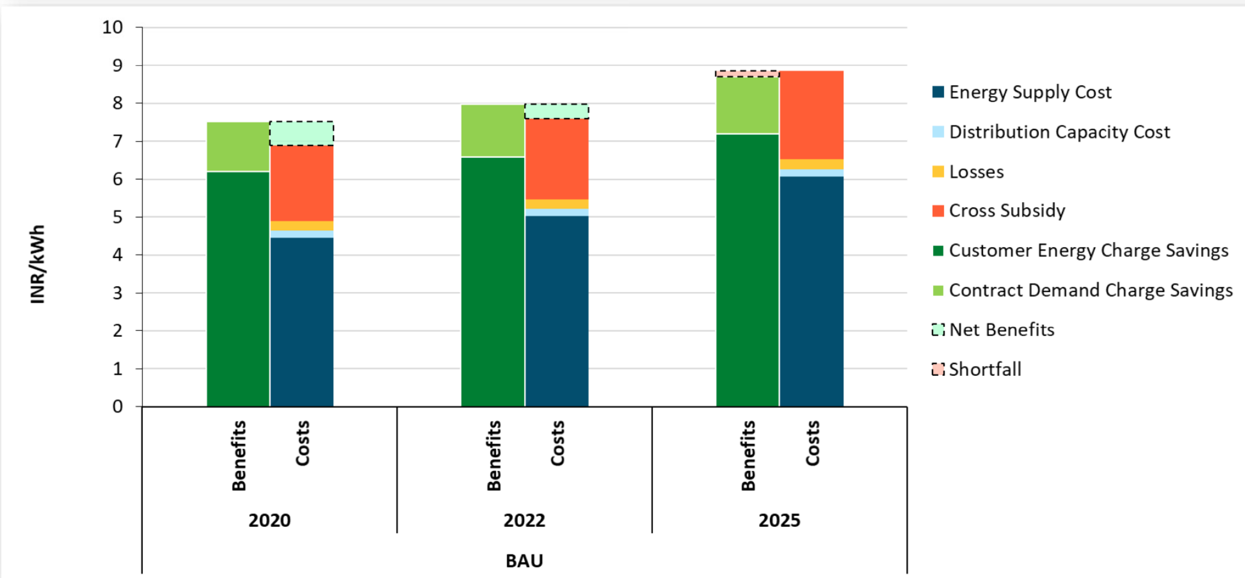
To understand the impact of this hypothetical energy transition rate design, it is important to evaluate any impact on non-participating customers. We used the Non-Participant Cost Test (N-PCT) cost-effectiveness evaluation for this purpose. For the N-PCT, we compared the costs of supplying energy to the new load with the benefits of the increased bill revenue. The costs of supplying energy included the supply energy cost, supply capacity cost, losses, and cross-subsidy for domestic customers. We calculated the N-PCT cost test for an example peaky customer (219 GWh annual

[17] 7.25 INR/kWh industrial rate used for "Current Tata Power-DDL Industrial RateTata Power-DDL industrial rate"

consumption, 30% load factor) with different participating years as shown. ETT rates and the cross-subsidy were escalated at 3% per year. The cost tests were conducted under the Low Scenario from Task 2, which represents a business-as-usual future for Tata Power-DDL assuming no significant change in Tata Power-DDL's resource mix.

As shown in the figure below, after including the 2 INR/kWh cross-subsidy for domestic customers, E3 estimated a net-benefit of 0.6 INR/kWh and 0.4 INR/kWh in 2020 and 2022, suggesting that this program has no negative impact on non-participant customers in early years. In particular, this is because the customer continues to pay the cross-subsidy fee and enough to cover the costs of incremental renewable energy. In 2025, depending on the rate of increase in supply costs, the proposed ETT program is not necessarily able to ensure cross-subsidy under the BAU scenario and shows a net cost of 0.1 INR/kWh (very near break-even). The net cost suggests that the ETT rates are not able to fully cover the 2 INR/kWh cross-subsidy. Several design changes could make this rate viable in the long term. For example, Tata Power-DDL could consider escalation of the energy costs pegged to the supply costs or simply set a higher escalation rate.

Figure 6-3. *Non-Participant Cost Test for Energy Transition DER Program under BAU Scenario*



To further explore the impact on the margins when the ETT subscription is high enough to transition Tata Power-DDL's resource mix, E3 tested two additional hypothetical scenarios: the first scenario assumed Tata Power-DDL adds in 115 MW of solar with the PPA priced at 2.6 INR/kWh and the second scenario added 1900 MW of solar at the same price to the resource mix. The first scenario tested how one large ETT customer changes the overall resource mix and supply costs in Tata Power-DDL. The 115 MW solar is sized to be able to provide the energy for one ETT customer on an annual basis (~200 GWh/year). In the second scenario, we assumed that Tata Power-DDL can attract more ETT customers and thus procure more solar energy. The 1900 MW of solar added can cover 100% of Tata Power-DDL's daytime electricity demand.

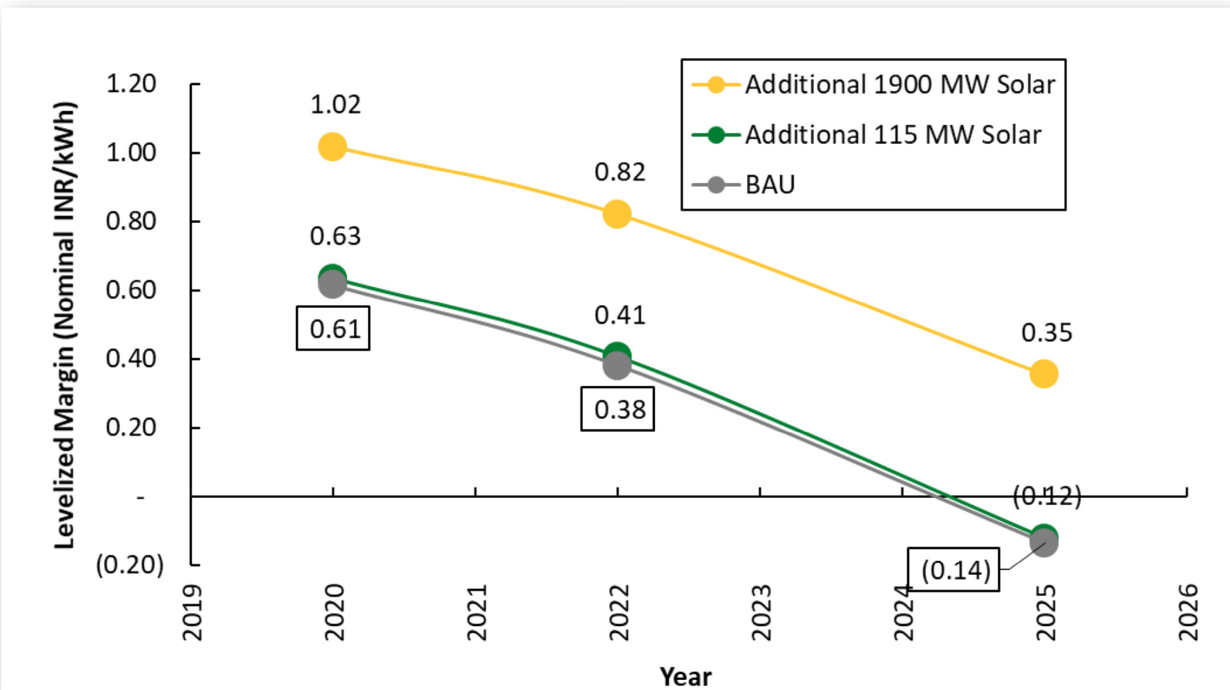
The figure below shows the margins by year for different supply scenarios. The 'margin' is defined as the net benefit in the previous N-PCT test and is equal to the benefits of the increased bill revenue minus the costs of supplying energy to the new load. As shown in the figure below, an additional 115 MW of solar has a small impact on the margins – the margins increase by 0.02 INR/kWh on average. When the renewable penetration level increases with the added

1900 MW solar, Tata Power-DDL's supply costs decrease and the margins increase by 0.44 INR/kWh on average. From 2020 to 2025, results show the margins to be 0.35 – 1.02 INR/kWh under the additional 1900 MW solar supply scenario.

This calculation assumes there is no obligation in holding the existing thermal generation contracts and there is no additional cost to terminate the existing coal contracts. We understand that there might be additional considerations for terminating the thermal PPAs, for example, contract terms and reliability considerations. Those should be discussed thoroughly before terminating thermal PPAs. In addition, the calculation presented here uses simplified assumptions, and it is intended to be used as an illustrative example. For a comprehensive cost-test analysis, different types of customers should be considered.

Since this program is cost-effective, can serve to support India's energy transition, and provides strategic benefits of retaining customers, Tata Power-DDL is looking closely at the opportunity and has filed some preliminary regulatory documents to make it possible to offer this program to customers eligible for direct access.

Figure 6-4. *ETT Margins under Different Supply Options*



6.2.2 Seasonal Air Conditioning (A/C) Setback

Given the hot summers in India, air conditioning is the single largest source of electricity use and drives the capacity need. At the same time, national policymakers have identified the health and economic benefits of changing behaviors so that buildings are not over-cooled. These benefits include health, environment, and economics. This program satisfies the national policy-maker request and is easy to deploy in the near term because it does not rely on complicated technology, just Wi-Fi-enabled thermometers to verify performance.

This program saves both capacity and energy by encouraging customers to keep their cooling setpoint at a higher temperature throughout the summer months. The *encouragement* will be both financial and informational. The financial incentive includes electricity bill savings (resulting from the customer using less electric cooling) as well as a separate financial incentive. The informational piece will include the health and environmental advantages of more comfortable temperature setpoints and reducing energy consumption. AC setback is not a 'dynamic' demand response to solely provide capacity, instead, it is designed to encourage a change in behavior related to thermostat setpoints. Programs that influence behaviors take a long time to have a broad effect on the pattern of overall energy use and help reduce capacity needs in the long term. Program participation will be monitored through Wi-Fi-enabled thermometers, allowing Tata Power-DDL program managers to monitor the temperature inside the buildings. Through an agreement to allow onsite access to the site, the Tata Power-DDL program managers will make site visits to verify the thermostat temperature readings and service the equipment, as needed.

Example cost test results for Tata Power-DDL

To perform cost tests for this program, E3 constructed an example scenario. For this example, we considered the aggregated commercial customers in the BDL (Badli) district of the Tata Power-DDL service territory. Here, air conditioning accounts for 35% of annual electricity consumption and we assumed that seasonal A/C setback could reduce 24% of AC annual electricity consumption. We assumed a program participation rate of 3%, without incentives. We considered the capital cost of installing Wi-Fi-enabled thermometers, estimated at 3559 INR/participant. Finally, we assumed a program lifetime of ten years for each participant.

For this program, E3 performed three cost tests: Total Resource Cost Test (TRC), Non-Participant Cost Test (N-PCT), and the Participant Cost Test (PCT). As shown in the figures below, the TRC reflects the monetized effects to the Delhi region, the N-PCT details the Tata Power-DDL savings on energy supply costs compared to bill revenue, and the PCT examines the monetized effects to the end-user who participates in the program. The cost test results shown are for the BDL (Badli) district as an aggregate. We found that from a total resource cost perspective this program is extremely cost-effective. Furthermore, participating customers enjoy ~12% of bill savings. However, like most every energy efficiency program, the program results in a bill revenue decrease to Tata Power-DDL of 0.1%. Furthermore, in the current situation of Tata Power-DDL with excess capacity, it may not be the right timing to promote this particular program since there is sufficient capacity.

Figure 6-5. Total Resource Cost Test for AC Setback DER Program

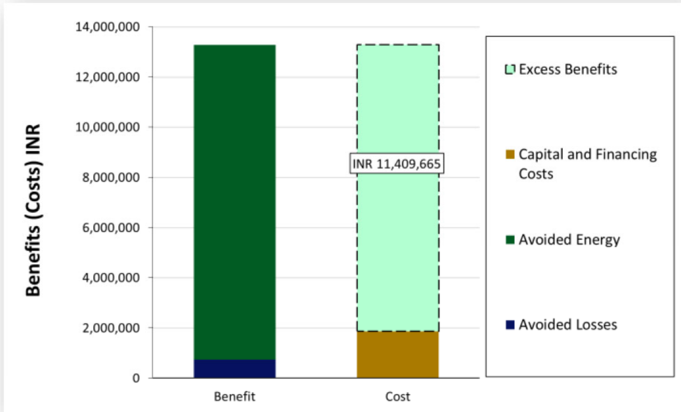


Figure 6-6. Non-Participant Cost Test for AC Setback DER Program

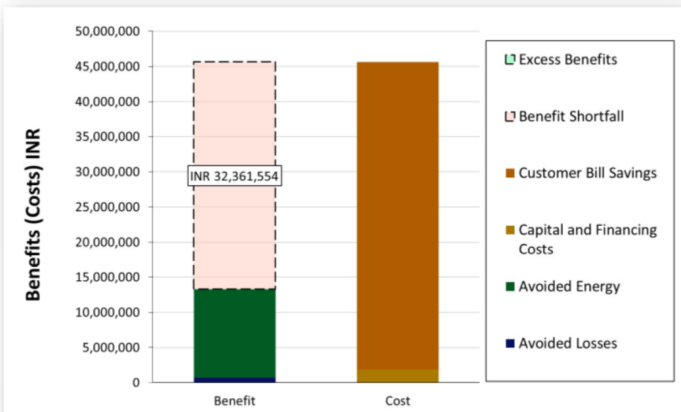
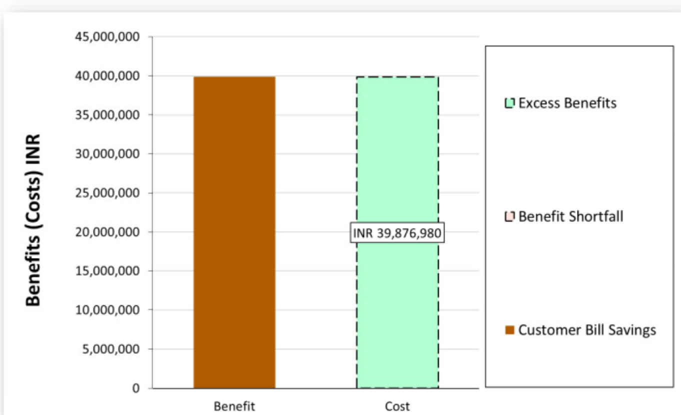


Figure 6-7. Participant Cost Test for AC Setback DER Program



E3 recommends that Tata Power-DDL works with the Ministry to see if there is room for a policy push and whether there is significant goodwill generated by supporting such a policy. Regardless of the Ministry's support, Tata Power-DDL could lead by example by changing their own office setpoints to the suggested 24-25°C range. To engage a broader customer audience, Tata Power-DDL will need to interview them to determine their specific needs and to also communicate the social benefits of such a program. Trial periods of a couple of weeks might also be a good way to illustrate the comfort levels realized by the proposed setpoints and, ultimately, gain traction.

After reviewing the results, Tata Power-DDL has decided to table the implementation of this program for now and focus on implementing other programs in the near term.

6.2.3 Distribution Hot Spot Demand Response

One of the challenges in planning and operating a distribution utility in New Delhi is the high cost of adding capacity in areas where the economic growth is increasing loads beyond local service capacity ratings. Sometimes finding available land to expand service is impossible or extremely costly. This program would add an additional approach for distribution planners and allow Tata Power-DDL to contract for local capacity with customers in targeted areas. It operates as a demand-response program to reduce capital expenditures and other customer costs relative to the traditional approach of building distribution upgrades through capital projects. We expect that customers would provide capacity with their existing systems for utility back-ups such as generators, as well as fossil-free alternatives including energy management systems, adjusted operation schedules, curtailed loads, energy efficiency, and battery storage.

This program will result in a tool for distribution planners and engineers to provide local capacity support through targeted demand response. The demand response payment will be based on the customer value of providing local load relief. This program is flexible enough to deploy year by year in different locations and makes use of the AMI data to monitor performance.

Examples of programs in other jurisdictions

One of the first programs in the U.S. that took steps towards value-based compensation for DERs was the New York (NY) Value Stack, or Value of Distributed Energy Resources (VDER),[18] which served as a replacement to net-energy metering. In VDER, the compensation is based on net electricity injections to the grid on an hourly basis. The hourly value stack then consists of energy, capacity, environmental benefits, and a market transition credit or an avoided distribution value (DRV). Finally, certain projects are also eligible for a locational system relief value (LSRV).

The DRV is provided on a $/kW-yr basis and the calculation of this value varies across the NY utilities, based on their Marginal Cost of Service (MCOS) studies. Next, the utility provides a list of top 10 hours and peak load during those hours (from the previous year) in its VDER credit statements and the DRV rate is allocated to those top 10 hours using a load-weighting methodology (i.e. the top load hour would receive the highest credit).

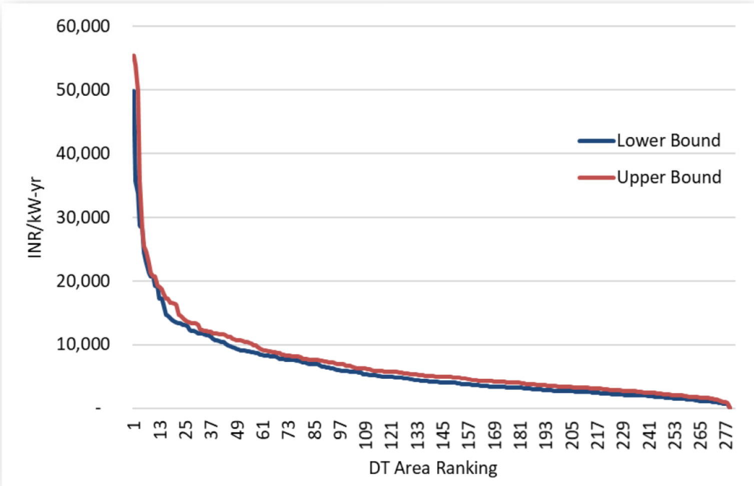
The LSRV credit is available to projects that are located in areas of the grid that are in need of distributed generation (DG) – in other words, highly congested areas. For this, each NY utility provides maps of LSRV zones and MW limits of needed DG capacity. The credit compensation is then tied to the utility's top 10 hours. Finally, zones, limits, and credits are posted monthly on the NY VDER website.

[18] New York VDER:
https://www.nyserda.ny.gov/All%20Programs/Programs/NY%20Sun/Contractors/Value%20of%20Distributed%20Energy%20Resources

Tata Power-DDL Distribution Deferral Opportunity Summary

To investigate the potential distribution deferral opportunities within Tata Power-DDL's territory, Tata Power-DDL calculated the deferral values for each Tata Power-DDL's distribution transformers based on the most recent CapEx plans (FY 2018 to 2023). Figure 6-8 below plots the deferral values from the highest to the lowest. The two lines show the upper and lower bound based on the assumed coincidence factor for areas with multiple transformers. Since this analysis is based on final line distribution transformer (DT) investments, they require load reduction to be located in very specific areas in Tata Power-DDL areas, or 'distribution hot spots'.

Figure 6-8. Sorted Value for Distribution Transformer Deferrals (2018 to 2023)



Example cost test results for Tata Power-DDL

To perform cost-effectiveness analysis for this program, E3 constructed an example case with a constrained residential + commercial zone needing a 1.5 MW peak reduction and with 1,220 INR/kW deferral value. E3 assumed the demand response program pays the customers an equivalent of 1,000 INR/kW for peak load reduction. Furthermore, we assumed that there is a maximum of ten demand response calls per year with a maximum duration of two hours. The administrative costs were assumed to be 100 INR/kW peak reduction with an inconvenience cost of 500 INR/kW to represent the inconvenience for the customer to shift or curtail their load (assumed mostly to be setting A/C setpoints higher). These are relatively conservative assumptions with approximately 250 DT Areas at equal or greater value and 50 DT Areas over 10,000 INR/kW.

E3 performed three cost tests: Total Resource Cost Test (TRC), Non-Participant Cost Test (N-PCT), and the Participant Cost Test (PCT). In general, the TRC reflects the monetized effects to the Delhi region, the N-PCT details the Tata Power-DDL savings on energy supply costs compared to bill revenue, and the PCT examines the monetized effects to the end-user who participates in the program.

As shown in the figures below, E3 found a positive N-PCT, suggesting there were no negative impacts on non-participating customers and participants could also still enjoy bill savings. E3 also found the TRC benefits to be positive, suggesting that the region benefits from deferring distribution upgrades.

Figure 6-9. Total Resource Cost Test for Distribution Hot Spot Demand Response DER Program

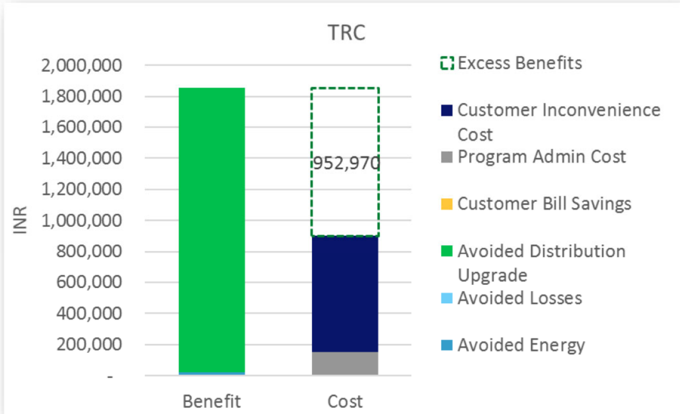


Figure 6-10. Non-Participant Cost Test for Distribution Hot Spot Demand Response DER Program

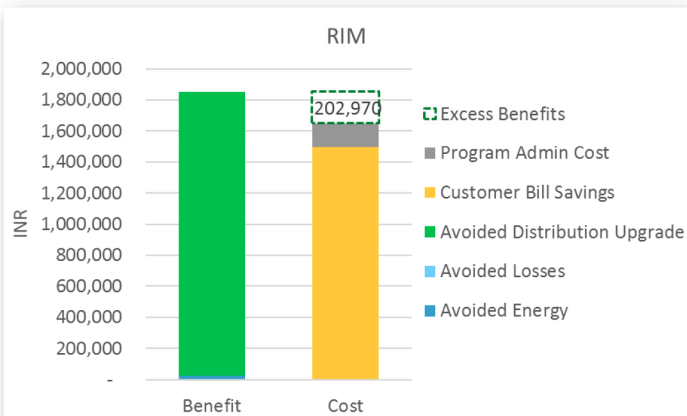
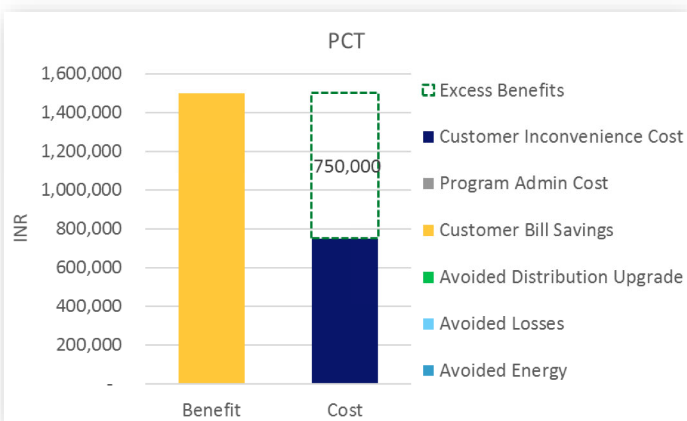
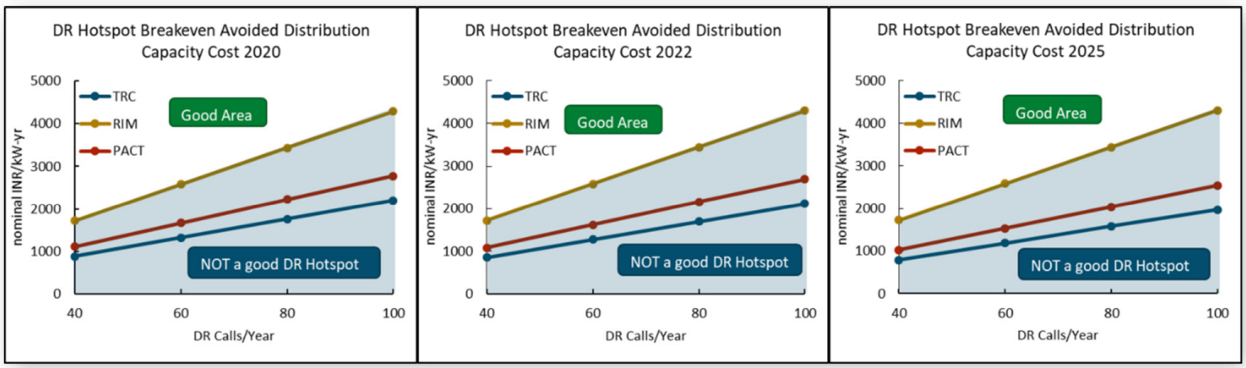


Figure 6-11. Participant Cost Test for Distribution Hot Spot Demand Response DER Program



To prepare for the deployment of the DR Hotspot Program, Tata Power-DDL would introduce an internal distribution 'screening' evaluation for all of their growth-driven planned distribution upgrades. For those areas where a demand response payment can be made for local capacity that is less than the costs of the distribution upgrades, Tata Power-DDL would begin to offer distribution capacity contracts to customers in those service areas. The following chart shows the breakeven distribution capacity costs varying by the number of DR calls per year from the three cost test perspectives for 2020, 2022, and 2025. The DR program would be cost-effective if the distribution location has a deferral value higher than the top of the three cost-test curves. For example, in 2025, any distribution locations with higher than 3200 INR/kW-yr could have a cost-effective DR program with the DR call hours being 80 hours/year. The breakeven avoided distribution capacity costs vary between ~1800 INR/kW-yr to 4000 INR/kW-yr.

Figure 6-12. DR Program Size



Based on the Task 2 results of the optimized portfolio, the initial program evaluation results described earlier, and additional analysis conducted by Tata Power-DDL, Tata Power-DDL has drafted a plan to roll out the demand response programs initially focusing on local distribution hotspots and scalable to system capacity as well in the future depending on system capacity needs.

6.2.4 Volt-VAR Optimization

In this program, Tata Power-DDL would deploy Volt/VAR optimization (VVO) on distribution circuits that require voltage support. Since Tata Power-DDL has sufficient system capacity, the use case is designed to save energy. This would not be a conservation voltage reduction (CVR) approach designed for demand response. In addition, with the VVO equipment deployed in the Tata Power-DDL service territory, additional visibility of distribution system operations is made available which could potentially provide visibility into theft by line segment. It could supplement other anti-theft initiatives underway and also allow Tata Power-DDL to better target investments and operational improvements in smart grid infrastructure.

New technologies are shown to deliver energy savings at a low cost (e.g. $0.01 to $0.02/kWh saved). They also provide power quality improvement, VAR support, and solar PV integration flexibility. Effectively, the VVO program suggested here is a utility-driven energy efficiency program. In the near term, Tata Power-DDL would target the most valuable locations, test the technology, and report on the results. In the long-term, Tata Power-DDL would implement the technology system-wide, allowing everyone to participate.

Examples of programs in other jurisdictions

One example of a VVO technology solution is the company Varentec.[19] This VVO solution involves a 4-part process: (1) monitoring of voltage outliers, (2) precise voltage regulation at the final line transformer (DT), (3) creation of significant voltage margin from lower ANSI band, and (4) the enabling of enhanced Conservation Voltage Reduction. The CVR capabilities include supply-side energy MWh savings, MW demand reduction, PV hosting capacity, or CapEx deferral.

In the U.S., Xcel Energy plans to deploy a total of 4,350 Varentec ENGO devices across 472 circuits servicing the city of Denver, Colorado.[20] They estimate the devices will increase the overall efficiency by ~1.5%. Their project cost is estimated to be $125 million.

Example cost test results for Tata Power-DDL

To perform cost-effectiveness for this program, E3 constructed a stack model to simulate a simplified Tata Power-DDL system dispatch based on PPA contracts. In this model, we assumed that Tata Power-DDL doesn't purchase power from the exchange market given the uncertainty in the future market exchange. Here, system benefits are the sum of avoided energy costs, transmission losses, and distribution losses. We assume the avoided energy is 1% of the Tata Power-DDL system load (i.e. assume VVO increases system efficiency by 1%). Avoided energy costs are then the product of avoided energy and the energy cost. Avoided transmission losses are assumed to be 0.1 INR/kWh and distribution losses are assumed to be 6% of the avoided energy (i.e. assume 6% technical losses). More details about the stack model are described in the Task 2 report.

For this program, E3 performed three cost tests: Total Resource Cost Test (TRC), Non-Participant Cost Test (N-PCT), and the Participant Cost Test (PCT). In general, the TRC reflects the monetized effects to the Delhi region, the N-PCT details the savings to non-participating customers with a comparison of bill reductions to avoided supply costs, and the PCT examines the monetized effects to the end-user who participates in the program.

As shown in the figures below, we found the device cost to be ~1.5 INR/kWh saved and the benefit to be ~3.2 INR/kWh saved. This result yielded positive TRC and PCT results. The results on the impact to non-participants vary. Without additional benefits from theft detection, the program appears largely as an energy efficiency program with negative non-participant cost test results. We found that the VVO program could yield rate-neutral results when the smart grid infrastructure deployed to implement this program led to a co-benefit of an approximately 48% reduction in monetized damages caused by power theft losses compared to 2017-18 level (assumed to be Rs 150 crore[21]), which would be difficult on top of the strategies already successfully deployed at Tata Power-DDL. However, the region (TRC) benefits from the program regardless of theft prevention due to a large amount of energy savings.

---

[19] Varentec: http://varentec.com/

[20] Xcel Energy and Varentec: https://www.greentechmedia.com/articles/read/varentecs-big-deal-with-xcel-energy-a-tipping-point-for-grid-edge-power-ele#gs.zChsVCMT

[21] https://economictimes.indiatimes.com/industry/energy/power/discom-claims-annual-loss-of-rs-150-crore-due-to-power-theft/articleshow/66006417.cms

Figure 6-13. Total Resource Cost Test for Volt-VAR Optimization DER Program

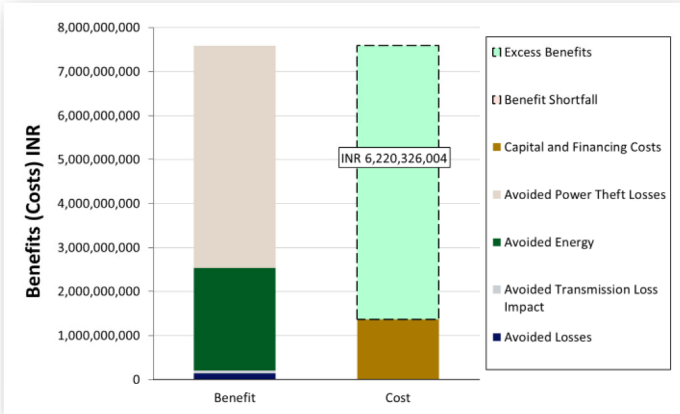


Figure 6-14. Non-Participant Cost Test for Volt-VAR Optimization DER Program

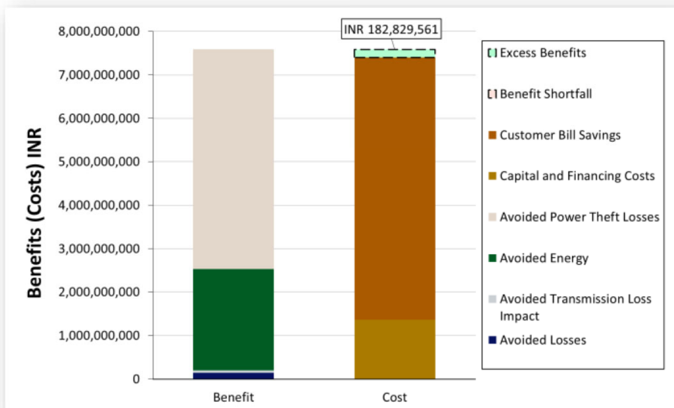
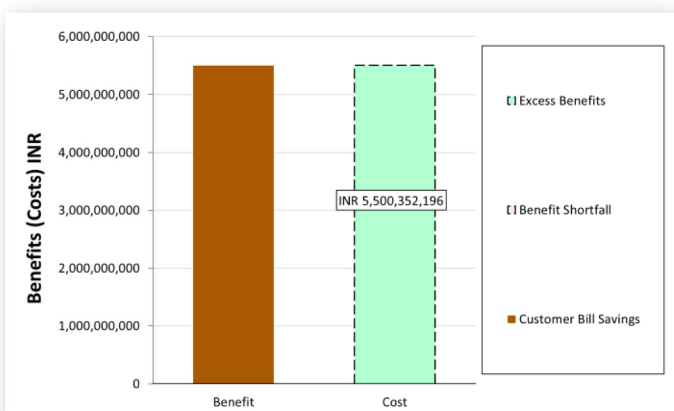


Figure 6-15. Participant Cost Test for Volt-VAR Optimization DER Program



6.2.5 Electric Vehicle Infrastructure

Tata Power-DDL is actively supporting all types of electric vehicles in support of state and national policy including design and build of interconnections for mass transit including electric buses, charge-swapping stations for small vehicle categories, fleet vehicles, rideshares, and metering and billing at the preferential EV retail rates. However, there are significant gaps in India for convenient charging of some vehicle types including small taxi vehicles that use battery swap, and fast charging for larger light-duty vehicles for people who do not have dedicated charging available, for example, in multi-family housing. As seen in many jurisdictions globally, the business case for chargers is fully dependent on the utilization factor of the charging system, but without charging available, EV purchases are low.

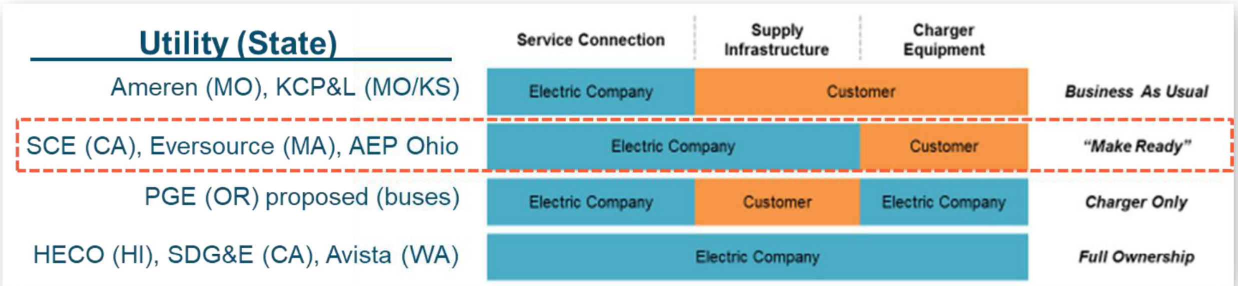
This program is designed to address this 'chicken and the egg' gap and accelerate the use of electric vehicles by deploying charging infrastructure and financing this cost as typical utility capital. There are several reasons why Tata Power-DDL is in a good position to deploy infrastructure to fill the EV charging gaps. In addition to solid financial strength, many Tata Power-DDL distribution substations located across its service territory have available space to serve as vehicle charging centers. Furthermore, these locations have available distribution capacity. Both spaces for charging and local distribution capacity to serve vehicle chargers are extremely expensive in New Delhi unless we leverage the existing Tata Power-DDL infrastructure.

This program involves the acceleration of EV deployment by providing turn-key infrastructure that serves as the foundation of the final EV service equipment (EVSE). In this program, Tata Power-DDL will initially invest in 100 chargers in 50 locations across different location types and then scale to 800 chargers through 2025. The approval for the cost of EV infrastructure must be granted by DERC. The specific arrangement for customer charging costs depends on the market. For public EV charging stations, DERC has set electric vehicle charging rates for electricity. In addition, there may be a convenience fee to pay for charging facilities. For multifamily charging facilities, a structure with a minimum bill has been proposed so that if the capital utilization factor (CUF) is below a given level there is still some recovery from the facility of charging infrastructure costs. For smaller vehicles, Tata Power-DDL is exploring battery swap stations that can serve 2-wheel and 3-wheel vehicles. This application requires less land and each swapping station can charge many battery packs simultaneously, which dramatically improves the number of vehicles it can serve. A driver simply exchanges a discharged battery with a charged battery for a fee. This also gives flexibility to the time of day when charging occurs through controlled battery-pack charging.

Examples of programs in other jurisdictions

Quite a few commissions in the U.S. have approved a variety of roles for utilities in providing charging services. A common role tends to be that utilities install and operate (or finance) a make-ready, which includes a service connection and supply infrastructure for the host to use for installing the charging equipment. The following figure depicts the various utilities and their associated roles in providing charging services in the U.S.:

Figure 6-16. Most common utility roles in providing charging services in the U.S.[22]



To illustrate the varying utility roles and increasing responsibility of commissions to step in on this topic, the following tables depict the resolved and pending cases in key U.S. jurisdictions.

[22] Graphic adapted from EEI: https://www.eei.org/issuesandpolicy/electrictransportation/Documents/Accelerating_EV_Adoption_final_Feb2018.pdf

Table 6-2. Key U.S. Jurisdictions: Resolved Cases

State	Utility	Key Topics
CA	Policy Ruling	Establishes balancing test for utility ownership
	PG&E	DCFC network & original own/operate proposal denied, ownership of L2 limited to MUDs and DACs, elsewhere only make-readies allowed DCFC network-- make-readies at 52 sites (234 chargers)
	SDG&E	Utility owned/operated L2 stations approved DCFC plaza charger demo– utility owned/operated, w/ partner
	SCE	Make-readies and rebates for L2 stations approved DCFC Park & Ride demo-- 8 utility owned/operated
FL	Duke Energy Florida	FPSC approved DEF's EV Charging Station Pilot Program as part of a larger settlement involving cancellation of a nuclear plant, grid mod, etc… DEF to "purchase, install, own and support" up to 530 L2 and DCFC Order authorizes recovery of $8M plus reasonable O&M over 5 years
FL	Gulf Power	FPSC approved a settlement with them too (5/2017), also includes EVSE Allowed to provide EV charging stations "on a revenue neutral basis."
HI	Hawaiian Electric	25 utility owned DCFC approved and subsequently reauthorized HPUC directed HECO to develop a comprehensive, long term strategic plan
KS	KCP&L	Application to rate-base extensive network of L2 and DCFC denied
MA	Policy Ruling	Utility ownership of EVSE permitted if meets criteria set by MDPU
	Eversource	12/2017 MDPU order allows Eversource to rate-base costs of DCFC make-readies and rebates. National Grid's case still pending.
MI	Consumers Power	Proposal for utility owned network of 810 L2 chargers and DCFC withdrawn following negative PD MPSC now overseeing stakeholder process on utility role
MO	KCP&L	Application to rate-base extensive network of L2 and DCFC denied
	Ameren	Application to rate-base pilot corridor network of 6 L2 and DCFC denied
OH	AEP Ohio	Utility originally proposes to own/operated DCFC, but settled for make-readies. Ohio PSC approved settlement
OR	PGE	Pilots with utility owned chargers.
	PacfiCorp	OPUC approved settlements for both utilities.
PA	PECO	They got something in their latest rate case
UT	Rocky Mountain Power	Approved cost recovery for a 5 year, $10M EV pilot devised pursuant to legislation. Allows up to $2M in grants for hosts that install DCFC.
WA	Policy Ruling	Utilities may own, operate and rate-base a portfolio of EVSE
	Avista	WUTC approved Avista's request to do a pilot installation of 265 L2 and 7 DCFC, however Avista deferred pursuit of cost recovery until a later rate case

Table 6-3. Key U.S. Jurisdictions: Pending Cases

State	Utility	Key Topics
MI	Consumers Power	Consumers EV strategy: Utility rebates w/o ownership focusing on 1) residential charging, 2) public/workplace charging, 3) DCFC and 4) IT Infrastructure
	DTE	Charging the Future of Michigan: 1) Improve EV experience for residential and commercial customers, 2) pilots testing VGI and consumer preferences and 3) implement sustainable program to grow EV adoption. Pilots include downtown municipal charging and corridor DCFC, and DR and battery storage integration, with 32 public DCFC, 1,000 L2 commercial chargers and 2,600 smart residential chargers

Example Cost Test

To perform cost-effectiveness analysis for this program, E3 created an example scenario that represents one of many possible modes for EV charging infrastructure. In this scenario, E3 assumed that Tata Power-DDL would install charging infrastructure for companies that would like to use electric rickshaws to provide last-mile transportation for employees. In this case, the EV charging is compared to an alternative program with gasoline-powered ICE rickshaws. These could also be compressed natural gas (CNG) rickshaws, which have similar results. We assume that companies would be installing 3.3 kW L1 Bharat charging stations (make-ready costs are not included in this example). Benefits and costs are reported as per each L1 3.3 kW Bharat charging station.

For this program, E3 performed three cost tests: the Total Resource Cost Test (TRC), the Non-Participant Cost Test (N-PCT), and the Participant Cost Test (PCT). In general, the TRC reflects the monetized effects to the Delhi region, the N-PCT details the Tata Power-DDL savings on energy supply costs compared to bill revenue, and the PCT examines the monetized effects to the end-user who participates in the program.

As shown in the figures below, we found positive net benefits for each of the cost tests. Therefore, we found this program did not negatively impact non-participating customers and that the region benefitted from an overall reduction in gasoline compared to a minimal increase in electricity costs. For participating companies, we found that the hosts enjoy the cost savings from avoided fuel purchases (after accounting for paid charging).

Figure 6-17. Total Resource Cost Test for EV Infrastructure DER Program

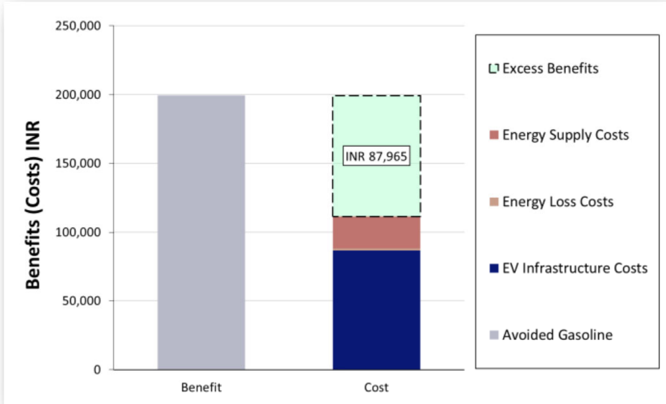


Figure 6-18. Non-Participant Cost Test for EV Infrastructure DER Program

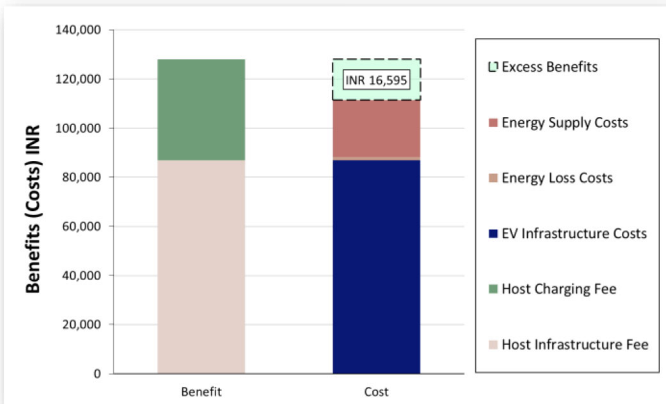
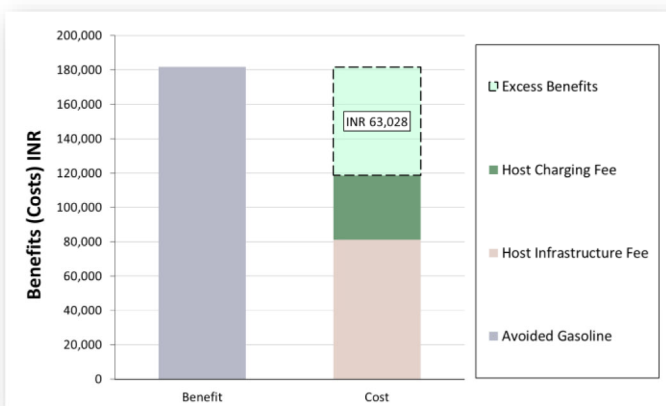


Figure 6-19. Participant Cost Test for EV Infrastructure DER Program



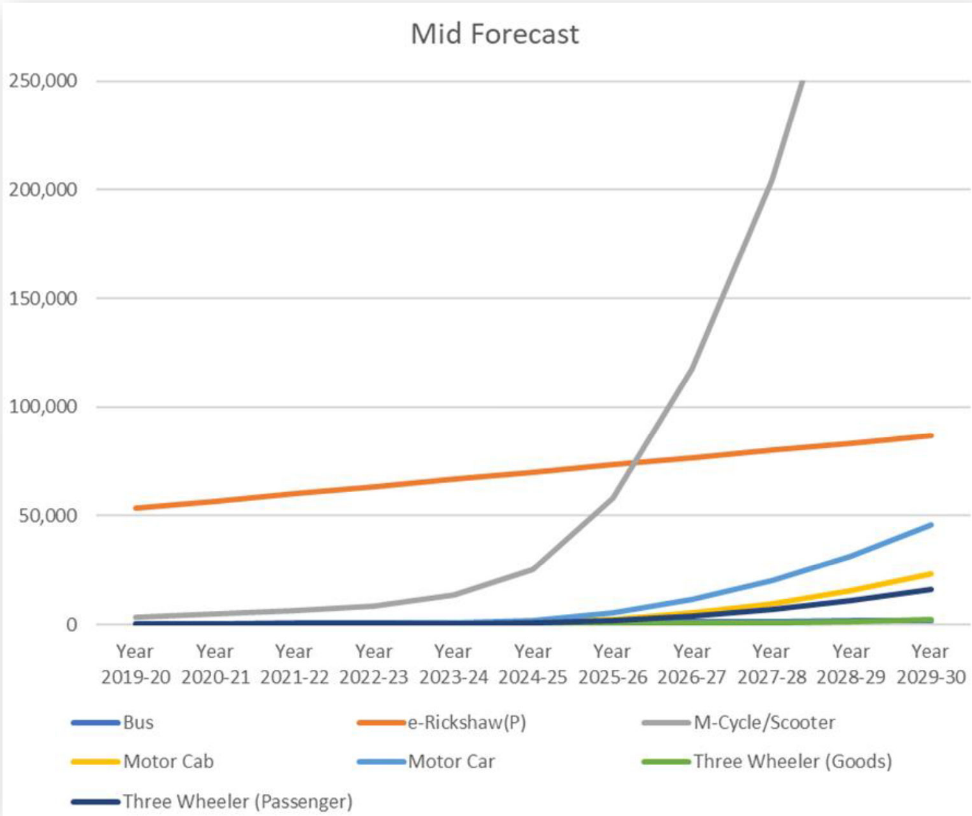
In addition to conducting a cost-effective analysis for a representative use case, the team also estimated the non-participating customer impact of the entire EV portfolio and charging stations for Tata Power-DDL's territory from now to 2030. EV adoption was based on projections given in "India's Electric Mobility Transformation: Progress to Date and Future Opportunities," NITI Aayog with Rocky Mountain Institute; April 2019 for 2030. The scenario mentioned in the report - "If FAME II and other measures are successful, India could realize EV sales penetration of 30% of private cars, 70% of commercial cars, 40% of buses and 80% of two and three-wheelers by 2030," was taken as a high scenario. The medium scenario is two-thirds and Low scenario is one-third of the high scenario. The table below summarizes the total sales projections for 2030 under the three scenarios.

Table 6-4. EV Sales Projections in 2030

Vehicle Category	% of Total Sales by 2030		
	HIGH	MED	LOW
4 Wheelers (Private)	30%	20%	10%
4 Wheelers (Commercial)	70%	50%	30%
2 Wheelers	80%	50%	30%
3 Wheelers (Auto-Rickshaw repl.)	80%	50%	30%
3 Wheelers (Freight)	80%	50%	30%
Buses	150% of DTC's fleet size.	100% of DTC's fleet size.	50% of DTC's fleet size.
e-Rickshaw (Cycle-Rickshaw repl.)	The estimates for e-Rickshaws in Delhi ranges from 100K to 200K, of which only about 50K are registered. For purpose of this study, we have estimated current population (FY2018-19) to be 150K. It is our assessment that the sector is approaching saturation. So going forward, we are assuming addition of 10K per year.		

Based on the 2030 sales projections above and the yearly vehicle sales extrapolated from Transport Department (GoNTCD) data, we estimated the vehicle adoption in Tata Power-DDL's territory by assuming the vehicle sales increase as exponential initially and linear in later years. Figure 6-20 below shows the EV adoption forecast in the mid scenario by year and by vehicle type.

Figure 6-20. Mid-range EV adoption Forecast by Vehicle Type



We then investigated the impact of building DCFC charging stations to accommodate this mid-level EV forecast on non-participating customers. We assumed 100 charging stations built to be operational in 2021 and a service charge of 2 INR/kWh applied in the DCFC charging stations. In addition, we assumed Tata Power-DDL receives a subsidy from the Ministry of Industry. Two types of DCFC charging stations were tested, unattended stations and attended stations. In both cases, the overall electric vehicle portfolio was cost-effective for customers overall after accounting for the DCFC station. The unattended stations broke even in 2027 and required approximately a 12% capacity utilization factor (CUF) at each station to break even. The attended stations broke even in 2029 and required approximately 26% CUF at each station to do so. The illustrative payback and CUF for both cases are shown in the figures below.

Figure 6-21. Illustrative Payback and CUF for Non-Participant Cost Test - Unattended

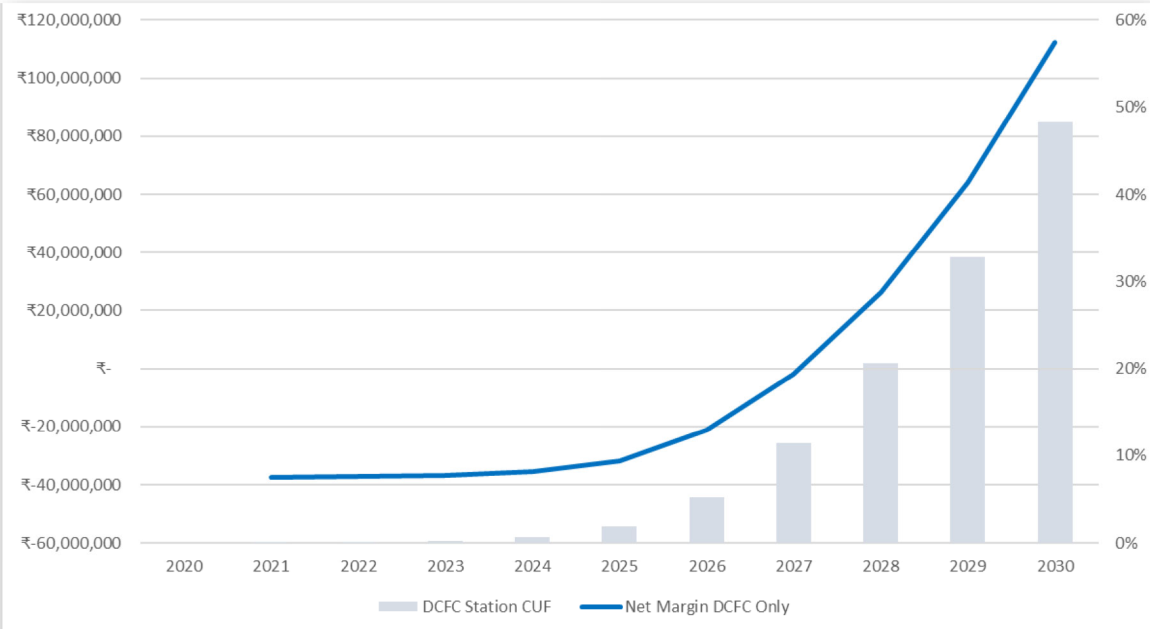
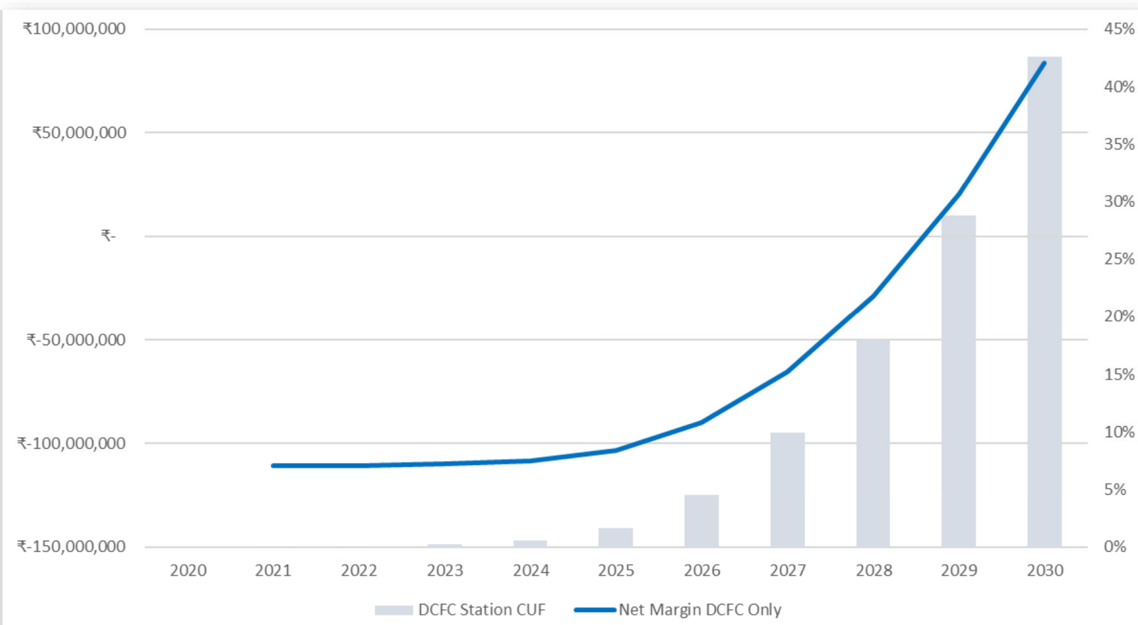


Figure 6-22. Illustrative Payback and CUF for Non-Participant Cost Test - Attended



6.2.6 Grid Storage

Grid storage is an emerging opportunity and one where Tata Power-DDL is already active in a large-scale storage pilot and has a keen interest to showcase the emerging technology. The goal is to gain operational experience with battery storage and the associated value streams to stay on the front edge of revolutionary technology. Driven in part by large investments in the automotive industry, costs and scale of battery storage are dropping even as performance and capability are improving. This has led to a quickly moving landscape in energy storage.

In the near term, this program is intended to establish pilots to understand battery use cases that are operable and can provide 'stacked' value streams that justify the cost of the battery. By 'stacked' we mean that a battery storage system can operate to capture several value streams with the same battery over the course of the year based on an optimal dispatch pattern developed in the DER tool. In the near term, the dominant value stream is the local distribution system support (similar to DR Hot Spot program for load reduction), but also includes energy arbitrage and ancillary services. We also evaluate participation to reduce Deviation Settlement Mechanism (DSM) penalties in the near term. As system loads increase, we anticipate additional benefits from system capacity relief, potentially larger differences in energy market prices that increase arbitrage opportunities and continued distribution value. As costs of battery storage fall, this resource type can quickly provide value for customers and therefore is in our Distributed Energy Transition Roadmap in the future as the value proposition improves, while in the meantime continuing to test existing battery systems.

There are two broad use cases that Tata Power-DDL considers using the DER tool:

- Minimizing system supply costs through 'stacked' benefits
    - System capacity
    - Distribution capacity
    - Energy arbitrage
    - Ancillary services
- Reducing Deviation Settlement Mechanism (DSM) penalties

Examples of programs in other jurisdictions

There are many possible use cases for battery storage. Three examples of grid storage being utilized in California are provided as examples, and there are many more.

System capacity: The first is an example of grid storage replacing a peaker plant, Moss Landing. In 2018, California utility regulators approved PG&E's proposal to build a 567.5 MW/2,270 MWh energy storage project to replace three aging gas plants for grid reliability services. This portfolio consisted of two storage projects: (1) a 300 MW/1,200 MWh system built by Vistra Energy in an existing power plant owned by its subsidiary, Dynegy, and (2) a 182.5 MW/730 MWh Tesla system that PG&E would own at a substation nearby.[23]

The second example project is also intended to provide system capacity and was inspired by a natural gas storage facility leak in southern California in 2015, which created concerns about available summer peak generation capacity.

[23] Moss Landing Storage Project: https://www.greentechmedia.com/articles/read/pges-recording-breaking-battery-proposal-wins-loses#gs.38mzjk

The Aliso Canyon Energy Storage project[24] included a total of 104.5 MWs of energy storage, procured to provide the summer peak demands that were originally served by gas plants.

Distribution capacity: A third example is to provide local distribution capacity. California has established an annual process to allow distribution energy storage resources to bid to replace distribution grid investments. First, California requires a Grid Needs Assessment (GNA) to identify distribution upgrade needs and then a Distribution Deferral Opportunity Report (DDOR) to screen for upgrades that are suitable for DER solutions. The utility then releases a request for proposal for DER bids.

Example cost test results for Tata Power-DDL

Minimizing system supply costs

To perform the cost-effectiveness for grid storage, E3 evaluated two use cases and several scenarios. The first use case was minimizing the supply costs. It should be noted that since grid storage is a Tata Power-DDL investment in front of the meter (part of the distribution grid) that does not change the revenue collected for customers, the TRC, N-PCT, and PCT are all the same. Furthermore, the benefits accounted for here included avoided capital, financing, and operations and maintenance costs from deferred generation capacity – the benefits shown below in this category are high since, at the time of analysis, Tata Power-DDL had contracted surplus power through 2021 and would need to procure additional capacity starting in 2021 – therefore, any reduction in necessary procurement would yield notable benefits. Additionally, we assumed that storage provides increased system flexibility (i.e. ancillary services). We estimated the value of ancillary services as the avoided cost of operational (efficiency) losses of cycling a coal plant, which was previously required to provide ancillary services. Here, we assume that providing ancillary services with storage reduces the coal plant generation from 100% to 80%. Coal prices were assumed to be 3459 INR/tonne from the 2014 E3 Tata Power-DDL DER study.

We considered three scenarios for solar+storage being an option for deferring generation capacity. We simply defined these scenarios by the solar+storage project benefit-to-cost (B/C) ratios: Less Favorable scenario had a B/C ratio of 0.53, Moderate Favorable scenario had a B/C ratio of 1.02, and the Favorable scenario had a B/C ratio of 1.06. The financing costs (comprised of debt interest rates and equity costs) drove the project costs, and, thus, the B/C ratios. In general, as the storage scenarios became more favorable, they deferred more and more generation capacity. In all scenarios, we assumed a 10 MW grid-scale utility-controlled storage project implemented in 2020. Next, we'll describe the results of each scenario.

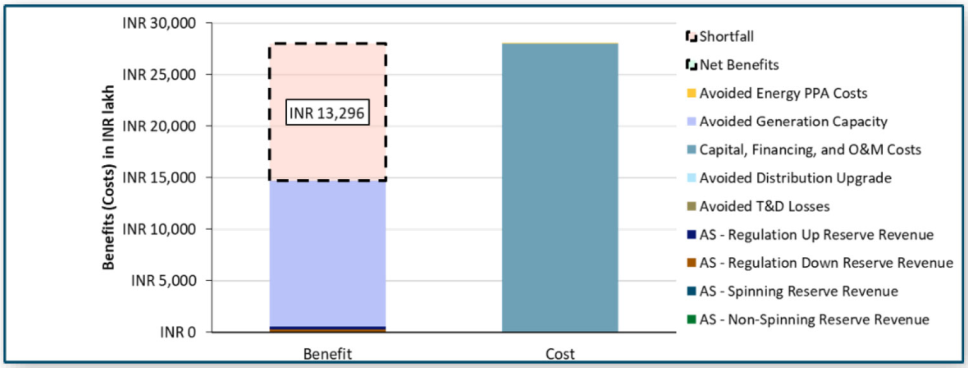
Least Favorable Storage Scenario

In this scenario, the project costs are higher than the benefits. Reduced avoided capacity costs, less energy arbitrage opportunity, and low regulation service cost in Tata Power-DDL limit the benefits of storage in the near term. Additionally, there is a low avoided distribution value (187 INR/kW-yr), as the system is less constrained in Tata Power-DDL.

---

[24] Aliso Canyon Storage Project: https://www.greentechmedia.com/articles/read/aliso-canyon-emergency-batteries-officially-up-and-running-from-tesla-green#gs.38lbje

Figure 6-23. Cost Test of the Least Favorable Grid Storage DER Project

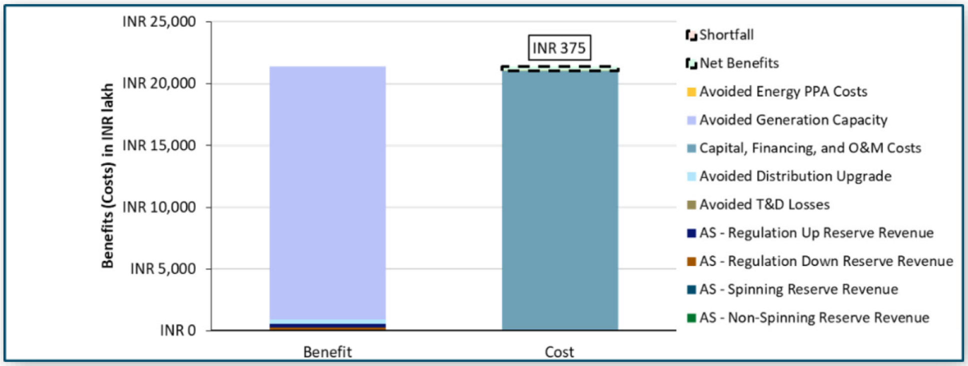


For the least favorable grid storage project, we estimate 94% of the system benefits to be from avoiding generation capacity and 6% to be from providing ancillary services.

Moderately Favorable Storage Scenario

In this scenario, the benefits are mostly from avoiding generation capacity build. We find a negative avoided PPA energy cost, which might be attributable to increasing system flexibility and storage round-trip efficiency loss. In this scenario, there are higher avoided distribution values (457 INR/kW-yr) and the system is moderately constrained.

Figure 6-24. Cost Test of the Moderately Favorable Grid Storage DER Project

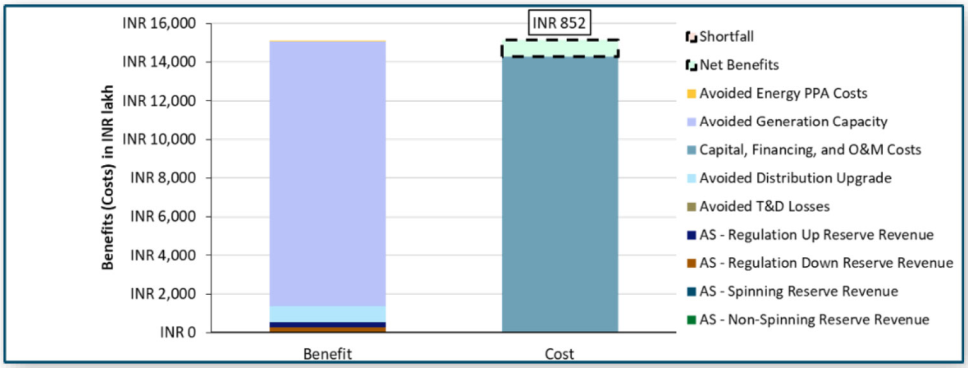


For the moderately favorable grid storage project, we estimate 3% of the system benefits to be from avoiding distribution upgrades, 4% to be from providing ancillary services, and 93% to be from avoiding generation capacity.

Favorable Storage Scenario

In this scenario, the benefits are mostly from avoiding generation capacity build. We find positive energy savings due to more energy arbitrage opportunities. This scenario observes the highest avoided distribution values (1096 INR/kW-yr) and the system is constrained.

Figure 6-25. Cost Test of the Favorable Grid Storage DER Project

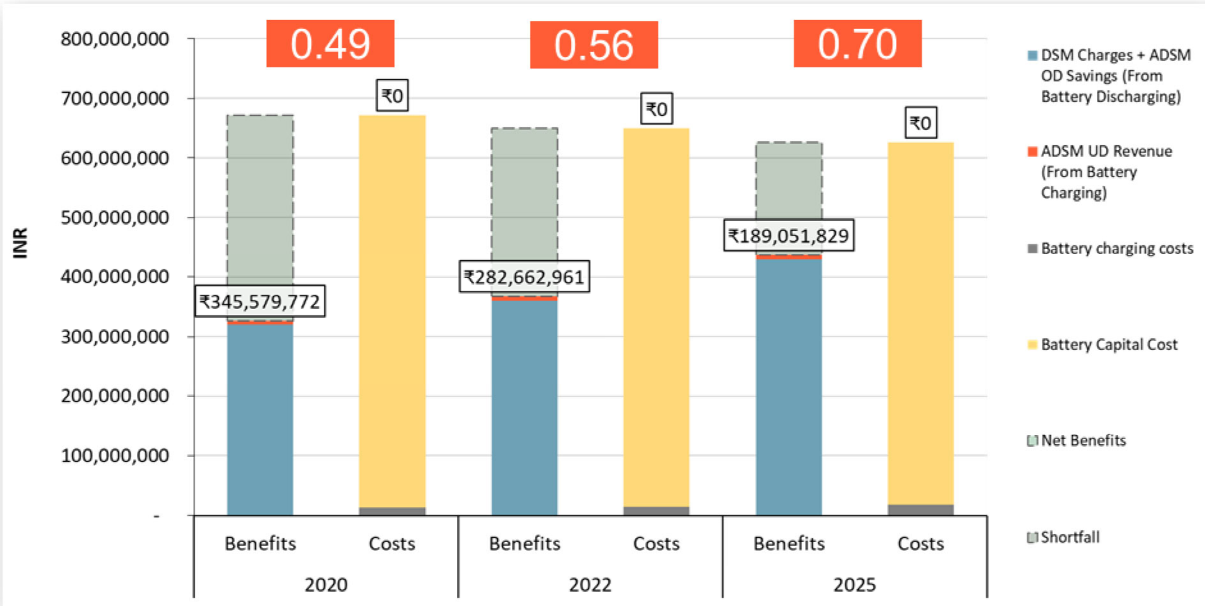


For the favorable grid storage project, we estimate 2% of the system benefits to be from ancillary services, 5% to be from avoiding distribution upgrades, and 92% to be from avoiding generation capacity.

Reducing DSM penalties

The second use case for grid storage was reducing Deviation Settlement Mechanism (DSM) penalties. The team estimated the total DSM savings by using energy storage to dispatch against the DSM prices for 2020, 2022, and 2025. The results reported below are for an example of 10 MW, 1-hour Li-ion storage. DSM is a mechanism used in India to balance the forecast utility system demands versus the contracted generation resources. Most of the savings come from DSM charge reductions and ADSM OD savings as shown in the figure below. Based on the assumptions used for this evaluation, the battery is not cost-effective in the near term for this use case though it is not far from cost-effective by 2025. There are also risks associated with the DSM use case. Since DSM penalties are set through regulatory price setting and do not reflect the underlying cost to provide balancing services, they are at risk for a policy change and could drop at any time should the wholesale market structure change and a competitive balancing market be introduced in India.

Figure 6-26. Program Administrator Cost Test (PAC) for Using Grid Storage to Reduce DSM Penalties



6.3 DER Programs Selected for Next Steps

Given the initial evaluation results and the discussions – both internally and with E3 – Tata Power-DDL decided to focus on a subset of DER programs and identified two DER pilots for the beginning of a distributed energy transition roadmap: EV charging centers and the DR Hotspot Program. In addition, further evaluation of promising new technology is scheduled for the future. The planned deployment of pilot programs is shown below.

Figure 6-27. Five-year Tata Power-DDL Distributed Energy Transition Roadmap

	Near Term Actions	1 to 3 Years	3 Years and beyond
Scale-up Programs		EV Charging Centers DR Hotspot – BDR Program AMI Applications Grid Scale Storage	EV Charging Centers DR Hotspot – BDR & ADR Transition Tariff Small Scale Storage Grid Scale Storage
Pilot Programs	EV Charging Centers DR Hotspot – BDR Program AMI Applications Grid Scale Storage	Small Scale Storage (Community & Pole Level) DR Hotspot – ADR Program Transition Tariff	Peer to Peer Local Energy Market Vehicle to Grid Integration
DER Valuation & Proof of Concept	Small Scale Storage (Community & Pole Level)	Peer to Peer Local Energy Market Vehicle to Grid Integration	Emerging Technologies like Hydrogen / Fuel Cell

DER Integration for Network Planning

Beyond this initial set of programs, we anticipate that technology cost and performance improvements, particularly in battery storage technologies of different scales, but also in communications and control technologies, will allow Tata Power-DDL to propose new distributed energy programs in one to three years.

Over the next three years, and subject to further regulatory approvals, the renewable tariff for large commercial and industrial customers can offer a renewable energy choice for large customers at a reasonable cost while maintaining regulated utility service without the need to take direct access. The 'energy transition rate option' would still collect fixed costs of the system from these customers which benefits all customers of the utility and creates a larger load committed to renewable energy purchases.

Small-scale battery storage is expected to continue to improve and be available at a lower cost and with better performance. When the small-scale battery becomes cost-effective, the best use of this technology is as an expansion of the fossil-free options to provide distribution capacity on the utility side of the meter in the DR hotspot areas. These smaller systems have a higher cost per kWh of storage capacity than the large-scale alternatives but offer the potential to be targeted in the distribution hot spots with high local costs to provide distribution capacity value. At the same time, they can also provide system benefits such as reducing supply balancing penalties (DSM charges) and serving to provide a system capacity resource.

For large-scale battery storage, Tata Power-DDL is currently engaged in active testing of a 10MW battery storage system in place at Tata Power-DDL and owned by AES and Mitsubishi Corp. This research project would operate the battery storage to maximize its value and assess the business case for future investment in large-scale grid-connected batteries as the cost of battery technology declines, the technology improves, and the need for flexibility in the grid increases due to higher renewable penetration. Since Tata Power-DDL currently has sufficient generation capacity, the initial value demonstration cases will deploy the battery to minimize Deviation Settlement Mechanism (DSM) charges which decreases Tata Power-DDL customer costs and improves the reliability of India's grid overall. In the future, with higher renewable penetration, we expect large-scale grid-connected batteries to provide new use cases that increase customer value.

Technology continues to advance at an accelerated pace, and the roadmap maintains to focus on research and development of promising new opportunities that would allow DER to provide value to utility customers, particularly with the AMI and smart grid platform under development at Tata Power-DDL.

6.4 Regulatory Filing Support

E3 supported Tata Power-DDL in developing information to support conversations on new DER programs with their regulator, Delhi Electricity Regulatory Commission (DERC). This work included support of the EV infrastructure proposal made by Tata Power-DDL, and the Automated Demand Response program pilot launched by Tata Power-DDL in summer 2021. For the EV Infrastructure proposal, E3 worked with the Tata Power-DDL team to develop scenarios of vehicle charging and the cost-effectiveness for Tata Power-DDL ratepayers. The Automated Demand Response program was a pilot program designed to scale. Industry-standard practice cost-effectiveness assessment was completed for both programs (and others not yet proposed) as part of the execution of Task 3. Documents shared publicly with the regulators that describe both the EV Infrastructure and Automated Demand Response programs are included as an appendix to the Task 3 report.

Task 4, the Preliminary Environmental Impact Assessment, provides an assessment of the impact of climate change on the distributed energy resources (DER) programs and the expected impacts from the proposed projects, including an assessment of emissions impacts. This task includes an in-depth Climate Resiliency Analysis, an assessment of Tata Power-DDL's baseline environmental conditions, and a description of the physical attributes and environmental impacts of the proposed DER rollouts.

7.1 Climate Resiliency Analysis

We provided a description of the current climate change trends within the Indian and Southwest Asian region and their potential effects on the proposed DER technologies.

The general consensus surrounding the impact of climate change on India and the region of Southwest Asia is that, on average, nighttime and daytime temperatures will increase across the whole region while precipitation during the monsoon season will increase and will become more variable across India. The following list provides climate change projections within the climate science community:

+ By 2050, the mean temperature increase across India will be roughly 1.5°C, with a 3.9°C increase by the end of the 21st century—all relative to 1970-1999 temperatures.[25] In addition, precipitation will increase around the coastal areas of India, while precipitation inland either will have no change or will decrease. By the end of the century, the average monsoon precipitation will increase by around 8.5%.[26]
+ Temperatures will increase in the range of 2.5°C-4.4°C by the end of the century, with an increase in precipitation of 15%-24%.[27]
+ There is high confidence in the projected rise in temperature in India and medium confidence in the summer monsoon precipitation increase in India over this century.[28]
+ The World Bank has used climate models to show that temperatures in India are increasing at 0.11°C/decade. The projections for precipitation showed no absolute trend, as historical precipitation showed too much volatility and uncertainty. It was noted, however, that western and central India have experienced both an increase in the intensity of extreme precipitation periods as well as more frequent dry periods.[29] This observation was also echoed in at least one other paper.

All climate modeling only projects noticeable changes in temperature and weather in the latter half of the 21st century. The scenarios analyzed within this DER framework only extend into 2023, meaning that the effects seen in the various climate models will not be as severe by 2023.

[25] "Downscaled climate change projections with uncertainty assessment over India using a high resolution multi-model approach," Pankaj Kumar et al., December 2013 https://www.sciencedirect.com/science/article/pii/S004896971300106X?via%3Dihub

[26] Ibid

[27] "Climate change projections over India by a downscaling approach using PRECIS," Prasanta Kumar Bal, et al., August 2016 https://link.springer.com/article/10.1007/s13143-016-0004-1

[28] "Climate Phenomena and their Relevance for Future Regional Climate Change," Jens Hesselbjerg Christensen, p.1273 https://www.ipcc.ch/site/assets/uploads/2018/02/WG1AR5_Chapter14_FINAL.pdf

[29] "South Asia's Hotspots, The Impact of Temperature and Precipitation Changes on Living Standards," World Bank Group, Muthukumara Mani, p. 22, p.28 https://openknowledge.worldbank.org/bitstream/handle/10986/28723/9781464811555.pdf?sequence=5&isAllowed=y

Climate science literature suggests that changes in rainfall variability will not be significant enough to impact the rollout of the DER programs for the scenarios studied. The effect of the increased variability of rainfall on the different DER technologies would be negligible, as most of these technologies are implemented indoors (specifically, energy efficiency (EE) and demand response (DR)). There would be no noticeable technical, commercial, or environmental impacts. Electric vehicles (EVs) and EV charging stations are designed to withstand outdoor climates of all types, meaning there would be little to no impact on EV rollout as well. Significant changes in cloud cover have not been projected or linked with increased precipitation; but if this were the case, it would have a modest impact on distributed solar (photovoltaic distributed generation, or DG PV). From a larger power system point of view, rainfall variability would likely have a technical impact on the viability of DG PV, as rainfall variability increases solar generation intermittency due to the increased variability in the cloud cover. As DG PV becomes more intermittent, maintaining a secure power system across India would become more expensive due to an increase in the amount of operating reserves that would be regularly called upon.

Though many models conclude that there will be an increase in precipitation in India by the end of the century, it does not necessarily mean there will be an increase in the number of rainy days. In fact, most of the research papers have stated that precipitation increases are mostly due to more frequent extreme weather events, meaning more severe monsoon seasons and more extreme dry periods. These extreme weather events and sustained periods of drought may have impacts on DER rollout; however, these impacts are extremely hard to quantify. One impact that could affect the program implementation would be increased flooding, which could result in energy storage projects going offline more frequently or undergoing repair more frequently. Most energy storage systems, specifically batteries, are located on the ground floor or basement of buildings, where flooding would be most likely. EE and DR would most likely be unaffected by extreme weather events, as would EVs (although EV charging stations may be damaged during floods). DG PV rollout may potentially be impacted due to increased drought periods. If DG PV is being installed in areas where water is scarce, it may become difficult to clean the solar arrays. It has been proven that solar panels that are cleaned twice a year produce 5.1% more electricity than those that are not cleaned.[30] Cleaning will need to be more frequent in areas where there are long periods of drought as dust will accumulate more quickly. For areas where precipitation will increase, Google had conducted an experiment involving their rooftop solar and concluded that rain sufficiently cleans solar panels to the point where they did not see an economical need to regularly clean them.[31]

The biggest climate change effect that could impact the DER program rollout would be temperature rise, which could affect DG PV, EV consumption, and even DR. For DG PV, increasing temperatures could affect panel efficiencies. For a 1°C rise in temperature, solar cell efficiency reduces by roughly 0.5%.[32] According to a paper on solar cell efficiency in Tripura, India, there is a strong correlation between ambient temperature and solar cell efficiency in the region via the following equation, where T is the ambient temperature:

$$\text{Efficiency} = 8.6621 + 0.1355 \times T$$

Increased average temperatures would not necessarily impact the rollout of EVs in India; however, it should be noted that with high temperatures, EV range will diminish and electricity consumption will increase. As temperatures rise, more EV owners will use climate control, thus consuming more electricity than usual and recharging more often. In Phoenix, Arizona, EV range can drop to as low as 49 miles when the average daily temperature is 105°F or 41°C. On

[30] https://energyinformative.org/solar-panel-cleaning/

[31] https://googleblog.blogspot.com/2009/07/should-you-spring-clean-your-solar.html

[32] https://www.thegreenage.co.uk/article/the-impact-of-temperature-on-solar-panels/

average, EV range is roughly 70 miles in Phoenix, Arizona.[33] Temperatures in Delhi, India, are comparable to those around Phoenix, Arizona, during the summer months; therefore, these numbers can give a rough estimate of changes that can occur in EV usage during extreme or high-temperature events. One other technology that might be impacted by higher temperatures would be DR. As temperatures increase, customers will become less likely to participate in DR as comfort becomes a higher priority during high-temperature days. EE and energy storage rollouts will not be severely impacted by increased temperatures.

7.2 Tata Power-DDL Baseline Environmental Conditions

In this section, we describe the different baseline environmental conditions within Delhi (specifically, air quality, water resources, waste, and noise pollution).

The baseline environmental conditions within Tata Power-DDL's territory are those found in parts of northern and northwest Delhi. The following conditions are found within Tata Power-DDL's territory:

+ The air quality of Delhi is poor, mostly due to the transportation sector, with large amounts of nitrogen dioxide (NO2), sulfur dioxide (SO2), and particulate matter.
+ The water resource around Delhi is also extremely non-uniform, with the availability of water ranging from only 1-2 hours a day to 24 hours a day. In addition, the Yamuna River is within water quality standards upstream of the Wazirabad Barrage, but not downstream. Groundwater resources have significantly diminished around Delhi as usage goes unchecked. Not only is the amount of groundwater reducing, but also the quality of groundwater has been labeled as unfit for human consumption.
+ Delhi's municipal waste is disposed of in three landfills around the city and is expected to grow as the population increases.
+ Noise pollution is extremely prominent in Delhi due to the large numbers of vehicles and resulting traffic, as well as noise from construction and various industries. It was found that noise levels exceed residential standards throughout Delhi (55dB in the day and 45dB at night), while noise levels in commercial and industrial areas were found to be within standards (for commercial, 65dB in the day and 55dB at night; for industrial, 75dB during the day and 70dB at night)[34].

The baseline environmental conditions within Tata Power-DDL's territory are consistently below standards and regulations, which could result in long-term negative impacts on the health and safety of its citizens.

7.3 Physical Attributes and Environmental Impacts of Proposed DER Rollouts

In this section, we describe the physical attributes of the different DER technologies and their potential environmental impacts. Physical attributes for the various DER technologies have been described previously in the Task 2 report "Task 2: Technical Analysis" and are found under Appendix A, 4.5 DER Technology.[35] All the technologies used within the studied DER program scenarios are considered clean energy technologies with zero emissions. The potential environmental impacts of the various DER technologies and remedial actions are described below. The table below illustrates that overall, DER technologies will provide a positive environmental impact if implemented.

---

[33] https://www.cmu.edu/me/ddl/publications/2015-EST-Yuksel-Michalek-EV-Weather.pdf

[34] "Environmental Concerns in National Capital Territory of Delhi, India," Singh et al. 2015 https://www.longdom.org/open-access/environmental-concerns-in-national-capital-territory-of-delhi-india-2332-2594-1000147.pdf

[35] "Task 2: Technical Analysis, Regulatory and Business Case for Distributed Energy Resources in India: Phase 2," E3 Inc., p. 104

Table 7-1. Environmental Impacts of DER Portfolios

Impact of DER Programs	Description of Environmental Impacts	Environmental Impact Directionality?	Mitigation of Negative Environmental impacts
Fossil Fuel Combustion	Reduced fossil fuel combustion results in direct reductions of criteria air pollutants and carbon dioxide emissions.	Positive	-
Vehicle Emissions	Increased EVs reduce the amount of harmful pollutants from ICE vehicle exhaust.	Positive	-
Urban Heat Island Effect	Increased rooftop solar reduces urban heat island effects by cooling temperatures in the area as well as reducing building cooling loads.	Positive	-
Dependence on Central Generation	Reduced dependence on the central generation might help avoid the development of new transmission lines. Developing transmission lines can be challenging from a social and economic perspective.	Positive	-
Central Generation Cooling Water	Less freshwater needed to cool central thermal generation exhaust prevents possible damage to river ecosystems.	Positive	-
Water Consumption	Overall portfolio reduction in water consumption due to decreased reliance on central fossil generation reduces potential harm to the river ecosystem as less warm water is being injected into rivers.	Positive	-
Solar Panel Cleaning	PV panels will require some cleaning, but overall net consumption will be negative.	Slightly Negative	Use gray water from within the building to clean solar panels
Noise Pollution	Noise pollution reduction due to increased EV deployment and retirement of ICE vehicles.	Positive	-
Waste Production	Less waste production due to reduced amount of central thermal generation fuels.	Positive	-
Displacement of Indigenous and Rural Communities	Reduced dependence on conventional fossil plants for capacity value may avoid the construction of new power plants and transmission lines, which in turn may help avoid the displacement of indigenous communities. Since DERs are locally located, rather than remotely, the DER itself will not result in indigenous community impacts.	Positive	-
Health Effects Due to Electricity Generation	Possible reductions in mortality and morbidity that result from exposure to criteria air pollutants. Less exposure to the operation of heavy machinery and hazardous fuels for workers.	Positive	-
Rooftop Solar Installations	Risk of injury or death when dealing with installing, repairing, or cleaning rooftop solar.	Negative	Safety standards and construction guidelines to be enforced.
Disruption of Land (tree clearing, etc.)	Minimal and negligible disruption of land is anticipated as DER technologies will be located locally, and largely on rooftop spaces or within buildings. Reduced dependence on conventional fossil plants for capacity value may avoid the construction of new power plants, which in turn will avoid land disruption.	Positive	-

The direct potential positive environmental impact of the full DER rollout from 2020-2022 can also be seen in noticeable reductions in air pollutants. The table shows that there are significant reductions in CO2 emissions compared to the rest of the air pollutants across all scenarios from 2020-2022. There is a noticeable increase in avoided emissions when DER incentives are available compared to the equivalent business-as-usual (BAU) scenarios where no incentives are available.

Table 7-2. Total Avoided Emissions from 2020-2022

Metric	Low - BAU	Low - Optimized	Mid – BAU	Mid - Optimized	High - BAU	High - Optimized
Avoided CO_2 emissions (kilotonnes)	40.6	45.3	43.8	51.3	48.9	58.0
Avoided SO_2 emissions (tonnes)	29.9	33.1	31.3	36.1	31.9	37.2
Avoided NO_x emissions (tonnes)	27.4	30.6	28.7	33.5	29.4	34.7
Avoided $PM_{2.5}$ emissions (tonnes)	4.9	5.2	5.1	5.6	6.1	6.8

8 Development Impact Assessment

The purpose of Task 5, the Development Impact Assessment, is to provide an assessment of expected economic and developmental impacts from the proposed projects. We provide both a qualitative and a quantitative assessment, with a focus on development impact measures.

8.1 Qualitative Assessment

Several effects may result from the implementation of the studied DER scenarios that may impact the development of India in the long term.

- Invigorated economy in India through increased energy industry and clean energy technology market activity.
- Increased awareness of renewable energy and DER technologies.
- Growth of businesses through the build-out of DER technology and the creation of new businesses.
- Decreased reliance on imported fuels, specifically fossil fuel.
- Reduction in land use through the deferral or shutdown of centralized power plants, and using existing infrastructure to accommodate new DER technologies. For example, rooftop solar, EE, DR, and storage can be installed mostly within buildings, and EV charging infrastructure can be developed on existing gas station sites.
- Quieter streets with the development of an EV fleet.
- Reduction in water consumption and air pollutants provides for a potential cleaner living environment within the city.

The adoption of DER technologies within the Tata Power-DDL territory could contribute to potential economic and developmental impacts. It may help to stimulate growth within the energy industry in India and the greater regional economy by creating new businesses and growing existing businesses. It would also help develop social awareness of clean technologies, while also positively impacting environmental development.

8.2 Quantitative Assessment

Our quantitative assessment focuses on a few specific developmental metrics to establish the impact that the proposed DER programs would have within the Tata Power-DDL territory within Delhi. It was established in the Task 4 Preliminary Environmental Impact Assessment that there were emissions reductions associated with the proposed DER programs, with much more avoided CO_2 emissions compared to the suite of other measured air pollutants. In addition to this, a few more metrics were established to provide more information on the development impacts associated with the proposed DER programs.

The table below shows that these developmental impact metrics across the various scenarios of the proposed DER deployment program. The focus is on three areas: energy & power, transportation, and CO_2 emissions.

Table 8-1. Development Impact Assessment Metrics for 2022

Metric		Low - BAU	Low - Optimized	Mid – BAU	Mid - Optimized	High - BAU	High - Optimized
Energy & Power	PV (MW)	10.9	10.9	12.9	12.9	25.4	25.3
	Storage (MW)	0 (a)	0 (a)	0 (a)	0 (a)	0 (a)	0 (a)
Transportation (b)	# Individual Drivers 2-Wheels	542	542	542	541	541	541
	# Individual Drivers 4-Wheels	6	6	7	7	9	9
CO_2 Emissions Avoided	Non-EV DERs (kilotonnes)	16	18	18	21	20	23
	EVs (tonnes)	534	534	552	551	589	589

(a) Storage was not included as a potential DER technology in the studied scenarios.

(b) Assumed that the number of individuals that drive a 2-wheel car and a 4-wheel car is 1. Rounded up to the nearest integer.

- DG PV capacity more than doubles from the "Low" scenario to the "High" scenario; however, PV adoption remains virtually unchanged between cases for different scenarios with and without incentives.
- The number of 2-wheel EV drivers is significantly greater than the number of 4-wheel EV drivers. This large difference is mainly due to the current distribution of vehicle sales in India, which is skewed heavily toward 2-wheelers. EV adoption stays relatively constant through the various scenarios, with incentives showing no effect. There is a slight increase in 4-wheelers from the "Low" scenario to the "High" scenario; however, EV adoption will stay relatively constant from 2020-2022.
- Avoided CO_2 emissions can be split between "Non-EV DERs" and "EVs." The avoided CO_2 emissions from "Non-EV DERs" are consistently higher than avoided emissions from EVs. Though avoided CO_2 emissions from EVs are consistent with the trend seen with EV drivers, the trends for all other DER technologies are different. First, there is a general increase in avoided CO_2 emissions between the "Low" scenario and the "High" scenario. Second, there is a noticeable difference between scenario cases with and without incentives. Cases with incentives have significantly greater amounts of avoided CO_2 emissions, compared to the cases that did not incorporate incentives.

Since all metrics remain relatively constant across the different scenarios, and the only metrics that seemed to be affected were the PV capacity and the "Non-EV DERs"-avoided CO_2 emissions, it shows that there is a small growth of EVs and DG PV, yet DG PV capacity does increase with greater DER adoption. However, the avoided CO_2 emissions between the BAU and case with incentives within each scenario must be coming from EE and DR if DG PV and EV deployment are staying constant. The table below shows that DR is the main technology that is adopted in the presence of incentives, with a small portion going towards the implementation of EE measures. Therefore, the main area of development from these programs will stem from DR, which may help incentivize existing DR companies to invest in DR technology within Tata Power-DDL's territory.

Table 8-2. EE and DR Capacity 2022

DER Technology	Low - BAU	Low - Optimized	Mid – BAU	Mid - Optimized	High - BAU	High - Optimized
DR	0.3 MW	0.3 MW	0.3 MW	31.3 MW	0.3 MW	63.2 MW
EE	5 MW	5.7 MW	5 MW	6 MW	5 MW	6.4 MW

9 U.S. Sources of Supply

The purpose of Task 6, the U.S. sources of supply, is to identify potential U.S. suppliers that may provide the equipment needed for the rollout of the proposed DER programs. This is a task that is typically required in all U.S. Trade and Development Agency (USTDA) projects.

9.1 Potential U.S. Suppliers

Several U.S. companies may have opportunities to provide DER technologies that support the potential program rollout. The table below lists various U.S. companies, including contact information and equipment that could be supplied.

Table 9-1. Potential U.S. Suppliers

Company	DER Technology	Manufacturer / Product Description	Contact Information (Name, phone/fax, email, address)
Solaria	Solar Panels	Manufacturer of shingled crystalline silicon solar panels, with a higher energy density than traditional panels.	Suvi Sharma, CFO **Email:** ssharma@solaria.com **Phone:** 1-510-270-2500; Fax: 1-510-793-8388 **Address:** 6200 Paseo Padre Parkway, Fremont, CA 94555, USA
Outback	PV Inverters	Designer and manufacturer of advanced power electronics for renewable energy. Product offerings include off-grid and grid-connected inverters. Specializes in providing balance-of-system components for solar installations.	Gord Petroski **Email:** GPetroski@alpha.com **Phone:** 1-360-220-8123; Fax: 1-360-435-6019 **Phone** (India office): +91-8861640001 **Address:** (Sales office in India) # 255, Block -25, LIC Jeevan sathi,10th Cross, J.P. Nagar Phase I, Bangalore - 560087 Karnataka (India)
Trojan	Batteries	Manufacturer of deep cycle batteries. Current battery applications include golf carts, utility vehicles, marine vehicles, and recreational vehicles. Recently acquired by C&D Technologies, another specialty battery manufacturer.	Erich Heidemeyer **Email:** help@batterysystems.net **Phone:** 1-415-648-7650; Fax 1-415-648-0333 **Address:** 10 Loomis Street, San Francisco, CA 94124 USA **India supplier:** Manak Engineering Services Subodh Raheja **Email:** subodhmn@gmail.com **Phone:** +91-9810411336; Fax: +91-9871381011

Company	DER Technology	Manufacturer / Product Description	Contact Information (Name, phone/fax, email, address)
			Address: B-46, Flatted Factory Complex, Phase-3, Okhla, New Delhi 110020, India
Charge Point	EV Charging Infrastructure and EV Charge Points	Operator of the largest network of EV Charging Stations in North America. Designs, develops, and manufactures hardware/software for EV infrastructure at large.	**Pasquale Romano**, President and CEO **Email:** sales@chargepoint.com **Phone:** +91-124-4889450 **Address:** 3rd Floor, AIHP Signature, 418-419, Udyog Vihar, Phase-4, Gurgaon, Haryana, India
Eaton	DR Controls	Eaton is a power management company that produces a wide variety of products for the electricity sector. It offers software and hardware products for DR forecasting and M&V practices, helping deliver the data and tools to optimize DR programs. On the software side, Eaton's Yukon Demand Response management software provides DR management capability and M&V solutions.	Rajiv Kumar **Email:** RajivKumar@Eaton.com **Phone:** +91-11-4223 2300 **Address:** Unit No. 1, Second Floor, TDI Centre, Jasola New Delhi-110 044 India.
Honeywell	DR Controls Energy Efficiency	Honeywell manufactures a variety of smart energy technologies and services and has been selected to manage large C&I and residential DR programs across the U.S. and India.	Sham R Pathak **Email:** Sham.Pathak@Honeywell.com **Phone:** International: 001 (480) 353-3020 **Address:** 300 S Tryon St Suite 500, Charlotte, NC 28202

Company	DER Technology	Manufacturer / Product Description	Contact Information (Name, phone/fax, email, address)
General Electric	DR Controls Energy Efficiency	General Electric (GE)'s Energy Consulting branch provides DR road mapping, business development, and smart grid integration impact analysis. GE also manufactures energy-efficient appliances including lightbulbs, dishwashers, and refrigerators.	**Mr. Shailesh Mishra** (GE Renewable Energy), Business Operations Leader **Email**: shailesh.mishra@ge.com **Phone**: +91-120-5021650 **Address:** 1st Floor, Tower 5, Plot No 1-14, Sector 128, Jaypee Wish Town, 201304 Noida UP
Cisco	Networking to Support DR	Cisco's Building Energy Management (BEM) solutions provide automated DR and the ability to manage loads across various appliances in a building (heating, ventilation, air-conditioning, and lighting).	**C. Prasanna Venkatesan**, Sr. Mgr. Market Development & Strategic Planning **Email**: prasanve@cisco.com **Phone:** +1-408-894-3362 (W) | +1-773-330-2338 (M) **Address** (India office): 7th Floor, Birla Tower, 25 Barakhamba Road, New Delhi 110 001 India
S&C Electric Company	Networking to Support DR and DERMS	S&C Electric Company is a leading provider of switching, protection, and control solutions for electric power systems. S&C provides a variety of products such as inverters and switches to support microgrids, non-wires alternatives, and renewable energy integration.	**Krishna Kumar** **Email**: Krishna.Kumar@sandc.com **Phone:** +65-6801-0361 **Address:** Westgate Tower, # 07-01, 1 Gateway Drive, Singapore 608531

As illustrated in the table, several U.S. companies are qualified to provide DER technologies that could support Tata Power-DDL with the program rollout and potential broader DER market development in Delhi. Based on the scenarios studied, the programs will have a large effect on DR technology since a large number of U.S. suppliers are focused on DR delivery.

9.2 Estimate of U.S. Export Potential for Tata Power-DDL

This study may result in U.S. export potential. We estimated the U.S. export potential for the proposed DER program rollout. These estimated U.S. export numbers are based on the technology cost assumptions shown in the table footnotes.

Table 9-2. Cost Estimate Sources for Estimation of U.S. Export Potential

Component	Unit type	Unit cost USD	Source of estimate
Solar Panels	Per Watt DC	$0.75	NREL
PV Inverter	Per Watt DC	$0.18 (a)	NREL
DR Controls	Per kW	$26	Tata Power-DDL procurement (b)
Energy Efficiency Measures	Per EE measure	$32	E3 (c)
Electric Vehicles - 4-Wheel/2-Wheel	Per Vehicle	$36,620/$2,400	Chevrolet/Flux Mopeds[36]
EV L2 Chargers	Per Charge Point	$1056	ISGF (d)

(a) Equates to $0.20/Watt_{AC}$ assuming DC to AC ratio of 1.15.

(b) Based on the prior USTDA smart grid studies, Tata Power-DDL-procured U.S.-based controls equipment to support the pilot demand response. These included companies such as Honeywell. Their actual procurement cost is used here. Conversion rate: INR 62 to 1 USD.

(c) This is an averaged cost of adopting a fan EE measure since that is the measure that is adopted the most in these scenarios. Prices for energy efficiency vary greatly. Conversion rate: INR 71 to 1 USD.

(d) This is the cost of 1 L2 public charge point. Also, calculations assume a charge point-to-EV ratio of 0.05. Conversion rate INR 71 to 1 USD. http://www.indiasmartgrid.org/reports/ISGF%20White%20Paper%20-%20EVSE%20Business%20Models%20for%20India.pdf.

The three different scenario sensitivities have varying levels of DER penetration in 2022; these are shown in the table below both for the BAU case and the same case optimized for incentives for all three sensitivities.

Table 9-3. 2022 DER Cumulative Adoption Composition

DER Technology	Low - BAU	Low - Optimized	Mid – BAU	Mid - Optimized	High - BAU	High - Optimized
Solar Panels	10.9 MW	10.9 MW	12.9 MW	12.9 MW	25.4 MW	25.3 MW
PV Inverter	10.9 MW	10.9 MW	12.9 MW	12.9 MW	25.4 MW	25.3 MW
DR	0.3 MW	0.3 MW	0.3 MW	31.3 MW	0.3 MW	63.2 MW
EE	5 MW	5.7 MW	5 MW	6 MW	5 MW	6.4 MW
EV	0.7 MW	0.7 MW	0.7 MW	0.7 MW	0.8 MW	0.8 MW

Using pricing estimates and the DER portfolio specifications, we estimate the following U.S. export potential in USD millions (M).

Table 9-4. U.S. Export Potential for DER Portfolio Implementation in Tata Power-DDL Service Territory

[36] http://www.fluxmopeds.com/

DER Technology	Low – BAU	Low - Optimized	Mid – BAU	Mid - Optimized	High - BAU	High - Optimized
Solar Panels	$8 M	$8 M	$10 M	$10 M	$19 M	$19 M
PV Inverter	$2 M	$2 M	$2 M	$2 M	$5 M	$5 M
DR Controls	$0.01 M	$0.01 M	$0.01 M	$0.8 M	$0.01 M	$1.6 M
Energy Efficiency Measures	$4.8 M	$5.2 M	$4.8 M	$5.4 M	$4.8 M	$5.7 M
Electric Vehicles	$1.5 M	$1.5 M	$1.6 M	$1.6 M	$1.6 M	$1.6 M
EV Charge Points	$0.03 M	$0.03 M	$0.03 M	$0.03 M	$0.03 M	$0.03 M
Totals	$16.3 M	$16.7 M	$18.4 M	$19.8 M	$30.4 M	$32.9 M

Note, the above estimates specifically show sales associated with the proposed DER program and do not reflect the entire India market for these technologies, which would be significantly higher. Furthermore, it should be noted that the figures for EE are based on an average cost of energy efficiency specific to these DER portfolios, which show a majority of fan efficiency measures. These figures can vary significantly, depending on the EE measures that are adopted.

10 Public Workshop and Training

The purpose of Task 7, the Public Workshop and Training, is to provide training and workshops to regulators and other Indian utilities interested in using the tool developed in this project to evaluate the economic impact of large-scale DER program designs following the proposed valuation framework and program development approach. While the project is conducted for Tata Power-DDL within its service territory, the tool and learnings from the project are meant to be applied to distribution companies (Discoms) across India upon project completion.

Tata Power-DDL collaborated with E3 to organize and execute a 2-day remote workshop and training on August 31st, 2021, and September 1st, 2021, for key stakeholders including regulators and other Indian utilities interested in using the tool to evaluate the economic impact of large-scale DER program designs. Workshop session #1 shared the overall evaluation and development approach of large-scale DER program designs in Tata Power-DDL's service territory by presenting the DER Transition Roadmap, describing three pilot programs on electric mobility, energy storage, and demand response that are in the field today, and then summarizing the planning and analyses behind them. Workshop session #2 showcased the DER Toolkit (the tool) used to evaluate the DER programs presented at workshop session #1, and provided a primer on using this tool, gearing towards technical staff interested in digging deeper into the analytical framework behind the DER Transition Roadmap.

Two workshop sessions witnessed over 300 participants in total from across the power sector including members from Central Electricity Regulatory Commission (CERC), Central Electricity Authority (CEA), State Electricity Regulatory Commissions (SERCs), NITI Aayog, and various other related organizations. Through the workshop and training, Tata Power-DDL and E3 successfully shared the tool (public version available for download) and key takeaways from the project with key stakeholders including but not limited to regulators and distribution companies (Discoms) across India upon project completion.

11 Conclusion

Figure 11-1. Five-year Tata Power-DDL Distributed Energy Transition Roadmap

	Near Term Actions	1 to 3 Years	3 Years and beyond
Scale-up Programs		EV Charging Centers DR Hotspot – BDR Program AMI Applications Grid Scale Storage	EV Charging Centers DR Hotspot – BDR & ADR Transition Tariff Small Scale Storage Grid Scale Storage
Pilot Programs	EV Charging Centers DR Hotspot – BDR Program AMI Applications Grid Scale Storage	Small Scale Storage (Community & Pole Level) DR Hotspot – ADR Program Transition Tariff	Peer to Peer Local Energy Market Vehicle to Grid Integration
DER Valuation & Proof of Concept	Small Scale Storage (Community & Pole Level)	Peer to Peer Local Energy Market Vehicle to Grid Integration	Emerging Technologies like Hydrogen / Fuel Cell

DER Integration for Network Planning

E3 supported Tata Power-DDL in the development of a DER roadmap and valuation framework, providing input to help guide proposals to move forward with two programs in the near term: the Demand Response Hot Spot Program (DR Hotspot) focusing on load reduction in local constrained areas, and the EV Charging Infrastructure Program focused on closing the gaps in deployed EV charging at Tata Power-DDL. The benefit-cost analysis framework and associated tool developed to support this decision-making can be used to guide Tata Power-DDL's DER strategy in the future, particularly as updated data becomes available about the performance of implemented DER programs to identify shortcomings and improvements. Beyond the EV Infrastructure and Demand Response Hotspot Programs, the Distributed Energy Transition Roadmap was put in place to guide the development and deployment of future DER programs – technologies with near-term viability are deployed through pilot programs, while nascent technologies are further researched until program implementation is deemed ready.

While the examples shown for the examined DER technologies earlier in this report draw from jurisdictions outside of India with differing policy and energy market environments, the lessons learned about EV infrastructure ownership structures, industrial tariff rate design, and grid-level energy storage projects provide invaluable guidance to Tata Power-DDL in designing and implementing strategies to develop robust DER portfolios that fulfill the following criteria to provide benefits to Tata Power-DDL and its customers:

Support All Customers: Detailed cost-effectiveness analysis has been completed for each of the proposed programs and they all provide economic benefits to all customers. The proposed programs are designed to provide downward pressure on rates. A detailed economic case is presented for each program, prepared in conjunction with the technical assistance of the USA consultants provided by the US Federal Government. All input assumptions, methods, and results are documented in detail in the attached program filing.

Support State and National Energy Policy: The proposed programs support India's energy transition including increased support for large-scale renewable energy deployment (above and beyond the RPO requirements) and rapid support of electric vehicles of all types that benefit all people. These initiatives reduce the reliance on imported fuels and increase the use of clean domestic energy supply (solar and wind) and foster greater energy security and independence.

Provide Environmental Benefits: The energy transition away from fossil fuels for power generation and mobility provides environmental benefits including better air quality and reduced greenhouse gas emissions. Reducing emissions from internal combustion engines can support a cleaner city and improve health outcomes in New Delhi.

Fits Tata Power-DDL Portfolio: The proposed programs fit with the existing conditions of the Tata Power-DDL generation portfolio and our needs for capital spending prioritization. Tata Power-DDL has excess procured generation capacity from legacy coal contracts that are difficult to restructure. The proposed programs benefit from either retaining load (as in the case of the energy transition tariff) or increasing load (as in the case of the electric vehicle charging program) to take advantage of the procured resources.

Prioritize Capital Spending: Tata Power-DDL, like many distribution utilities in India, has a limit to the capital it can spend and collect through reasonable rates. Therefore, Tata Power-DDL must prioritize capital projects that provide the greatest value. The DR Hotspot program is an innovative approach for using demand response to provide local load reductions at customers in place of capital to maintain reliability while conserving capital for other needed projects in the system.

Provide Leadership: The conditions that are present at Tata Power-DDL are similar across India. A distributed energy transition roadmap that works for Tata Power-DDL can also benefit cities across India. Therefore, we also propose making public the assessment, tools, and plans presented in these programs available through workshops and providing other information as these programs go to the market to all distribution utilities.

12 Appendix

This appendix contains the following documents. Appendices 4-7, 10-13, and 17 are confidential and removed from the public version.

1. Task 1 Report
2. Task 2 Report
3. Task 3 Report
4. Task 3 Report Appendix 1. Tata-Power DDL Roadmap Document (March 2020)
5. Task 3 Report Appendix 2. Tata-Power DDL EV Infrastructure Proposal (August 2020)
6. Task 3 Report Appendix 3. Tata-Power DDL DR Hotspot Summary (May 2021)
7. Task 3 Report Appendix 4. Tata-Power DDL Draft Energy Transition Tariff Document (November 2020)
8. Task 4-6 Report
9. Task 7 Report
10. EV Peer Utility Review
11. Regulatory Policy Review - EVSE Ownership
12. WRI Working Paper: Implementation Guide for Utilities: Designing Renewable Energy Products to Meet Large Energy Customer Needs
13. Tata-Power DDL Draft Program Design and Ranking
14. DER Toolkit User Guide
15. DER Transition Workshop (remote)
16. DER Toolkit Training Workshop (remote)
17. Participant List of Virtual Workshop on DER Transition