# Battery Energy Storage Systems to Enable Energy Transition in Indian Cities

## – Assessing Opportunities and Use-Cases in Urban Applications

# FINAL REPORT

Prepared by

ICLEI

Local Governments for Sustainability

SOUTH ASIA

**Battery Energy Storage Systems to Enable Energy Transition in Indian Cities - Assessing Opportunities and Use-cases in Urban Applications**

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This document has been prepared by **ICLEI - Local Governments for Sustainability, South Asia** under the **'Strategies for Enabling Energy Storage in Indian Cities'** project.

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# List of Abbreviations

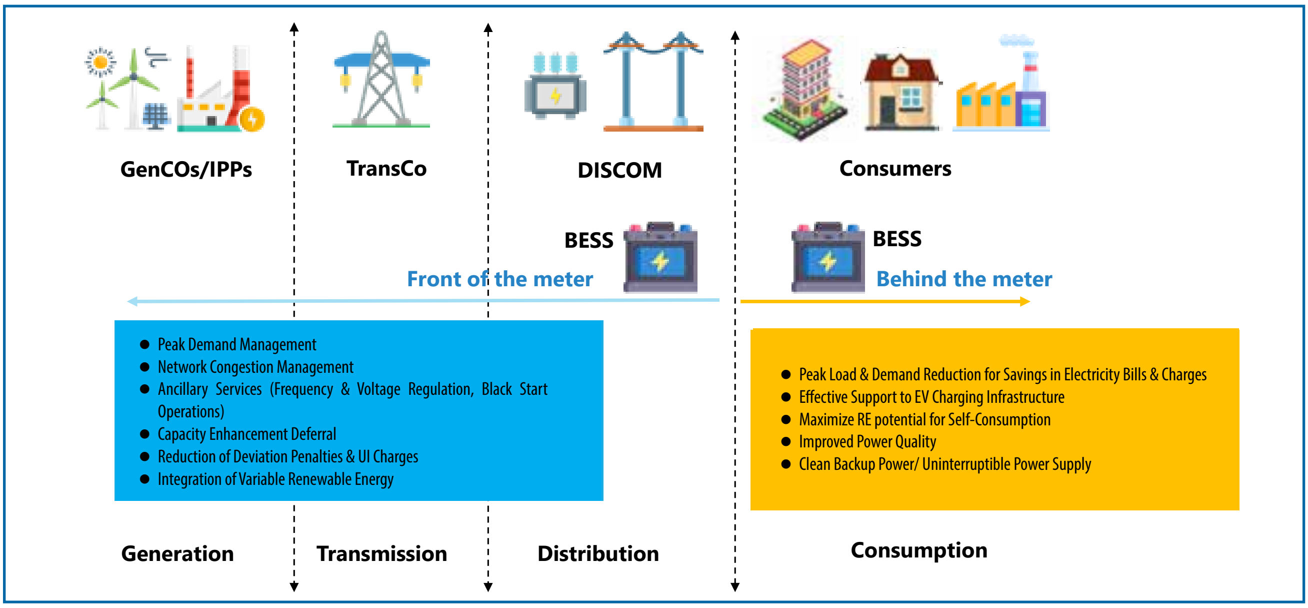
| | |
|---|---|
| AC | Alternating Current |
| AT&C | Aggregated Technical and Commercial |
| BESS | Battery Energy Storage Systems |
| BMS | Battery Management System |
| BNEF | Bloomberg New Energy Finance |
| BRPL | BSES Rajdhani Power Limited |
| BRTS | Bus Rapid Transit System |
| BtM | Behind-the-Meter |
| BYPL | BSES Yamuna Power Limited |
| C&I | Commercial and Industrial |
| CDP | City Development Plan |
| CEA | Central Electricity Authority |
| CEEW | Council on Energy, Environment and Water |
| CEF | Centre for Energy Finance |
| CERC | Central Electricity Regulatory Commission |
| CoP | Conference of Parties |
| CREDAI | Confederation of Real Estate Developers Association of India |
| CSCAF | Climate Smart City Assessment Framework |
| DC | Direct Current |
| DER | Distributed Energy Resources |
| DGVCL | Dakshin Gujarat Vij Company Limited |
| DISCOMs | Electricity Distribution Companies |
| DoD | Depth of Discharge |
| DREAM | Diamond Research and Mercantile |
| DT | Distribution Transformers |
| EMS | Energy Management System |
| EPC | Engineering, Procurement and Construction Company |
| ESCO | Energy Service Company |
| ESO | Energy Storage Obligation |
| EVCS | EV Charging Station |
| EVs | Electric Vehicles |
| FSI | Floor a Space Index |
| FtM | Front-of-the-Meter |
| GDCR | General Development Control Regulations |
| GEB | Gujarat Electricity Board |
| GEDA | Gujarat Energy Development Agency |
| GENCO | Power Generation Company |
| GERC | Gujarat Electricity Regulatory Commission |
| GETCO | Gujarat Electricity Transmission Company |
| GIPCL | Gujarat Industries Power Company Limited |
| GPCL | Gujarat Power Corporation Limited |
| GSECL | Gujarat State Electricity Corporation Limited |
| GSRTC | Gujarat State Road Transport Corporation |
| GTG | Greening the Grid |
| GUDC | Gujarat Urban Development Company |
| GUDM | Gujarat Urban Development Mission |
| GUVNL | Gujarat Urja Vikas Nigam Limited |
| HTP | High-tension Power |
| HVAC | Heating, ventilation, and air conditioning |
| IEA | International Energy Agency |
| IEX | Indian Energy Exchange |
| IPP | Independent Power Producer |
| ISTS | Inter State Transmission System |
| IT/ITes | Information Technology Companies |
| kVA | Kilovolt Ampere |
| kW | Kilowatts |
| kWh | Kilowatt Hour |
| MGVCL | Madhya Gujarat Vij Company Limited |
| MoP | Ministry of Power |
| MPSEZ | Mundra Port and Special Economic Zone |
| MW | Megawatts |
| MWh | Megawatt Hour |
| MYT | Multi-Year Tariffs |
| NLDC | National Load Dispatch Centre |
| NRDC | National Research Development Corporation |
| NREL | National Renewable Energy Laboratory |
| PGCIL | Power Grid Corporation of India Ltd |
| PGVCL | Paschim Gujarat Vij Company Limited |
| PT | Power Transformer |
| RE | Renewable Energy |
| RLDC | Regional Load Dispatch Centre |
| RMC | Rajkot Municipal Corporation |
| RPO | Renewable Purchase Obligations |
| RUDA | Rajkot Urban Development Authority |
| SDB | Surat Diamond Bourse |
| SECI | Solar Energy Corporation of India Limited |
| SLDC | State Load Dispatcher Centre |
| SMC | Surat Municipal Corporation |
| SNA | State Nodal Agency |
| SRAS | Secondary Reserve Ancillary Service |
| SUDA | Surat Urban Development Authority |
| TCO | Total Costs of Ownership |
| ToD | Time of Day |
| TOZ | Transit Oriented Zone |
| TPDDL | Tata Power Delhi Distribution Limited |
| TPL | Torrent Power Limited |
| TRAS | Tertiary Reserves Ancillary Services |
| TRANSCO | Transmission Company |
| UD&UHD | Urban Development and Urban Housing Department |
| UDA | Urban Development Authority |
| UGVCL | Uttar Gujarat Vij Company Limited |
| UI | Unscheduled Interchange |
| ULB | Urban Local Body |
| USAID | United States Agency for International Development |
| VRE | Variable Renewable Energy |

# Executive Summary

India has set ambitious targets for clean energy and mobility transition and is taking strides in this direction through its national policies, programs and regulations focused on enabling deployment and integration of Variable Renewable Energy (VRE), Electric Vehicles (EVs) and their supporting charging infrastructure into the Indian power system. Increasing contribution of renewable energy (RE) in the power generation side, large uptake of new loads such as EVs and rising power demand in cities, bring new challenges such as electricity demand and supply gaps for the power distribution companies (DISCOMs). In order to achieve the grid flexibility necessary to integrate the expanding RE and EV deployments – both of which may be extremely variable in terms of generation and power demand – across the nation, energy storage systems (ESS) are becoming increasingly pivotal. Battery energy storage system (BESS) and pumped hydropower storage (PSH) are the most mature technologies in the market for energy storage and need to be encouraged through national policies and regulations.

India's current power system landscape and challenges unfolding from the national impetus on energy and mobility transition is in turn unwinding significant opportunities to deploy ESSs as energy management asset for the power sector, especially at the urban scale, due to the thrust for urban development and transformation through national missions such as the Smart Cities Mission (SCM) and Atal Mission for Rejuvenation and Urban Transformation (AMRUT).

Further, the Indian power sector is at the cusp of transformation and has in recent years witnessed several reforms and policy measures aimed at pushing it onto a trajectory of sound commercial growth and better planning and coordination between the state and the central power systems, and enabling clean energy transition by overcoming the challenges posed by its unique conditions. This has created new opportunities for novel technologies like BESS which can ensure grid reliability and power quality by providing grid services at different levels of the electricity value chain.




*BESS can be deployed to add value at different levels of the electricity system*

In addition to national targets and reforms, there are sub-national policies and targets from state governments on renewable power generation and mobility transition to EVs. States such as Gujarat, Chhattisgarh and Maharashtra have decided against investing in new thermal power plants, while setting-up ambitious RE deployment targets through their wind, solar and hybrid power generation policies.

Notably, in few states, Gujarat being one, the share of solar and wind in the power system is already significantly higher than the national average. They are redefining their operation of power systems to manage higher integration of VRE. Gujarat has set targets to install over 64 GW of renewable generation capacity by 2030 and is likely to face major challenges in integration of VRE ahead of other states. An International Energy Agency (IEA) report suggests three options for improved flexibility in Gujarat's case: 1) improving demand-side response, 2) thermal plant flexibility, and 3) increasing investment in energy storage system especially BESS.

Further, Gujarat's state government has launched an ambitious EV Policy to boost the EV adoption in the state, establish a supportive environment for EV manufacturers and investors, and scale-up EV charging infrastructure. City governments, whose policies and targets are generally in line with the state policies, are pushing to shape the local public transportation sector to transition to electric mobility (e-mobility) through local targets and programs in line with state and national initiatives.

This assessment study was undertaken in Surat and Rajkot cities of Gujarat to explore and identify specific applications and use-cases for deploying BESS as an energy management asset to support VRE and EV deployments and power infrastructure. The two cities were selected based on their diversity in terms of size, characteristics, upcoming urban development, presence of both public and private DISCOMs, proactiveness, plans for RE scale-up and EV penetration, upcoming city development and Smart City plans.

Surat and Rajkot have witnessed a rapid increase in the deployment of rooftop solar PV plants owing to the state government's favourable Gujarat State Solar Policy 2015 (revised in 2021) and related provisions. Further, the municipal corporations in Surat and Rajkot city, Surat Municipal Corporation (SMC) and Rajkot Municipal Corporation (RMC) respectively, are increasing the share of RE to meet power requirements in various municipal facilities. Both cities are making ambitious efforts to increase their EV fleet and put in place supporting infrastructure including EV charging stations. With their urban development trajectory and plans, Rajkot and Surat are both poised for an increase in building stock, infrastructure and utilities, leading to a rise in energy demand at the city-scale.

The assessment study was conducted through literature review and analyses coupled with on-ground information gathering and stakeholder engagements. It adopted an approach wherein initial baseline reviews of the two cities were conducted and use-cases for deployment of BESS were identified through literature review based on primary and secondary research.

A review of the policy and regulatory landscape was undertaken in parallel. Based on literature review and engagements with stakeholders mapped at the state and city level, opportunities and challenges for BESS deployment in the two cities were identified. This helped identify the technical, institutional or policy, and regulatory gaps and barriers for BESS deployment from an urban perspective and to prioritize the evaluation of use-cases. The **key gaps and barriers** identified are listed below:

- Lack of long-term vision, roadmap and adequate policy impetus for BESS at national or state level. There is ambiguity or lack of strong enabling interventions regarding BESS in existing national policies and regulations.
- Urban development planning processes for Indian cities do not consider urban energy requirements (including energy storage) with respect to the development of infrastructure and expected urban growth. An institutional framework and capacities for integrating BESS deployment into urban planning at local and state levels is lacking.
- Inadequate coordination and knowledge sharing between various stakeholders including DISCOMs, urban local bodies (ULBs) and other concerned state departments acts as a major barrier to integrated planning and urban development.
- Technical standards for BESS and associated technologies, and understanding and expertise on planning, operating and maintenance of BESS are lacking.
- Unavailability of data and reliable estimates on energy demand and load profiles to assess BESS feasibility and potential for different applications and use-cases.
- Limited knowledge and information on benefits of BESS projects and best practices to enable replication

- High capital cost; limited options for local procurement of BESS; high import duties; low investor confidence and interest owing to lack of clear market opportunities, limited evidence of pilot projects and business models on-ground

### Identification of BESS use-cases for Rajkot and Surat

Based on the current policy and regulatory landscape, urban development trajectory, and consultations with urban and power sector stakeholders, five use-cases for BESS were shortlisted for Rajkot and Surat. The shortlisted use-cases include:

| BESS for BtM applications | BESS for FtM applications |
|---|---|
| 1. EV charging infrastructure | 4. DISCOM load management at power distribution side |
| 2. End-use consumers (commercial, industrial and residential) | 5. Generation and transmission management |
| 3. Municipal utilities and services | |

RMC, SMC and a local DISCOM in Surat were interested in examining the feasibility of BESS application in specific use-cases, including a) load management at EV charging infrastructure, b) peak load and power backup management in water pumping station, and c) peak load management at Distribution transformers, respectively. To this end, these stakeholders were engaged during the pre-feasibility technical and cost analysis undertaken for these specific use-cases.

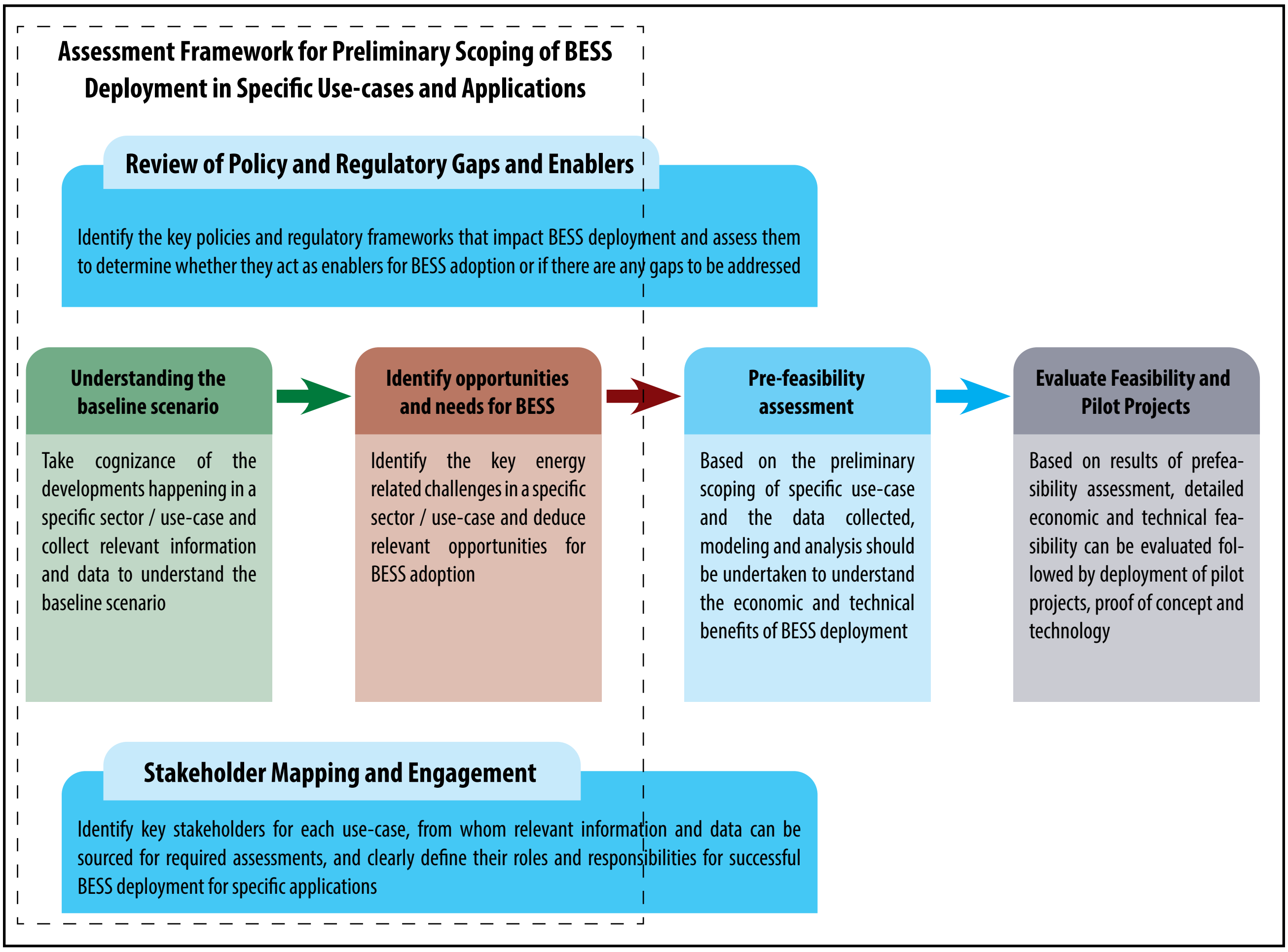
### Assessment Framework for BESS use-cases and applications

For the five shortlisted use-cases, an Assessment Framework was developed to assist stakeholders in preliminary scoping of BESS deployment. The Framework allows stakeholders to examine prospects and do an initial check for BESS deployment in the local urban context, before going into technical pre-feasibility studies.

It helps to better understand the energy related opportunities and requirements that BESS can address, while outlining relevant information and data to be gathered for technical evaluation of BESS across the five use-cases. This guiding framework is intended for city level stakeholders such as urban planners, local policymakers, and urban and energy sector practitioners, especially aimed at supporting stakeholders who may not be conversant with the requirements and challenges arising in the power sector due to growing energy demand, RE integration and e-mobility transition and how BESS can support them.

The Assessment Framework has a step-by-step approach and includes the following elements:

- **Understand the baseline scenario** – taking stock of the current status and developments through understanding targets, plans, entry points and drivers that would have implications on how and where BESS potentially fits in for the specific use-case
- **Identify the key opportunities and needs for BESS** – narrow down on the key energy related opportunities, needs and applications where intervention is required and which can be catered to by BESS
- **Stakeholder mapping and engagement** – identification of key stakeholders and engaging with them for gathering information and data to support the assessment
- **Review of existing policy and regulation** – to understand whether the current landscape, frameworks and mechanisms act as enablers or barriers to BESS deployment
- **Supporting elements and enablers for BESS adoption** – Policy, regulation and stakeholder coordination




*Overall approach of the Assessment Framework*

**Cost analysis and evaluating preliminary feasibility for BESS use-cases**

Once the assessment framework has been applied for preliminary scoping of a particular application and its suitability for BESS is insightful, a pre-feasibility level technical analysis is crucial to determine a quantitative understanding of the technical benefits and financial feasibility. Such a pre-feasibility analysis was undertaken for four shortlisted BESS use-cases using Total Cost of Ownership (TCO) analysis. The TCO analysis accounted for prevalent capital and operational costs over the period of the service of BESS. To evaluate preliminary feasibility of BESS in each use-case, the TCO for the baseline (without BESS) was compared against the potential TCO incurred on implementation of BESS. Different scenarios with different combinations of grid-based power, RE and BESS deployment were considered in the analysis.

## BtM applications

**EV charging infrastructure management**

- BESS for a mid-scale commercial EV charging station
- BESS for a large-scale e-bus charging station

**End-use consumers (Commercial, institutional, industrial and residential)**

- BESS for a large-scale hotel
- BESS for a mid-scale hospital

**Municipal utilities and services**

- BESS for a water pumping station

## FtM applications

**DISCOM load management**

- BESS for distribution transformer load management and deferral of upgrade

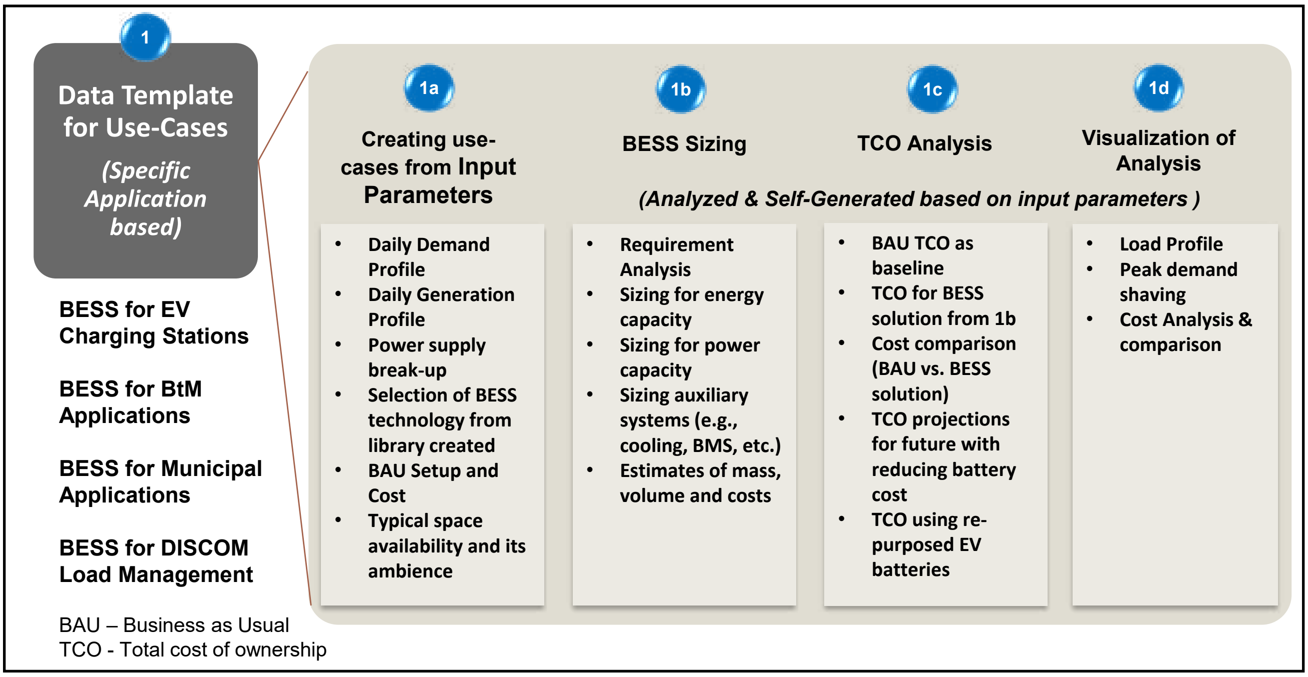
For the use-case analysis, specific Excel based templates were developed. Each template built a use-case for assessment based on an input parameters module, which sets the required boundary conditions, including the cost and technical parameters for developing the Business-as-Usual (BAU) case through inputs fed-in by the user. The data and information required as per the data templates were sought from relevant local stakeholders, specifically SMC, RMC and a local DISCOM. Any data gaps were plugged by using representative data and assumptions from secondary sources.

The analysis showed that BESS is technically a viable solution for BtM applications, to reduce the peak demand of the facilities and for power factor correction. It also helps maximize the self-consumption from RE generation and provides reliable power-backup during grid outages. A cross-comparison of TCO analysis for BtM applications indicates that large facilities with high load demands such as industrial units, large commercial establishments and municipal facilities are likely to benefit more with BESS implementation. Deploying BESS for BtM applications at the end-consumers side also offers co-benefits in the electricity system, in terms of reducing the loading on local Distribution Transformers (DTs) and hence deferring requirements for distribution network upgrade by DISCOMs.

Based on the TCO analysis and cross comparison of results from different scenarios, it can be inferred that with declining costs of BESS and increasing grid energy charges in the future, deploying BESS can be financially viable or at least be at par with the cost of operations borne without BESS deployment. BESS is likely to become feasible sooner for end consumers with high demand, especially when deployed alongside RE system, as compared to consumers with low to medium load demand. Notably, in the case of a municipal water pumping station, having a solar PV system to meet about 10% of its total energy requirements, the TCO value on deployment of BESS is found be almost at par with the base-case TCO (marginal difference of <6%) for a future scenario (5 years hence).

With regard to the FtM use-case, the analysis looked at deployment of BESS by DISCOMs for load management at the DT level. In this case, BESS deployment was evaluated as a solution to support the reduction of peak demand and overloading of DT. The annualized cost of BESS deployment was compared against that for upgrading or deploying a new DT.

It was evident from the analysis that deploying BESS primarily for load shaving application was viable only when the peak loading occurs for shorter intervals and requires only low load shaving requirements or demand. However, when such systems deployed at the distribution scale can be utilized to cater to multiple applications earning benefits from multiple revenue streams, made possible due to enabling policies and regulations, they can be financially viable and enable distribution licensees to reap several technical benefits as well.




*Technical approach of use-case analysis using Excel tool developed*

A sensitivity analysis to compare the TCO estimates for BESS based on electricity tariffs from other states led to interesting insights. The viability of BESS deployed with the RE system improved, while the TCO was significantly lower and closer/at par with baseline costs for states where the power and fixed charges are higher (such as Uttar Pradesh, Rajasthan) as compared to the relatively lower grid power charges currently levied in Gujarat. Further, undertaking the analysis using repurposed or second-use batteries (which have lower capital costs compared to fresh batteries) revealed that the viability of BESS improves significantly, and has relatively lower TCO in comparison with BAU when deployed along with RE system. However, the establishment of a market for repurposed batteries will need more time and policy interventions in India. It could be developed in future when existing EV batteries and BESS systems would be retired at the end of first life and a regulatory regime for repurposing them would be in place.

**Business models for BESS implementation**

Experimenting with different business models and strategies is key to deploying new technologies into a market. The penetration of energy storage is still at a nascent stage, and no single business model has yet been crystallized into an effective implementation model for deploying energy storage solutions. However, several players from different value chains of the power markets across the globe are experimenting with different business models including typical strategies based on the location of energy storage asset in the value chain and ownership and innovative models, gaining experience and building partnerships. Business models identified for BESS deployment, both commonly employed as well as emerging innovative models, include:

| Front-of-the-Meter models | Behind-the-Meter models |
|---|---|
| • BESS as Generation Asset<br>• BESS as Transmission Network Asset<br>• BESS as Distribution Network Asset<br>• BESS as Merchant Asset | • BESS under CapEx Model<br>• BESS under ESCO/RESCO Model |

Out of these models, BESS deployed as an energy management asset in the transmission and distribution (T&D) network of the power system can provide the maximum technical benefits while also earning revenues from multiple revenue streams, thereby ensuring such models have the highest level of bankability. Further, deployment of BESS at the distribution level can lead to new opportunities for collaboration with end consumers, especially those with high contract demand and who can benefit from BESS being in place. Such innovative business models that have been experimented with in the other power markets across the globe should be explored for the Indian context. However, collaboration and coordination between different power sector stakeholders is necessary, impetus for which can come from a long-term policy vision and roadmap for BESS deployment in the Indian power market.

**Enabling actions and recommendations for BESS adoption**

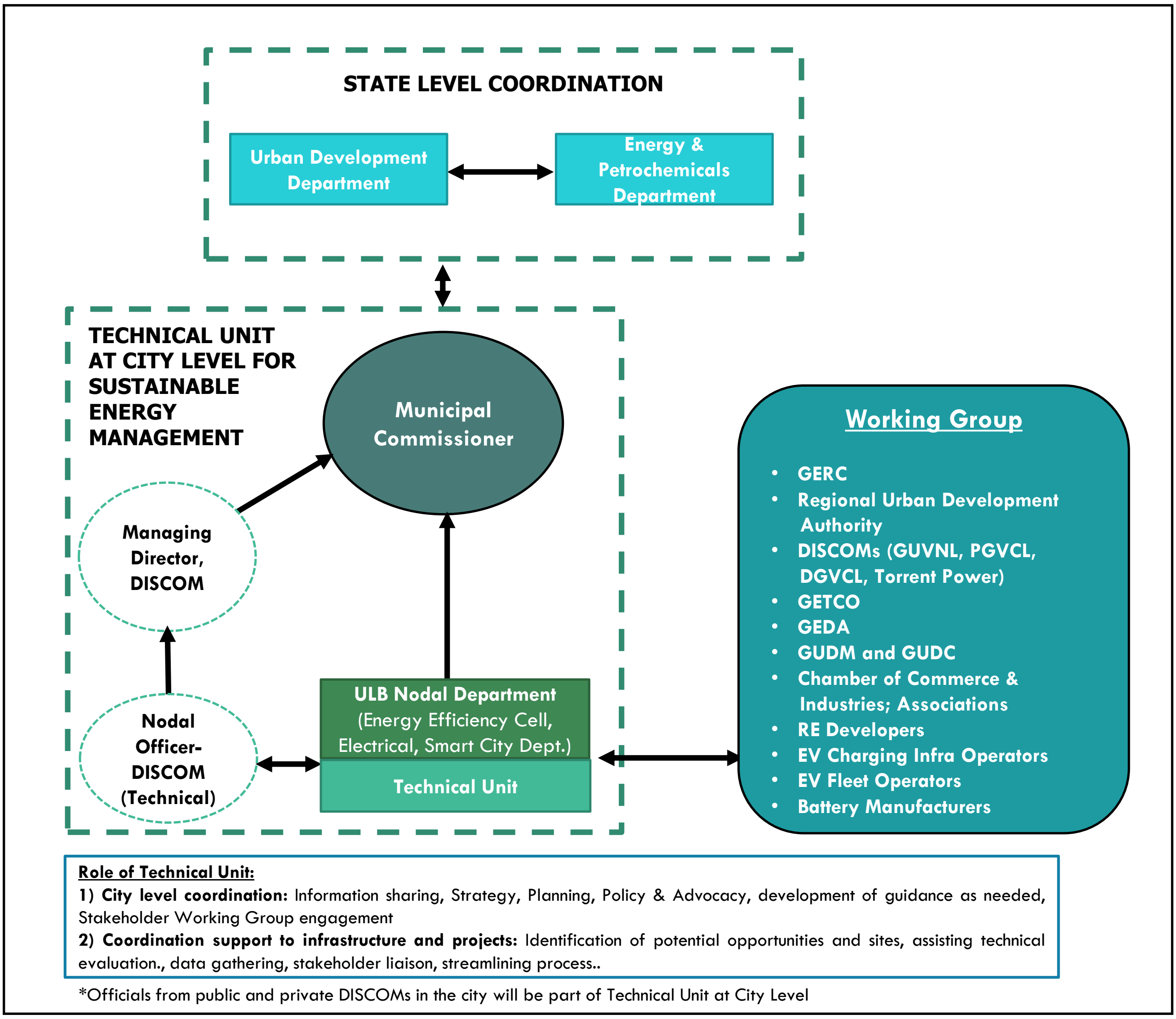
From the assessment, key enabling actions and recommendations related to urban planning interventions, joint action by ULBs and DISCOMs, and policy and regulatory measures were identified.

***Leveraging urban planning linkages and coordinated action between urban and power sector authorities***

ULBs and DISCOMs are recommended to collaborate on integrated spatial and energy planning at the city-scale, which will help facilitate inclusion of energy planning into urban planning process and support the integration of RE, E-mobility and solutions such as BESS. Greater involvement across corresponding planning mechanisms and regular exchange of information between DISCOMs and ULBs can help to utilize opportunities to promote BESS through urban development regulations and related measures.

Avenues for such integrated urban and energy planning and promotion of BESS exist at the urban scale in greenfield developments, redevelopments, high-density development corridors, commercial and industrial zones, among others. For instance, being better informed about sites where densification or redevelopment has been proposed by the ULB will help DISCOMs to assess future power demand, strengthen power distribution planning, and tap into the right opportunities for BESS deployment in power distribution networks and infrastructure. ULBs can promote or incentivize RE and BESS through provisions in the urban development regulations targeted towards energy-intensive consumers such as industries and large commercial complexes, thereby helping reduce power demand and load on the power distribution infrastructure in congested areas to support DISCOMs. DISCOMs can provide inputs to ULBs related to zoning, development mix and building prototypes in greenfield areas and growth centres such as the Dream City in Surat and Rajkot's Smart City area, so that the spatial development and buildings are tailored for efficient energy use and to enable deployment of BESS.

ULBs and DISCOMs can coordinate during the planning and implementation of E-mobility and sustainable energy infrastructure to promote BESS. Opportunities for ULBs and DISCOMs to work closely in this regard include promotion of RE and BESS as an integrated solution to power public and commercial EV charging infrastructure, to identify spatial distribution of large-scale municipal RE projects, to evaluate opportunities to deploy BESS with RE systems in municipal utilities, and to jointly develop and implement BESS pilot projects for demonstration.To help facilitate such coordination, it has been suggested to develop an institutional framework in the medium term, centred around a technical unit deployed within the ULB and ably supported by the local DISCOM(s) and a working group comprising of various stakeholders.

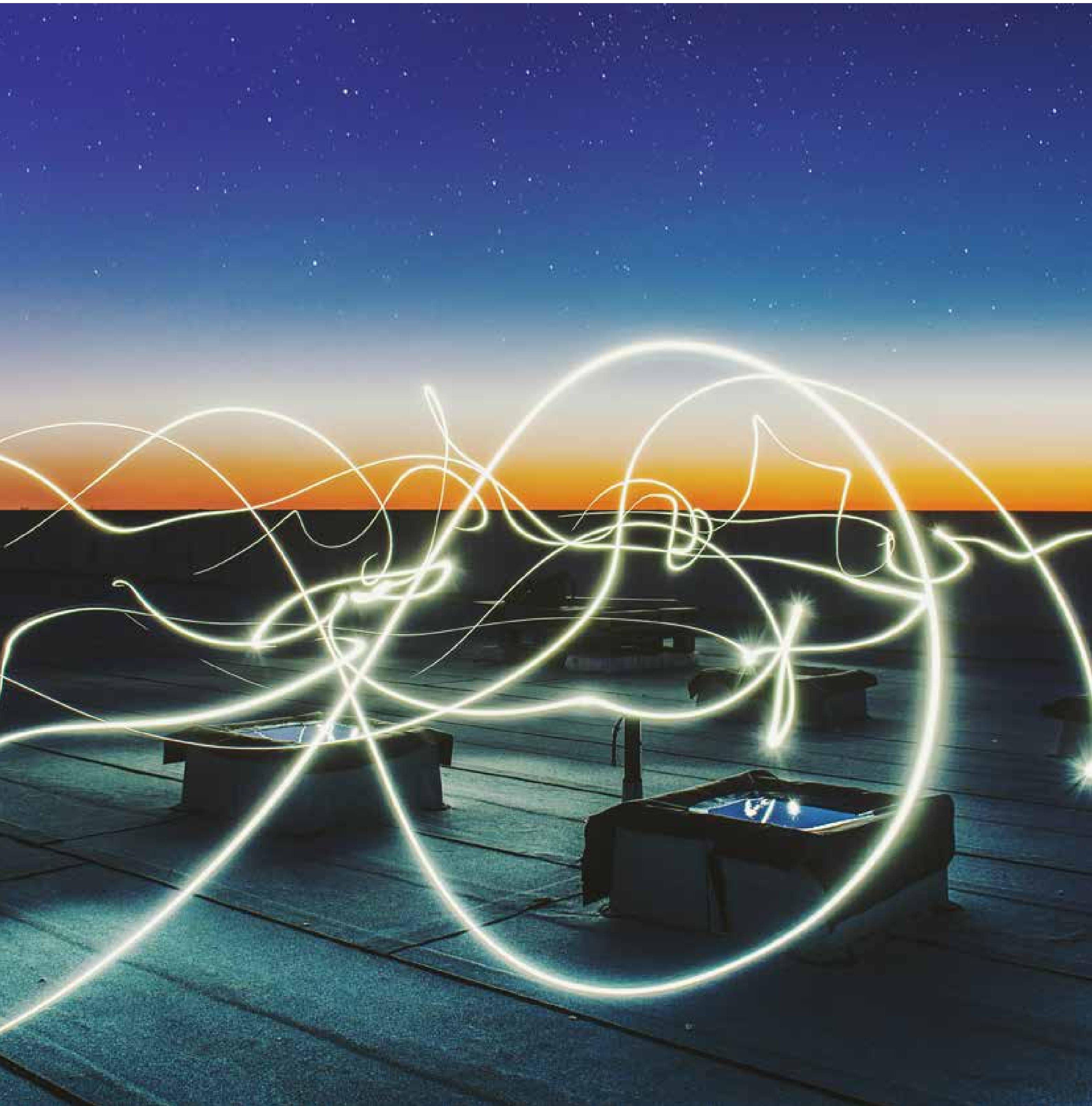



*Institutional framework for coordination between local implementing authorities, DISCOMs and other stakeholders*

***Policy and regulatory measures to enable BESS adoption***

As a key enabling policy measure, the study recommends a national-level comprehensive National Energy Storage Policy that guides the development of the energy storage industry by providing a long-term vision and road map for proliferation of storage systems and supporting the establishment of necessary incentive structures to attract private-sector participation. Other measures include encouraging energy storage in RE policies, encouraging pilot projects for BESS deployment at urban scale, including BESS in sustainable development plans and climate action plans of cities, providing incentives for early adopters, and developing market for repurposing retired EV batteries for BESS applications.

The key regulatory enablers suggested by the study include recognition of energy storage systems, especially BESS as fast responding asset, and the value of flexibility brought in by them in key national regulations; allowing BESS to provide primary regulatory ancillary service through a market based mechanism as is increasingly being done in developed markets across the globe, but in consideration with the Indian power market dynamics and realities; and enabling energy storage assets to earn revenue from multiple value streams. Further, it is imperative that National level standards for energy storage technologies and other relevant technologies be established.



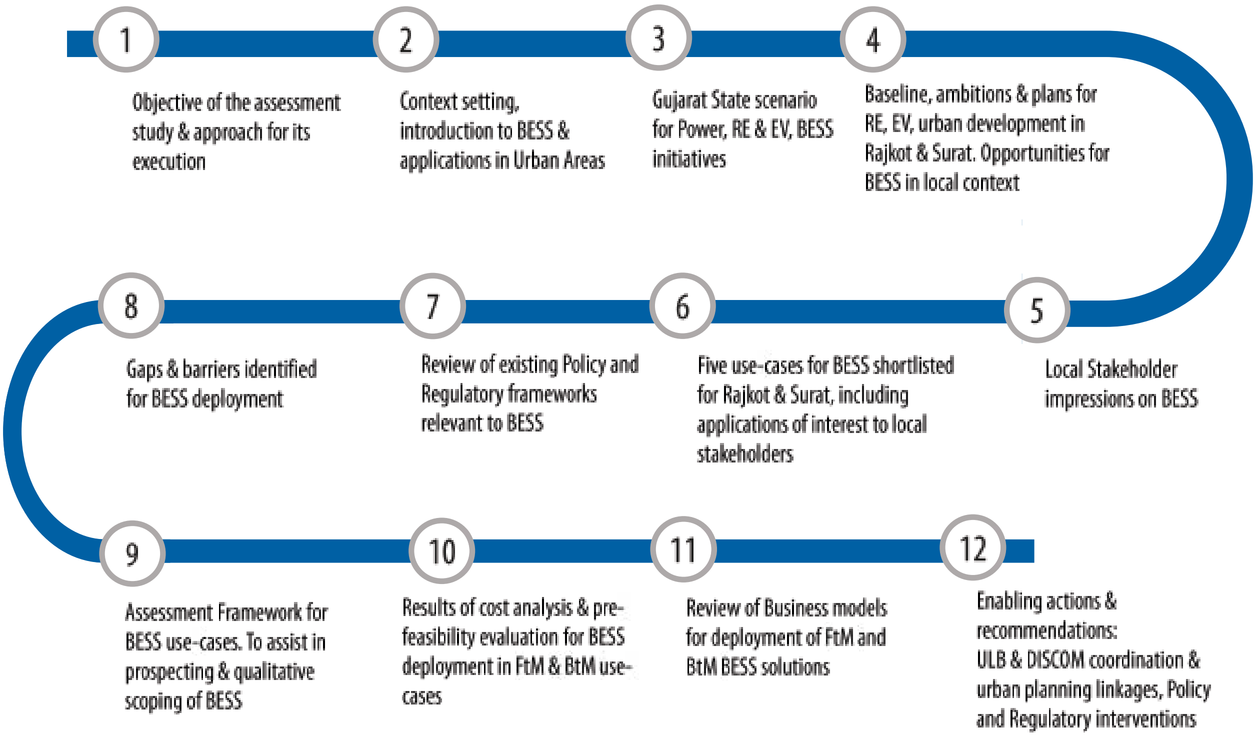
# Introduction to the Report

This report presents the information collected and analysed as a part of the 'Enabling Energy Storage in Indian Cities' project with a focus on two cities of the Indian state of Gujarat, namely Rajkot and Surat.

The intent is to highlight and understand the potential opportunities for stationary battery energy storage to support the sustainable energy, electric mobility (e-mobility) and net-zero transition at the city level, in the two cities assessed in this study as well as other Indian cities.

The report is organized into sections to synthesize insights, analysis and findings from different elements of the technical assessment, as depicted below:

**Document Map – Overview of Sections and Information presented in the Report**




BESS: Battery Energy Storage System; RE: Renewable energy; EV: Electric vehicles; FtM: front of the meter; BtM: behind the meter; ULB: Urban Local Body; DISCOM: Electricity Distribution Company

# 1. Project Background

Energy storage technologies increasingly play a pivotal role in the low-carbon and sustainable energy transition around the globe. Battery-based energy storage can support the integration of large and small scale distributed renewable energy (RE), respond to the growing energy demand and newer loads such as e-mobility, and enable efficient supply and use of energy.

Given their improving cost competitiveness and the various services and benefits they offer, battery energy storage systems (BESS) can help enable the transformation to RE and electric vehicle (EV) paradigm and support net-zero emission goals in Indian cities. Deployments of BESS can support energy requirements at different locations in the power sector chain, ranging from grid-scale in power generation, electricity transmission and distribution networks, to end-consumers of electricity in cities.

The current landscape in India presents opportunities for integrating BESS to cater to the rising energy demand, changing load profiles, and increased urban renewable generation, both in existing areas and in new urban development brought on by flagship initiatives such as the Smart Cities Mission. Distribution companies (DISCOMs) face challenges in terms of rise in competitive renewable supply options with increasing cost of conventional fossil power, shifting of consumer base, fall in revenues, and unutilized/idle excess conventional base-load capacities. The significant rise in distributed renewable generation and e-mobility infrastructure deployment along with the technical and financial challenges of RE integration add to the complexities in grid planning and operations for DISCOMs and regulators. Decisions such as spatial distribution of rooftop solar photovoltaic (PV) systems and EV charging infrastructure can have implications for both, the distribution network and the potential to integrate RE generation and technologies such as BESS.

To fully realize the potential of BESS, DISCOMs and energy regulators need to undertake closely coordinated action with city governments, and urban development and planning agencies. All stakeholders including DISCOMs, energy regulators and planners, city governments and urban planning agencies should understand the aspirations, drivers, and challenges in RE and EV scale-up and BESS adoption. The financial viability of BESS projects at the city-scale will depend on the cost–benefit analysis of the intended applications and use-cases, which needs to be properly assessed and understood from the perspective of all the stakeholders involved in the power system value chain.

In this context, ICLEI South Asia has undertaken a project to understand and highlight the potential opportunities for BESS in the Indian urban context. **The assessment study was conducted in the cities of Rajkot and Surat in Gujarat state** to explore and identify specific use-cases and applications for BESS, particularly to support the RE and EV transition in the two cities and its applicability to other Indian cities. The project intends to highlight avenues for coordinated action on BESS between urban and energy stakeholders, particularly city governments and DISCOMs, and to support the RE and EV transition. It also seeks to identify linkages between urban planning and energy planning, and opportunities for joint promotion of BESS. Additionally, the project aims to identify gaps, enabling actions, approaches, and policy and regulatory measures for the promotion of BESS in Indian cities.

## 1.1. Project Objective

- The overall objective is to enable urban local authorities and DISCOMs to identify strategies and policy interventions for leveraging urban planning linkages to promote demand for energy storage at the city-scale.
- DISCOMs and city governments are made aware of potential drivers for BESS at the urban scale and the opportunities and challenges associated with it.
- Specific use-cases for battery energy storage in key applications in urban areas, both behind-the-meter (BtM) and front-of the-meter (FtM), are prioritized and quantified in order to support RE and EV deployment.
- Specific opportunities and strategies for increased coordination and coherence between the urban authorities and energy sector actors are identified.

- Business models for BESS deployment are identified from global use-cases for both BtM and FtM systems.
- Potential regulatory and policy measures are identified to address barriers and facilitate adoption of BESS.

The outcomes are targeted towards actors in the urban and energy sectors, including DISCOMs, Urban Local Bodies (ULBs), regional development agencies, state and local urban planning departments, Smart City agencies, energy development agencies, regulatory authorities for power and energy, and the private sector.

## 1.2. Project Approach

The approach adopted in the assessment study which focused on Surat and Rajkot is described below and depicted in Figure 1. These cities were selected based on diversity in terms of size, characteristics, upcoming urban development, presence of both public and private DISCOMs, proactiveness, plans for RE scale-up and EV penetration, upcoming city development and Smart City plans. The assessment was conducted through literature review and analyses coupled with on-ground information gathering and stakeholder engagement.

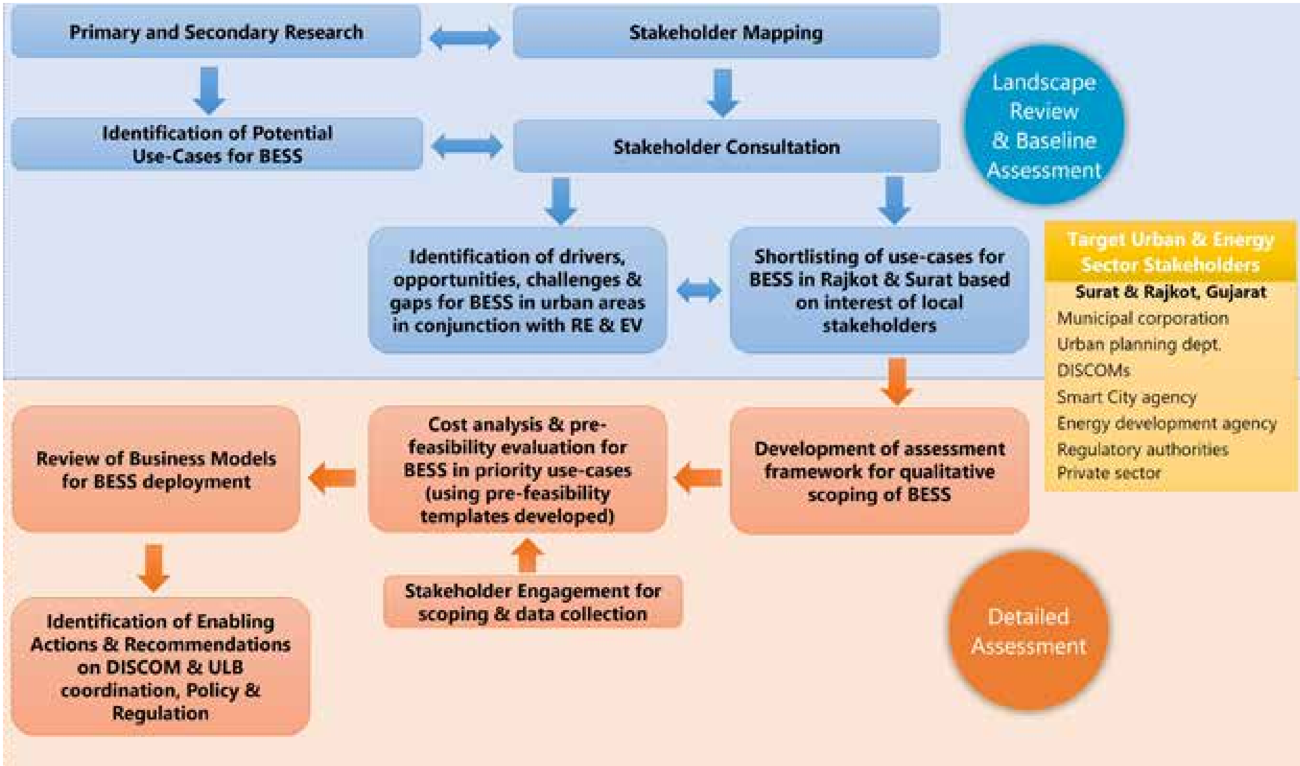



**Figure 1: Project Approach**

**Primary and secondary research** were conducted to understand the utility and applicability of BESS to cater to different requirements and applications within the power sector and at the city level (see Section 2). A landscape and baseline review with relevance to BESS was undertaken at the national, state and local levels. This included understanding the current power sector scenario, institutional structure, national and state policies to support BESS, existing and proposed plans for RE and EVs in Gujarat and the two selected cities (see Sections 3 and 4). A review of policy and governance frameworks, and information gathered from planning documents on RE and climate goals, e-mobility, and urban development, relevant to Rajkot and Surat, was undertaken. Potential drivers, opportunities and challenges for energy storage were identified for both BtM and FtM applications through literature review. Potential stakeholders at the local and state levels were identified to enable BESS adoption in the power sector and at the urban scale. **Potential use-cases, applications and opportunities for BESS** were identified for the local level, based on primary and secondary research. These were subsequently substantiated through consultations with local stakeholders. Available national and international case studies and use-cases were studied to assess enabling factors for BESS applications.

Simultaneously, **stakeholder mapping** was carried out to identify key state and local level stakeholders to support the enabling of BESS (see Section 5). Stakeholders such as relevant state government departments, DISCOMs, transmission companies, municipal corporations, urban planning/development departments, Smart City SPVs and departments, energy development agencies, and relevant government and technical institutions were identified. **Stakeholder consultations**, through one-to-one discussions, were carried out at various stages of the assessment (see Section 5). Stakeholders were engaged over the course of the study to understand the local energy and urban growth status and trajectory, and the potential opportunities, barriers and gaps in relation to BESS. Interviews were conducted with identified stakeholders through questionnaires structured to validate information and gather further inputs on the aspects mentioned above. The identified use-cases were discussed for their recommendations and to prioritize them based on the local stakeholders' interests.

**Shortlisting of use-cases for BESS** was done through literature review and stakeholder consultations (see Section 6). Five BESS use-cases (3 BtM, 2 FtM) were identified for the local context. These are 1) EV charging infrastructure, 2) end-use consumers (commercial, industrial and residential), 3) municipal facilities and services, 4) generation and transmission applications, and 5) DISCOM load management on the power distribution side. Based on the interest of local stakeholders in evaluating BESS feasibility, particularly that of Rajkot Municipal Corporation (RMC), Surat Municipal Corporation (SMC) and a local DISCOM, three of the five use-cases were prioritized. The three specific use-cases are i) load management at EV charging station, ii) peak load and power backup management at water pumping station, and iii) curtail peak load and deferral of upgrade at the distribution transformer (DT) level. Gathering data and inputs during the pre-feasibility level evaluation and cost analysis for these prioritized use-cases was facilitated through deeper engagement with the three corresponding stakeholders.

A **review of the existing policy and regulatory frameworks** at the national and state levels was conducted to understand the current state-of-play with relevance to BESS and, opportunities and gaps (see Section 7). **Gaps and barriers in relation to BESS** were identified through literature review and stakeholder consultations (see Section 8). The gap assessment addressed policies and regulation, institutional frameworks, and technical and financial aspects. Based on the objectives of the study, the current institutional framework and practices for the energy and urban sectors were assessed to identify gaps and challenges for coordinated planning and action for promoting BESS in the two sectors.

**An assessment framework for BESS use-cases and applications** was developed to assist stakeholders in a preliminary qualitative scoping for the identified use-cases. Comprised of a decision flowchart and various indicators for each use-case, the assessment framework involves a step-by-step approach to understand the baseline scenario, and identify the key energy-related challenges of a use-case as well as its opportunities for BESS (see Section 9). It addresses the enabling elements that can support BESS adoption such as stakeholder coordination, information or data required to support the assessment, and existing regulatory and policy mechanisms.

**Pre-feasibility level technical analysis** was undertaken for each prioritized BESS use-case to evaluate preliminary feasibility, as well as compare the total costs of ownership (TCO) for the baseline (without BESS) against those with BESS implementation (see Section 10). The TCO analysis accounts for prevalent capital and operational costs for BESS deployment as against the base case. The analysis was carried out using spreadsheet-based analysis tools, specific to each BtM and FtM use-case, developed for this study. BESS sizing and specifications in the analysis are based on product datasheets of Li-ion BESS modules offered by select manufacturers. Sensitivity analysis was conducted to understand the impact of future variations in cost components such as battery costs and energy costs. For the TCO and pre-feasibility analysis, information on the site/location to identify the primary requirements that BESS could serve, was sought from the three relevant local stakeholders (SMC, RMC and a local DISCOM). Energy-related technical data including monthly electricity consumption and bills, contracted load, daily operational and power demand patterns, daily load profile, specifications of RE systems and backup power on-site, among other parameters, were also sought from them. Any data gaps such as daily load profiles and RE generation were plugged in using representative data and assumptions from secondary sources.

As a next step, key **business models** that can be employed by investors, policy makers, public decision-makers, customers and private players in the power market value chain were reviewed. Commonly employed implementation models along with emerging innovative business strategies are discussed in Section 11. **Enabling actions and recommendations** were identified, pertinent to the prioritized BtM and FtM use-cases, to enable BESS deployment in urban areas (see Section 12). Based on the state and local context in Rajkot and Surat, opportunities, actions and urban planning linkages were identified to facilitate urban and power sector stakeholders (specifically ULBs and DISCOMs) to jointly promote BESS at the city-scale. Suggestions are made on policy-related measures and regulatory interventions to support BESS adoption. To share the results of the analysis and findings of the assessment undertaken in Rajkot and Surat, and seek inputs of the stakeholders, the final project workshop was conducted on August 26, 2022. The workshop provided insights on the implications, challenges, benefits and a way forward in enabling strategies and interventions to scale up BESS deployment in cities.

# 2. Battery Energy Storage to Enable Sustainable Energy Transition in Cities

## 2.1. India's Clean Energy and Electric Mobility Ambitions

India's energy demand has grown significantly in the last two decades. Driven by its expanding economy, population, urbanization and industrialization, the country is now the world's third largest energy consumer. Since 2000, around 900 million citizens have gained access to electricity.[1] The Indian electricity market finds itself at the forefront of major transformation, with the country expanding its capacity to meet the anticipated energy demand and simultaneously striving to integrate sustainable solutions at scale to meet its ambitious climate goals.

A sharp rise in variability from RE sources has been a key feature in the growth of India's electricity market. India is the third largest RE producer in the world with an installed RE capacity of 160 GW, which constitutes around 39.7% of the total installed capacity.[2] India has further pledged to increase its RE capacity to an ambitious 500 GW by 2030. The rapid increase of solar PV and wind share in the total energy mix has been notable, together accounting for more than 7% of the total power generation in the country. In some renewable power-rich states, solar PV and wind now contribute as much as 15% of the total power generation.[2]

With the Government of India (GOI)'s aggressive push for adoption of EVs through a range of policy initiatives, road transport is set to emerge as a key end-use of electricity. India aims to achieve 30% share of EVs in new vehicle sales by 2030. About 1.06 million EVs have been registered in the country since 2012, with 0.42 million EVs sold in the year 2021-22 alone. EV adoption is expected to amplify significantly in the coming years, with projections estimating the total EV sales in the country to reach 14.8 million by 2030.[3] To adequately supplement the EV transition with the development of adequate EV charging infrastructure, the Bureau of Energy Efficiency (BEE) has laid out targets for the installation of at least one publicly accessible charger within a 3km-by-3km grid in cities, one charging station every 25 km on both sides of highways, and one fast-charging station every 100 km on highways.

Responding to the need for accelerated global climate action, India announced at the 26th Conference of Parties (COP26) at Glasgow in 2021,[4] its increased ambition to target 'net-zero greenhouse gas (GHG) emissions' by 2070 and 500 GW non-fossil energy capacity by 2030. As per the nationally determined contributions (NDC) targets recently approved by the cabinet[5], India aims to realize its net-zero GHG emissions ambition through the following mid-term targets centred around energy:

- 50% cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030
- Reduce emissions intensity of its GDP by 45 percent by 2030, from 2005 level

## 2.2. Role of BESS in India's Renewable Energy and Electric Mobility Transition

Based on the ongoing efforts and goals for renewable transition, the Indian electricity grid is evolving from a fossil fuel-dominated grid to one where increasingly, RE generation will be fed in. This transition has created a need to balance the grid's power supply and load with significantly greater efficacy.

Until now, the need for grid flexibility has been met predominantly by coal-fired, hydro and gas-fired power plants as they can be ramped up and down as per the grid requirement relatively easily and are considered relatively stable sources of electricity supply. The push and need to make the grid greener have led to a rise in the pace of adding RE (solar/wind) capacity, which is inherently intermittent due to the variable nature of renewable sources, to the grid. The capacities of traditionally stable or balancing sources of supply viz. coal or gas are not increasing as rapidly, coal being non-sustainable energy and gas, though relatively cleaner, being considered economically inefficient as it is limited and expensive. This is creating an imbalance in the grid between the stable and intermittent sources, making it difficult for controllers to operate the grid efficiently. On the demand side, loads and consumption are increasing as significantly variable loads such as e-mobility are being added. Thus, there is a need to adopt a cleaner and stable supply.

Energy storage technologies can play a pivotal role between green energy supply and the response to growing electricity demand. BESS is a potential enabling solution that offers increased system flexibility, and supports India's anticipated variable renewable energy (VRE) integration and EV charging infrastructure deployment for e-mobility transition.

## BESS and Its Components

BESS is an electrochemical device with rechargeable batteries as underlying technology. BESS collects and stores energy from the grid or renewables, and releases the stored energy when required to provide electricity or other grid services.

A BESS unit is comprised of hardware and software components, primary among them:

- **Battery system:** It contains individual battery cells that convert chemical energy into electrical energy. The cells are arranged in modules and form battery packs.
- **Battery management system (BMS):** The BMS ensures the safety of the battery system. It monitors the condition of battery cells, measures their parameters and states such as state-of-charge and state-of-health, and protects them from fires and other hazards.
- **Inverter or power conversion system (PCS):** It converts direct current (DC) produced by batteries into alternating current (AC) supplied to facilities. BESS has bi-directional inverters that allow for both charging and discharging.
- **Energy management system (EMS):** It is responsible for monitoring and control of the energy flow within a BESS. The EMS coordinates the work of the BMS, inverter and other components of a BESS. By collecting and analysing energy data, an EMS can efficiently manage the power resources of the system.
- BESS can also include safety and temperature control systems, with relevant monitoring and control units.

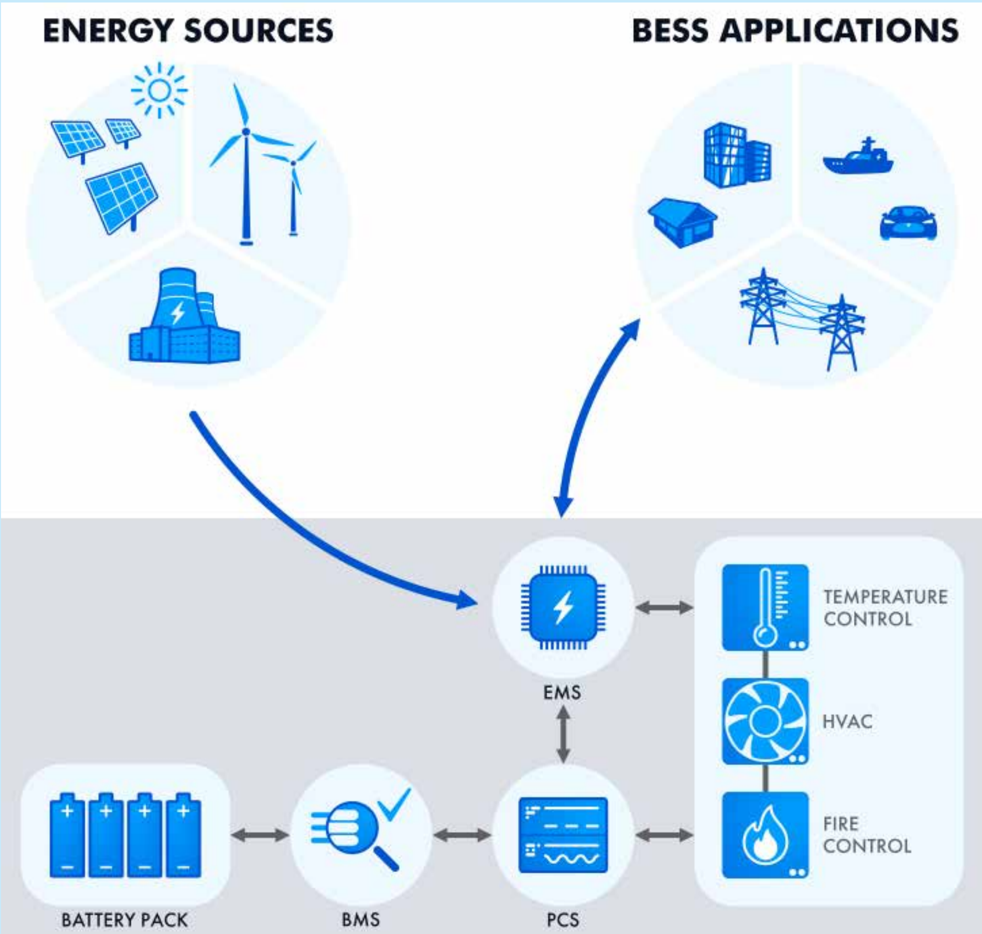



**Figure 2: Components of Battery Energy Storage System**

Battery technologies in BESS may vary, including Li-ion, lead-acid, nickel-cadmium and flow batteries among others. Technical specifications of each battery type make it suitable for different uses and affect the efficiency of battery energy storage. Key battery characteristics include:

- **Energy (storage) capacity:** The maximum amount of stored energy or electricity, kilowatt hour (kWh) or megawatt hour (MWh), that a BESS can hold
- **Rated power capacity:** The total possible instantaneous discharge capability (in kilowatts [kW] or megawatts [MW]) of the BESS, or the maximum rate of discharge that the BESS can achieve, starting from a fully charged state
- **Round-trip efficiency:** The ratio of energy delivered by a battery during discharge to the energy supplied to the battery during one charging cycle
- **Depth of Discharge (DoD):** The percentage of energy discharged from a battery relative to its total capacity
- **Lifetime:** Amount of time or cycles for which a BESS can provide regular charging and discharging before failure or significant degradation
- **Response time:** The time a BESS needs to move from the idle state and start working at full power
- **Ramp rate:** The rate at which the system can increase or decrease its power output, or ramp up or down, respectively

**Sources:**

Integra Sources (2021): Efficient Energy Management and Energy Saving with a BESS (Battery Energy Storage System)

NREL (2019): Greening the Grid – Grid Integration Toolkit. Grid-Scale Battery Storage: Frequently Asked Questions

Batteries have already been proven to be a commercially viable energy storage technology, are quickly deployable, have high ramping rates, and are modular systems that can be deployed in standard shipping containers, thus providing power system flexibility wherever needed both on the supply and demand side. Utility-scale BESS is well adapted to the short-run flexibility that the Indian power system requires to match its midday solar-led generating peak with its early evening consumption peak. BESS offers a large range of installation sizes for prospective deployment at different types of sites. The potential of BESS has also increased in recent years with its cost falling globally. All these factors have established BESS as a key enabling solution for boosting flexibility as well as energy security.

BESS can be deployed to add value at different levels of the electricity system, and can be sited as an FtM application (connected to transmission and distribution networks at utility scale) and as a BtM application (consumer-sited batteries connected behind the utility meter). Some of the key services offered by BESS in these two applications are depicted below:

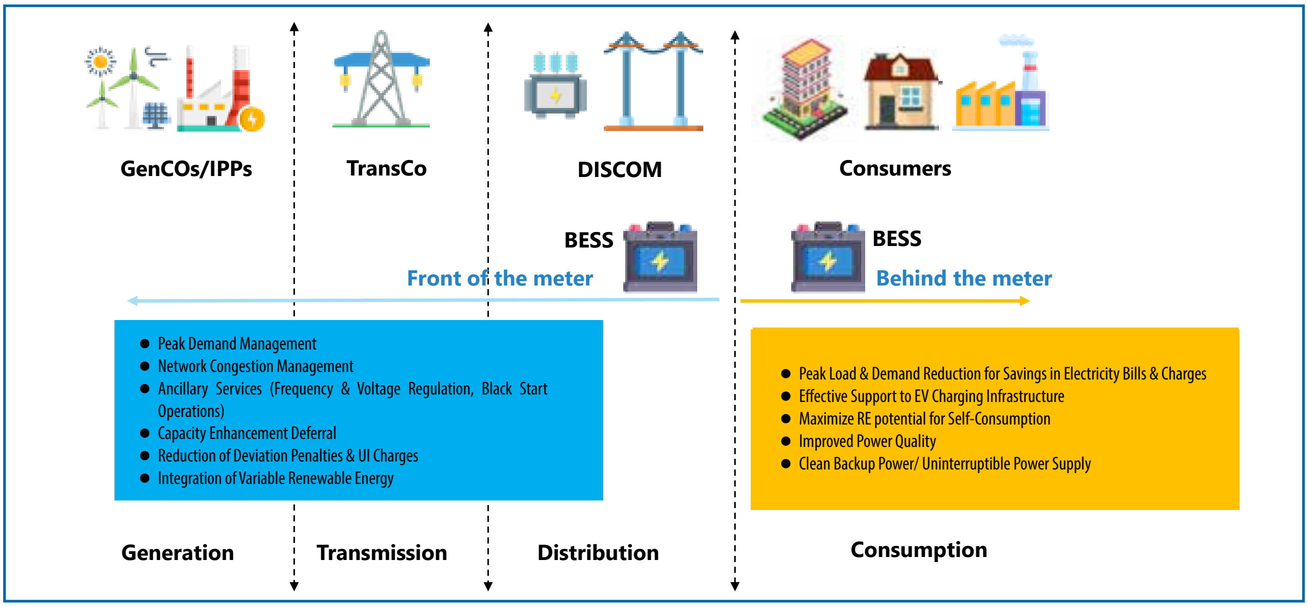
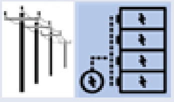
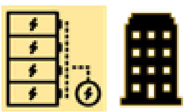



**Figure 3: Role of BESS in the Electricity Grid**

| | |
|---|---|
| **Energy grid services (FtM Applications)**<br> | **Peak demand management and network congestion management**<br>● By storing power during off-peak periods and supplying it during periods when there is more demand than usual (peak demand), BESS can help ease the stress on the power utility to meet demand by purchasing costly power from other sources.<br>● When the upstream network does not have space to accommodate any more electricity or if network lines are under maintenance/fault, BESS, which is installed downstream of congestion, can alleviate the load stress. |
| | **Ancillary services (frequency and voltage regulation, black start operations)**<br>● Its ability to respond in milliseconds enables BESS to ably support power imbalances and hence support frequency regulation.<br>● BESS can inject or absorb both active and reactive power as required, helping maintain the required voltage profile.<br>● BESS does not need any external power source and hence can support black start operations viz. charging a power station or the network.<br>● Large generators need an external power source to perform vital functions before they can start generating electricity (known as black-start). BESS can utilize stored energy without continuous reliance on external source to support black-start. Generally, this power is supplied by the grid, but in the event of a grid failure, BESS can provide this necessary support service. |
| | **Capacity enhancement deferral**<br>● By helping in peak load management, BESS can help postpone or avoid investments in capacity augmentation, or replacement of the power transmission and distribution network and equipment, to meet increasing power demand. |
| | **Reduction in deviation penalties and Unscheduled Interchange (UI) charges**<br>● BESS can store and discharge electricity as and when required, helping minimize the regulatory penalties that a utility would have to pay for occasional overdrawing/underdrawing of power for various reasons. |
| | **Integration of VRE**<br>● BESS can support grid integration for VRE (capacity firming) and RE-powered Distributed Generation System (mini-grids). |
| **BtM Applications**<br> | **Peak load and demand reduction for savings in electricity bills and charges**<br>● To take optimal advantage of time-of-day (ToD) tariffs, BESS deployed on the consumer side can be charged from the grid during off-peak hours at lower costs, and utilized to supply energy during peak tariff hours. This can help reduce peak electricity consumption and charges for consumers.<br>● Demand charges are levied on consumers based on the load/capacity (kVA or kW) connected to the power grid. BESS can help lower the load requirements from the grid and hence help reduce the demand charges incurred. |
| | **Effective support to EV charging infrastructure**<br>● Energy storage can help reduce peak power requirement and support better integration of RE to make EV charging solutions more energy efficient and cost effective. |
| | **Maximizing RE potential for self-consumption**<br>● Integration of BESS with the RE system (such as rooftop solar PV) can maximize RE potential by storing the surplus energy generation. BESS can help increase captive/self-consumption of RE-based electricity and utilize this stored energy during night-time or peak hours. |

| | |
|---|---|
| | **Improvement in power quality**<br>● Consumers encounter voltage drop issues in grid power, which impacts the performance and life of their equipment. BESS can locally help in improved management of voltage and the power factor of the system, alleviating these concerns. |
| | **Clean backup power/uninterruptible power supply**<br>● BESS can provide clean, reliable, instantaneous and silent backup power during power outages as compared to diesel generators. It helps ensure the continuity of operations and alleviates concerns of downtime for consumers. |

Though high costs and low round-trip efficiencies of lead-acid and other battery technologies prevented mass deployment of BESS in the past, the advent of **Li-ion batteries in consumer electronics and EVs has led to an expansion of global Li-ion battery manufacturing capacity, resulting in significant cost reduction that is expected to continue in the coming decade.** Other battery technologies such as redox flow batteries and sodium-sulphur batteries are also explored for used in energy storage solutions, given the geo-political and geographical limitations to accessing lithium that is crucial for scale-up of Li-ion battery manufacturing to meet growing demand. Li-ion batteries' low cost and high efficiency have been instrumental in pilot BESS deployment in recent years for both small-scale (BtM) installations and large-scale (grid-level) deployment. This has, and will further, help reduce costs, identify viable use-cases and develop business models that are crucial to the scale-up and future of BESS.

Given its declining costs, improvements in performance and increasing deployment, BESS is expected to become competitive with existing prevalent technologies and offer an attractive proposition across different applications over the next decade, in both FtM and BtM solutions (see Table 1).

**Table 1: Market Attractiveness of Battery Energy Storage across Stationary Applications by 2030**

<table>
<tr><th>Applications</th><th>2020</th><th>2025</th><th>2030</th></tr>
<tr><td>Microgrids Applications/Diesel Replace-ment</td><td>High</td><td>Medium</td><td>Low</td></tr>
<tr><td>Grid Support/Ancillary Services</td><td colspan="3">High*</td></tr>
<tr><td>Renewable Integration</td><td>Medium</td><td colspan="2">High</td></tr>
<tr><td>Transmission & Distribution Upgrade Defer-ral</td><td colspan="2">Medium</td><td>High</td></tr>
<tr><td>Commercial & Industrial (C&I) BtM</td><td>Medium</td><td colspan="2">High</td></tr>
<tr><td>Residential BtM</td><td>Low</td><td colspan="2">Medium</td></tr>
</table>

*Note:*Assuming participation in wholesale ancillary markets is possible*

*Source: NITI Aayog, RMI, and RMI India (2022): Need for Advanced Chemistry Cell Energy Storage in India (Part I of III)*

As per the estimates of the Central Electricity Authority (CEA), the grid connected battery storage requirement in the country is likely to rise to 27 GW by 2030.[6] A recent Lawrence Berkeley National Laboratory study estimated that India will require 63 GW/252 GWh of BESS to achieve the goal of 500 GW of RE generation capacity.[7] The International Energy Agency (IEA) has pegged India to have about 140 GW of battery storage deployed by 2040, making it one of the largest markets for storage.[8] However, the BESS implementation and market in India is currently at an early stage and evolving. The potential for deployment of energy storage depends on many factors, including operational characteristics of the power system, policy and regulatory framework around energy storage technologies especially BESS, and the inherent technical and financial challenges in deploying such novel technologies. The **key enabling factors identified for scaling-up of BESS** in different use-cases and applications at consumer/prosumer and utility levels are: **a) reduced upfront costs, b) conducive policy and regulatory framework, c) pilot projects, and d) knowledge dissemination.**[9]

The GoI has introduced various initiatives and policy actions to accelerate the deployment of BESS. In 2019, the National Mission on Transformative Mobility and Battery Storage was launched to establish the country as a competitive battery manufacturer. The Ministry of Power, in 2022, issued guidelines for the procurement and use of BESS as part of generation, transmission and distribution (GT&D) assets, along with ancillary services that will enable and facilitate the growth of the battery storage sector and establish a uniform framework for large-scale deployment.

Initial advancements have taken place in the deployment of grid-scale BESS projects. India's first utility-scale BESS project was commissioned at Delhi in 2019 by Tata Power Delhi Distribution Ltd., AES and Mitsubishi Corporation. The three organizations partnered to implement a 10 MW/10 MWh grid-connected FtM battery storage system for peak load management, system flexibility and reliability. Other stakeholders have also begun working on deployment of grid-connected battery storage systems. Powergrid Corporation of India Limited (PGCIL) has collaborated with USAID, under the Greening the Grid- RISE initiative, for testing FtM applications of grid-connected BESS. Early-stage pilots have paved the way for larger grid-scale deployment, with about 85 MWh of BESS in place or under construction and further energy storage projects of 4.6 GWh being developed as of early 2022.[10] In several of these projects, BESS is tied to large-scale RE generation installation to support integration and address VRE. At the distribution level, utilities such as BSES Rajdhani Power Limited and Tata Power, among others, have deployed BESS to minimize overloading of DTs, manage peak load, regulate power quality, provide reliable backup and support energy arbitrage.[11] BESS has also been explored for BtM applications in commercial and industrial end-uses, although challenges in financial feasibility have hampered BtM projects from being realized at large in India.

## 2.3. Cities will shape India's Energy Demand and underpin Realization of Climate Goals

India's NDC reports that 40% of its population would be urbanized by 2030 and contribute to as much as 75% of the gross domestic product (GDP). The country's urban population is expected to double by 2050 from 2018 levels, adding about 416 million people.[12] India's built space is anticipated to be more than double over the next two decades, with 70% of new construction taking place in urban areas.[13]

As hubs of growing population, economic activity and infrastructure, Indian cities will shape a large portion of the energy consumption patterns in the future. Low-carbon transitions in urban energy will also drive the realization of India's climate and sustainable development goals. Several Indian cities are responding to the increased national ambition towards RE, net-zero GHG emissions and Sustainable Development Goals (SDG), and taking action at the local scale, often underpinned by city-scale action plans and strategies on low-carbon development and sustainable energy. For instance, **Rajkot's Climate Resilient City Action Plan has targeted a 14% reduction in annual city-wide GHG emissions by 2022-23 from the 2015-16 baseline. Similarly, Surat's Sustainable Energy and Climate Action Plan aims to achieve 40% reduction in GHG emissions by 2030 as compared to 2019**. Fifty-seven cities from India, including Surat, have signed up to the global 'Race to Zero' campaign, as of June 2022, through which over 1,000+ cities have committed to reach net-zero latest by 2050.[14] Local governments and urban development institutions are driving the implementation of e-mobility, charging infrastructure, distributed and rooftop RE systems in cities under central and state programs as well as through their own initiatives.

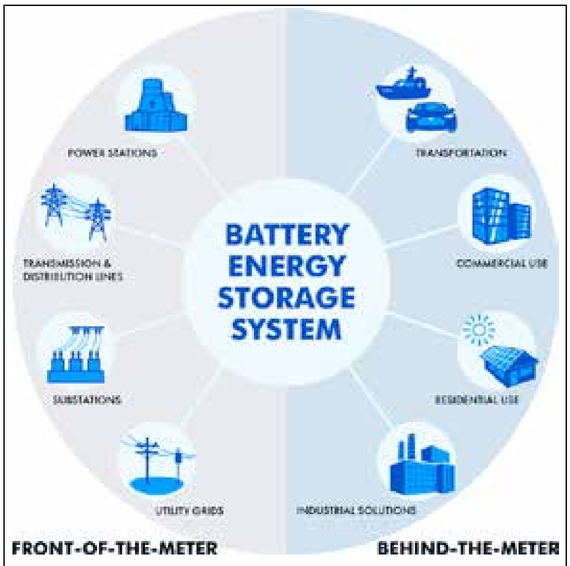
## 2.4. City Level Applications of BESS

BESS deployment will be required at the grid-scale along with the adoption of BtM solutions in cities. BESS applications across the power sector, RE sector and EV charging infrastructure are summarized in the following section.

### 2.4.1. Power Sector

BESS finds varied use in the power sector value chain. From the power sector's purview, advancement of battery technology has been facilitated primarily due to its capability to provide necessary balancing for intermittent RE power generation system (solar and wind based) in the wake of the push to adopt renewable sources of energy.

India's 19th Electric Power Survey Report[15] projects the peak demand requirements of the country to grow to 299 GW by 2026-27 and 370 GW by 2031-32. The expected increased peak energy demands will be significantly driven by cities, which are centres of expanding infrastructure, economic activities and growing population.




*Source: www.integrasources.com*

**Figure 4: BESS Broad Use across sectors (Segregated based on location of energy meter)**

For meeting the required energy demands, India is persistently increasing its installed energy capacity, while also pushing for greater RE penetration in the total capacity, in line with its climate ambitions. BESS can support power generators in integrating expanding RE capacity and the resulting increased intermittent electricity that is to reach consumers in cities.

Apart from serving the important role of balancing intermittent power, BESS can provide several other benefits to generators serving urban areas. These include:

- Frequency and voltage regulation
- Ancillary services and grid stability – BESS systems can charge and discharge quickly, making them ideal for balancing the grid on demand or production side.
- Operating reserves and capacity firming
- Peak shaving and reduction of grid congestion
- Energy arbitrage
- Black-start and ramp rate control

In urban locations, conventional generators may often not be located close to the load to provide peaking capacity, given concerns about emissions or land usage. With its scalable design, BESS offers a cleaner solution that can be co-located near the load with lesser site concerns. BESS integrated micro-grids can be deployed to supply reliable and clean power for areas in urban outskirts and for greenfield areas in cities.

Growing loads and short-term peak demand requirements in cities will also necessitate the expansion of the existing transmission and distribution (T&D) networks, which may not be possible and might be expensive in many congested urban areas. Further, the exponentially increasing RE capacity will significantly add to the network augmentation requirements. BESS deployment at the T&D scale can help postpone the need for additional grid network capacity investments, with BESS being charged during low demand periods and discharging to meet local demand during high-demand periods. Storage systems located in the distribution network can help ease congestion, lower transmission and distribution losses, and deal with power quality concerns. Distribution-level BESS systems can potentially offer enhanced resilience during extreme weather occurrences.

BESS, implemented at BtM scale, can provide significant energy cost savings to consumers, including large commercial buildings, public utilities and infrastructure, and industrial units, by offering capabilities such as peak shaving, energy time-shift and differential tariff saving from ToD charges, and reducing electricity demand charges. Despite the growth of dependable and affordable electricity services, power outages are still common in many cities, making power backup necessary. BESS can help deliver dependable and uninterrupted power supply to critical loads such as hospitals and emergency services.

The load burden may be minimized by utilizing BESS during peak hours and enhancing the voltage profile and power factor of the system. BESS can also enable flattening of the load profile of EV chargers or charging stations to reduce the burden on the distribution grid. Further, BESS can help in reducing the energy costs at the consumer end by minimizing the amount of power purchased when time-of-use (TOU) prices are highest (peak hours), by moving those purchases to times when rates are lower.

### 2.4.2. Renewable Energy Integration

India's ambitious plans to use RE sources (particularly solar and wind) to meet its climate targets, necessitate significant flexibility in the power system due to the highly variable and intermittent nature of renewable resources. This can also put pressure on the reliability of the existing grid system. BESS can overcome the problem of intermittency by introducing more flexibility to the grid. Utility-scale BESS are emerging as a potential solution to enable large-scale integration of VRE in power systems by enabling greater feed-in of renewables into the grid, firming the RE output and hence improving the viability of the system.

At the city scale, deploying renewables and BESS can offer energy-time shift capabilities, load management, peak demand shaving, and back-up power to consumers and ULBs. Given cities are increasingly focusing on energy and e-mobility transition, BESS deployed along with RE can help support the power utilities in managing the peak-load, capacity enhancement deferral, ancillary services, and achieving the renewable purchase obligations (RPO) targets. BESS with RE can provide reliable and cheaper electricity in micro-grids and off-grid communities, which otherwise depend on fossil fuel-based generators.

Further information on BESS applications and opportunities with regard to RE integration is presented in sections 9.1 and 9.2.


Source: Wärtsilä Corporation

**Figure 6: BESS for RE Power**

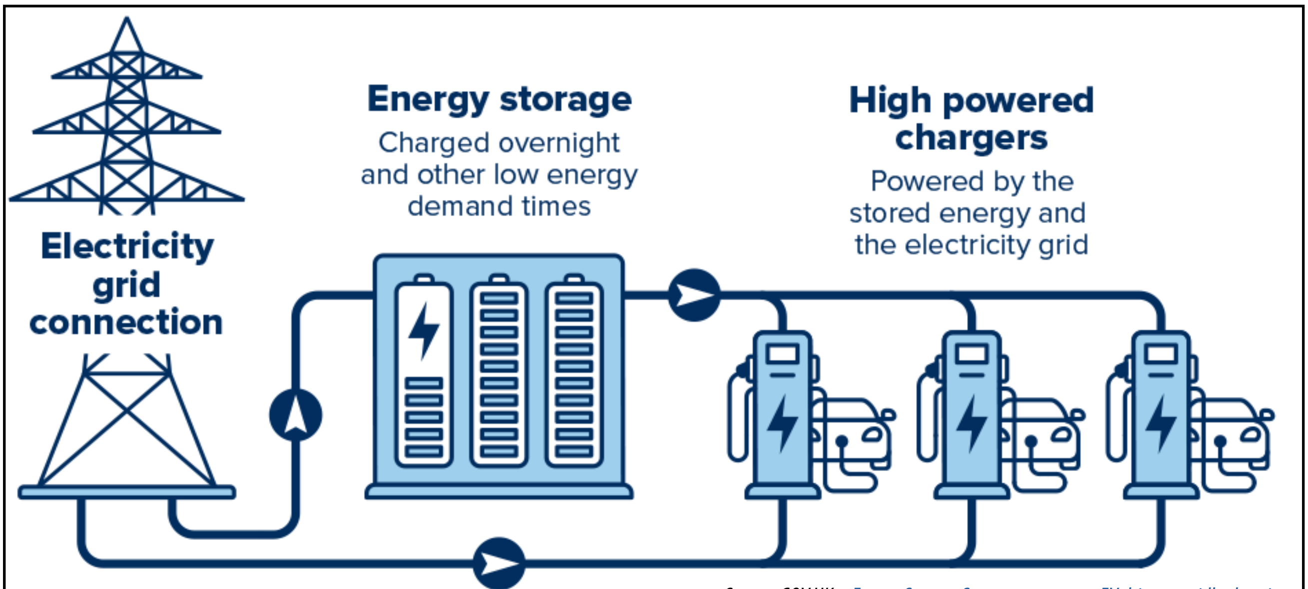
### 2.4.3. Electric Vehicle Charging Infrastructure

The transportation sector in India is witnessing rapid transition towards e-mobility owing to the aggressive promotion of EVs by the national and sub-national governments, especially in urban areas. This transition demands prompt development of charging infrastructure, which further necessitates significant flexibility in the power system due to the highly variable and intermittent nature of e-mobility loads.

As the rate of EV adoption increases, so does the demand for accessible and faster charging infrastructure. To accelerate growth in this sector, charging networks must provide fast-charging capabilities without incurring high demand charges or increased costs for infrastructure upgrades. Deployment of energy storage systems (ESS) in EV charging infrastructure can help feed the grid during low demand and release power to charge an EV during peak demand time. Energy storage can help in peak shaving to make EV charging solutions more energy efficient and cost effective.

BESS has the potential to provide the required grid flexibility and address the congestion caused in the network due to charging infrastructure being developed, especially in cities. It supports better integration of renewables such as solar PV and can be deployed along with renewables to power the EV charging station, entirely on green energy, which can further help cities meet their energy transition targets. Thus, BESS for EV provides increased opportunities across multiple services.

Further information on BESS applications and opportunities in EV charging infrastructure is presented in section 9.1.1.




Source: GOV.UK – Energy Storage Systems to support EV drivers rapidly charging

**Figure 5: Energy Storage Systems to support Electric Vehicle Charging Infrastructure**

# 3. Energy Generation and Electric Vehicle Scenario in Gujarat

Gujarat is one of the more developed Indian states in terms of power market development, having significant potential and robust targets for deployment of renewables, financially stable DISCOMs, and the intent to stop the commissioning of new coal projects from 2021. The IEA reports that in recent years, Gujarat had one of the highest final per capita energy consumptions and the highest per capita energy demand among Indian states.[16] With an EV policy in place, the state aims to introduce 1 lakh new EVs in three years with charging infrastructure. The procurement of about 550 e-buses has been sanctioned in many cities, including Rajkot, Surat and Ahmedabad under phase 2 of the Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India (FAME-II) scheme.

## 3.1. Power Sector

The power sector in India is a concurrent subject as the responsibility for the development and efficient functioning of the sector lies with both the central and state governments. While the state governments are responsible for developing and operating intra-state GT&D infrastructure, the central government is responsible for interstate generation and transmission infrastructure, and the integrated operation of the entire national grid.

In 2005, Gujarat's power sector, governed by the erstwhile Gujarat Electricity Board (GEB), was vertically unbundled into seven state-owned subsidiaries with different functional responsibilities of the power system value chain, as part of the state government's efforts towards liberalization and restructuring of the power sector. Under the new structure, the Gujarat State Electricity Corporation Limited (GSECL) is responsible for electricity generation and the Gujarat Energy Transmission Corporation Limited (GETCO) for building, operating and maintaining the state's transmission network. The distribution network service has been split among four government-owned distribution companies: Uttar Gujarat Vij Company Limited (UGVCL), Dakshin Gujarat Vij Company Limited (DGVCL), Paschim Gujarat Vij Company Limited (PGVCL), and Madhya Gujarat Vij Company Limited (MGVCL), catering to the northern, southern, western and central parts of the state respectively. In addition to these, a private electricity generation and distribution company i.e., Torrent Power operates in Ahmedabad and Surat.

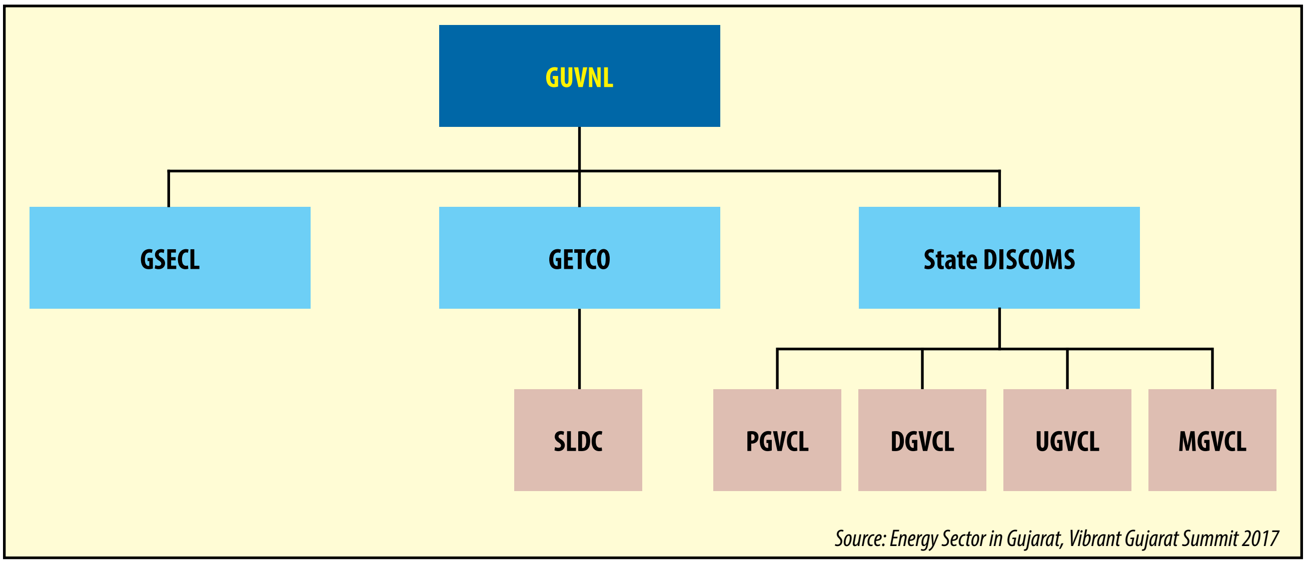



**Figure 7: Gujarat Power Sector Structure**

All four distribution companies along with GETCO and GSECL have been structured as subsidiaries of a holding company called Gujarat Urja Vikas Nigam Limited (GUVNL). Apart from supervising, co-ordinating and facilitating the activities of its six subsidiary companies, GUVNL also serves as Gujarat's single bulk buyer, bulk supplier to the state DISCOMs and the sector's power trader.

The Gujarat Electricity Regulatory Commission (GERC) determines tariffs, issues licenses, resolves disputes and regulates all intra-state level functions of the power sector, whereas the interstate generators and transmission network, regional load dispatch centres and other such constituents of the national power sector and their functions are under the purview of the Central Electricity Regulatory Commission (CERC).

The key state-level regulations established by GERC are:

- **Intra-State Open Access Regulations 2011:** The Regulations provide flexibility to source cheaper electricity from different generators for consumers who demand more than 1 MW. The consumers can avail short-, medium- and long-term open access (OA) depending on the duration of the agreement. The Regulations promote competition by providing open platform for buyers and sellers, and the power can be sold or purchased from within or outside the state. The Regulations also specify imbalance and reactive energy charges for OA customers who are also consumers of the distribution licensee. However, other OA customers and generating stations come under the purview of the intra-state availability-based tariffs, as notified by GERC, and pay UI for deviation from scheduled injection/drawal.
- **Gujarat State Grid Code 2013:** The Code provides rules, guidelines and standards to be followed by various entities in developing, maintaining and operating the state's power infrastructure; and establishes standards and framework to reduce technical and operational risk for engineering, procurement, and construction (EPC) and other power companies, while carrying out any work in the state's power infrastructure.
- **Gujarat Multi-year Tariff Regulations 2016:** The Regulations provide predictability of electricity tariff over the control period, minimizing the risk for investors and enhancing the ease of doing business in the state's power sector. They also ensure standardization, reduce subjectivity in power procurement and protect consumers' interest through transparent and economical procurement of power.
- **Forecasting, Scheduling, Deviation Settlement and Related Matters of Solar and Wind Generation Sources Regulations 2019:** The Regulations provide forecasting, scheduling and commercial mechanisms for settling deviation charges for all wind and solar generators with combined installed capacity above 1 MW, which are connected to the grid/substation inside or outside the state or are consuming power generated for self-consumption. They also encourage the grid operator to make full use of the flexibility from conventional power plants, as well as the capacity of inter-grid tie lines to accommodate the maximum wind and solar power, while maintaining grid security.

**Status of power generation in Gujarat:** Gujarat has been a power surplus state since 2009 and accounts for around 9% of India's electricity demand. As of June 2022, the installed generation capacity of Gujarat was 43.5 GW. Of that, the publicly owned state generator GSECL has a capacity of 7 GW.[17] The state is also rich in RE, with around 44.7% of its installed capacity being from renewable resources such as wind, solar and hydro.[18] The fuel-wise split of the installed power generation capacity of Gujarat is shown in Figure 8. In 2021-22, the annual share of solar and wind-based electricity generation stood at about 13% in Gujarat.[19]

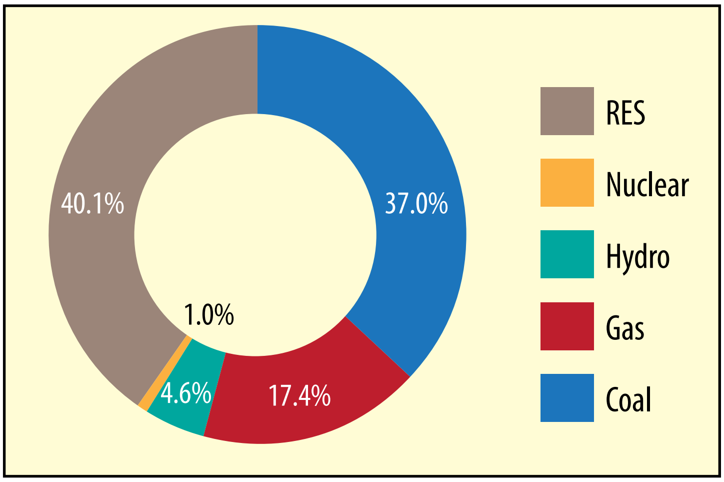



**Figure 8: Gujarat's Fuel-wise Power Generation Capacity as of June 2022**

Private participation in Gujarat's power sector is significant at almost 72% of the installed generation capacity. The state also sees private participation in the distribution network, under the distribution licensee model, where entities such as Torrent Power cater to Ahmedabad, Gandhinagar, Surat and Dahej SEZ supply areas, and Mundra Port and Special Economic Zone (MPSEZ) Utilities Private Limited to the MPSEZ supply area.

## 3.2. Renewable Energy Sector

With an installed capacity of 17.3 GW[20] (as of June 2022), contributing to 15.3 per cent of India's RE portfolio, Gujarat is making rapid strides in the RE sector. To promote the uptake of RE, Gujarat has the following policies in place:

Gujarat Solar Power Policy (2021) – The policy aims to accelerate the deployment of solar power by implementing large-scale projects, small-scale distributed systems and ultra-mega solar parks. As per the new policy, the state government would purchase surplus energy from residential and micro, small and medium enterprise consumers after setting off against their consumption on the billing cycle. In the case of industrial, commercial, institutional and other non-residential consumers, the energy set-off shall take place between 7am and 6pm of the same day for High Tension/Extra High Voltage consumers, while for Low Tension consumers, the energy set-off shall take place between 7am and 6pm of the same billing cycle.

Wind Power Policy (2016) – Gujarat is blessed with wind energy potential of more than 80 GW because of its long coastline and desirable wind speeds. The state government launched the Policy with an aim to create a conducive environment and investment framework to spur more competition and private sector participation for the development of wind projects, while keeping the interests of all stakeholders in mind.

Wind-Solar Hybrid Power Policy (2018) – The state government announced the Policy to provide a framework for the promotion of large grid-connected wind-solar PV hybrid systems for optimal and efficient utilization of the transmissions infrastructure and land, and to reduce the variability in renewable power generation.

Gujarat Small Hydel Policy (2016) – The state government announced the Policy to provide a framework to promote, support, facilitate and incentivize investments in small hydel projects to harness the maximum possible clean and renewable energy from rivers, streams and canals.

Waste-to-Energy Policy (2016) – The Policy aims to facilitate and promote utilization of municipal solid waste (MSW) as a renewable resource for generating electricity. Gujarat has eight municipal corporations and 162 municipalities. The solid waste generated in these urban areas can support power plants of around 100 MW capacity. The policy recognizes that the cost of generating energy from MSW can be reduced if ULBs (a) make MSW available to generators at designated locations free of cost, (b) give land for waste-to-energy projects for free to developers, and (c) exempt waste-to-energy projects from taxes/duties/levies.

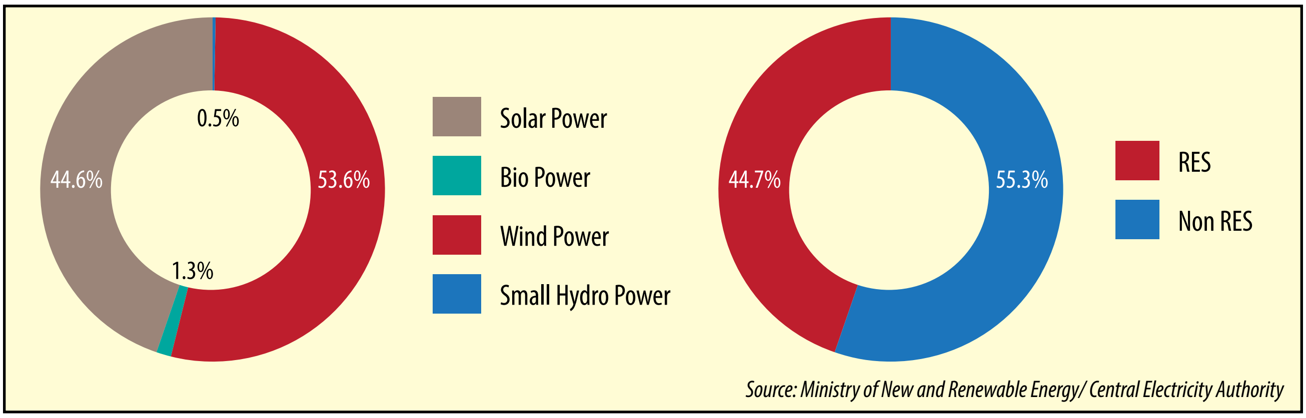



**Figure 9: Installed Renewable Energy Capacity Distribution in Gujarat (as on 31.08.2021); Share of Renewable Energy in Total Installed Capacity (as on 31.03.2021)**

## Potential Opportunities for Energy Storage in Gujarat

As part of its India Energy Outlook Report 2021, the IEA undertook modelling for Gujarat's power system to look at 2030 projections and renewable integration challenges. The IEA estimates place Gujarat's 2030 RE targets at over 44 GW in solar and wind capacity to cater to the state's power requirements, with an additional 20 GW to be contracted to other states.[21] This trajectory would increase the annual share of solar and wind generation to almost 40% of total generation from around 13% in 2019. On an hourly basis, it is expected that solar and wind power will meet up to 77% of the demand at certain times of the day by 2022, as per IEA estimates. By 2030, the renewable output is estimated to exceed the total demand in many hours of the year, posing significant system challenges and dramatically increasing the likelihood of curtailment. While Gujarat has negligible levels of solar and wind curtailment at present, 44 GW of solar and wind power by 2030 would lead to annual curtailment of around 7% of the solar and wind generation in 2030 – a significant level of lost output. The IEA report suggests three options for improved flexibility in Gujarat's case: include demand-side response, thermal plant flexibility and investment in BESS. Regarding

BESS, a four-hour duration battery storage addition of 4 GW is suggested to allow for high solar output during the day, to be stored for meeting the evening demand. It is noted that as dispatchable thermal capacity declines relative to peak demand, battery storage would also help reduce short-term energy purchases and import dependency.

The India Smart Grid Forum and India Energy Storage Alliance report on Energy Storage System Roadmap for India (2019-32) envisages Gujarat's energy storage requirements at 1.45 GW by 2027 to help better integrate an anticipated 9.1 GW of distributed rooftop solar PV.[22]

Gujarat has implemented a BESS project in conjunction with a large RE-based plant for electrification at Modhera. Gujarat Power Corporation Limited (GPCL) has installed 6 MW solar PV along with 15 MWh BESS to electrify Modhera village with 100% RE. The project delivers round-the-clock (24x7) solar energy to 1600 houses and to the Modhera temple. While the project was completed in 2021, limited information is available on GPCL's experiences and best practices during implementation and operations. Recently, GSECL invited bids for the design, engineering, erection, construction, installation and commissioning of a 35 MW grid-connected solar project with 57 MWh of BESS in Kutch district of Gujarat.

## 3.3. Electric Vehicle Scenario

The Government of Gujarat launched an ambitious EV Policy to boost the adoption of EVs and establish a supportive environment for manufacturers and investors. With a total outlay of INR 870 crore, the Policy will support the purchase of the first two lakh EVs either under individual use or commercial use. It is estimated that up to INR 5 crore fuel expenditure and minimum 600,000 tonnes $CO_2$ emissions can be reduced.[23]

The Policy also provides support for charging infrastructure as well as the manufacture of EVs and their components, and provides 25% capital subsidy on equipment/machinery (limited up to INR 10 lakhs per station) for the first 250 commercial public EV charging stations for two-, three- and four-wheelers.

The Policy also states that the state distribution licensees (DISCOMs) shall allow charging of EVs from the existing connection of a consumer at their existing tariff, except for agricultural power connections. The operating period for the Policy is four years, commencing July 2021.

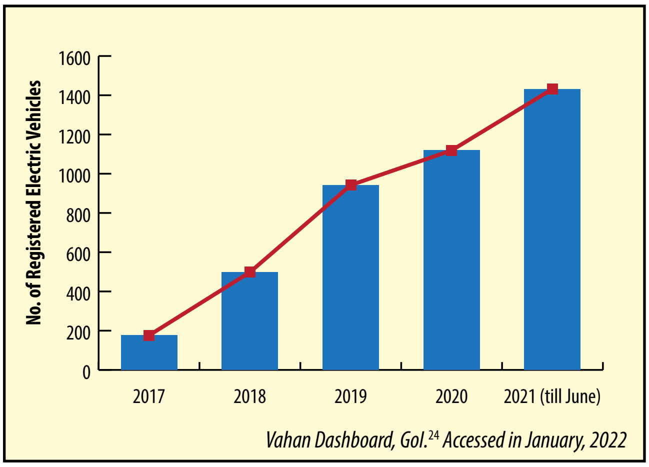



**Figure 10: Electric Vehicles Registered in Gujarat Year-wise**

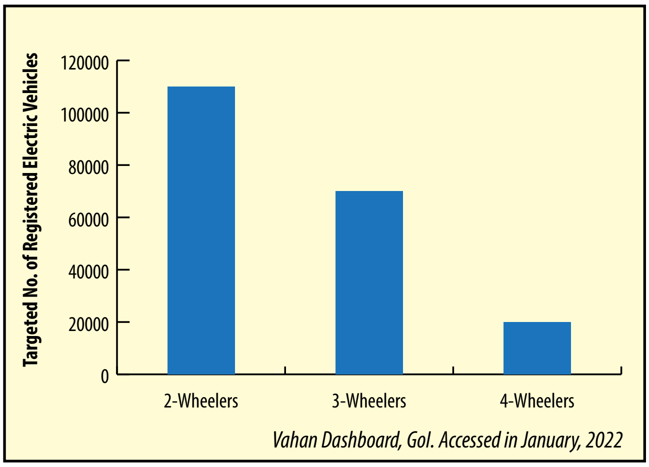



**Figure 11: Electric Vehicle Targets under Policy Period in Gujarat**

**Focus on Surat and Rajkot**

Surat and Rajkot, key commercial and industrial hubs in Gujarat, are growing and developing rapidly. Both cities have set ambitious targets for RE integration and are working to achieve their climate goals, while being model cities for the deployment of e-mobility and related charging infrastructure. Surat and Rajkot were selected as the study's focus cities in Gujarat to identify opportunities for BESS deployment, given their diversity in terms of size, characteristics, upcoming urban development, mix of DISCOMs serving the two cities (public and private), and their legacy of leadership on sustainable energy and climate action. The following section focuses on these aspects and highlights opportunities for BESS in their local contexts.

# 4. Baseline Review and Opportunities for BESS in Rajkot and Surat

## 4.1. City Profiles

**Surat** is Gujarat's second-largest city, spread over 462.14 sq km with an estimated six million people. It is known for its textile, trade, and diamond cutting and polishing industries, besides intricate zari work, chemical industries and gas-based industries at Hazira, established by leading firms such as ONGC, Reliance, ESSAR and Shell.

**Rajkot** is Gujarat's fourth largest city with 1.9 million people. The city ranked 22nd amongst the fastest-growing global cities and urban areas from 2006 to 2020, as per Oxford Economics Research (Rajkot Urban Development Authority, 2021). A major industrial centre, Rajkot is the hub for the manufacture of bearings, diesel engines, cutting appliances, watches, automotive parts and machine tools, as well as forging and casting industries.

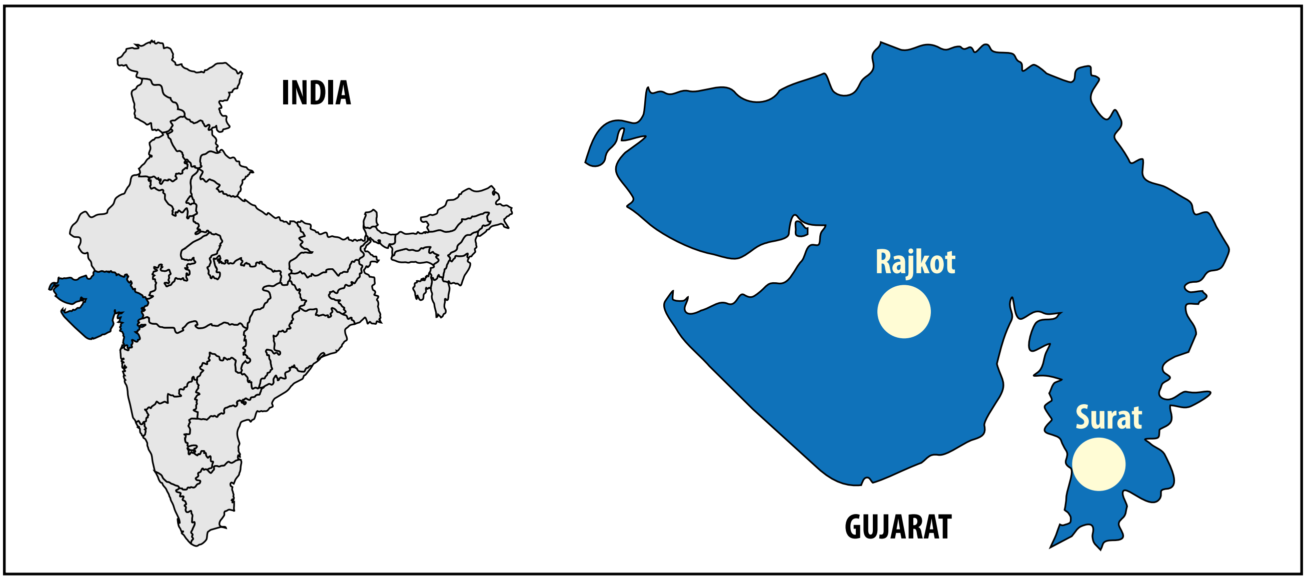



**Figure 12: Location map of Surat and Rajkot**

**Table 2: Profile of Surat and Rajkot**

| Details | Surat | Rajkot |
|---|---|---|
| **ULB** | Surat Municipal Corporation | Rajkot Municipal Corporation |
| **Area (sq km) (2021)** | 462.14 | 161.86 |
| **Population (2021)** | 6 million | 1.9 million [25] |
| **Population density (per sq km)** | 18,400 | 11,309 |
| **Economic profile** | Hub of textile factories and diamond cutting and polishing, chemical, engineering, and petrochemical industries | Hub of manufacturing (bearings, diesel engines, cutting appliances, watches, automotive parts and machine tools), forging and casting industries |
| **Climate target** | 40% reduction in annual city-wide GHG emissions by 2030 from 2019 | 14% reduction in annual city-wide GHG emissions by 2022-23 from 2015-16 baseline |

## 4.2. Power Scenario

The electricity DISCOMs are DGVCL and Torrent Power in Surat, and PGVCL in Rajkot. Commercial, industrial and residential sectors are significant consumers of power in both cities.

Stakeholder consultations revealed unscheduled power demand during peak hours and overloading at DTs as few of the issues being faced by the DISCOMs. DGVCL expects to meet about 60-70% of its total energy requirements through RE by 2030. Increase in the demand for power, due to growing urbanisation and increase in the number of EVs, may require strategic planning.

| Power Scenario | | |
|---|---|---|
| **Specifics** | **Surat** | **Rajkot** |
| DISCOMs operating in the city | 1) Private: Torrent Power<br>2) Public: Dakshin Gujarat Vij Corporation Limited (DGVCL) | 1) Public: Paschim Gujarat Vij Corporation Limited (PGVCL) |
| Peak demand | DGVCL – 1000 MW<br>Torrent Power - 700 MW | Not available |
| Average T&D losses (2020-21) | DGVCL – 7.4%<br>Torrent Power – 4.2% | PGVCL – 7.33%[26] |
| Total electricity consumption (2020-21) Total electricity consumption (2020-21) | 6,156 Million units | 1,749 Million units[27] |
| Share of electricity consumption by category (2020-21) | • Commercial (59%)<br>• Residential (27%)<br>• Industries (12%)<br>• Government use (2%)[28] | • Residential (37%)<br>• Commercial and service sector (37%)<br>• Industries (25%)<br>• General lighting (1%)[29] |

### Potential Opportunities for BESS

- GUVNL is procuring power from exchanges at a higher cost to meet demand during peak hours (unscheduled power). BESS can help provide power at lower costs during such peak demand periods or during summer-time peaks and can be charged with cheaper power during the off-peak period. It can also support accommodation of additional RE.
- Increased demand due to urban growth in some areas is directly impacting DTs due to overloading. Integrating BESS at the DT level can help meet the excess demand, prevent overloading of DT and defer DT augmentation.
- Considering the significant demand from commercial establishments and industries in the overall electricity demand with high tension (HT) connections, integration of BESS at BtM offers potential energy cost savings. Currently, HT consumers in both cities have to pay additional TOU charge for power consumption during peak hours (7am to 11am and 6pm to 10pm) and get concessions for consumption during night time (10pm to 6am). BESS implemented at BtM scale can offer peak shaving, energy time-shift and differential tariff saving from ToD charges, and reduce demand charges by cutting the load requirement from the grid.
- BESS at BtM can support power reliability during grid outage and power failure experienced in areas served by DGVCL (Surat) and PGVCL (Rajkot), especially for industrial and commercial establishments as well as essential end-uses such as hospitals and municipal utilities. Currently, municipal utilities such as water supply and wastewater treatment are equipped with diesel generator (DG) sets, sized nearly to their total connected load. With both cities encountering limited disruptions in power supply, the DG sets are primarily standbys and an expensive option during power outages. BESS deployment in large municipal facilities can provide a cleaner source of power back-up, besides reducing power demand.

## 4.3. Renewable Energy Scenario

Surat and Rajkot have observed a rapid increase in the deployment of rooftop solar PV plants, owing to the state government's favourable policy, namely Gujarat State Solar Policy, 2015 (revised in 2021), and related provisions. Residential consumers are offered financial assistance for solar PV capital costs through state government empanelled agencies to install rooftop solar plants. SMC and RMC are also increasing the share of RE to meet power requirements in various municipal facilities. More than 35% of the total electricity requirement of municipal facilities in Surat is being fulfilled by RE (solar, wind and biogas) and it is proposed that 15.25 MW of captive solar PV in total could meet the municipal energy demand in both cities (11 MW in Surat and 4.25 MW in Rajkot), with 6.3 MW of wind power plants planned for Surat.

| Renewable Energy Scenario | | |
|---|---|---|
| **Specifics** | **Surat** | **Rajkot** |
| **Renewable Energy Status (Existing)** | | |
| Total annual RE consumption (city level) | Not available | 65,610 MWh<br>(solar: 19,630 MWh; Wind: 45,880 MWh)<br><br>3.6 % of total city-wide electricity requirements[30] |
| Total RE generation capacity (municipal facilities) | 51 MW<br>(solar: 7 MW, wind: 38.7 MW; biogas: 5.35 MW) | 1 MW (solar) |
| Total RE generation for municipal facilities | 99,000 MWh<br>(35% of total municipal electricity requirements) | 1,460 MWh<br>(2% of total municipal electricity requirements) |
| **Renewable Energy Status (Proposed)** | | |
| Total RE generation capacity proposed (municipal facilities) | • 17.3 MW in FY 2022-23 (6.3 MW wind and 11 MW captive solar PV on SMC's reserved plots)<br>• Target to increase RE generation to 42% in 2022 from 35% in 2020 | • 4.25 MW solar power plant in FY 2022-23 (4 MW in closed dumpsite for captive use and 250 kW rooftop solar PV)[31] |

### Potential Opportunities for BESS

- The Gujarat Solar Policy 2021 includes requirements that HT/Extra High Voltage (EHV) consumers shall consume solar energy generated for captive use between 7am and 6pm of the same day, with surplus energy to be sold to the DISCOM through gross-metering mechanism at INR 2.15 per kWh. The Policy also promotes maximizing the solar PV potential in the consumer's premises, by removing the previous ceiling, which required that the solar PV project should not exceed 50% of the sanctioned load or contract demand. BESS can help commercial, industrial and large institutional consumers store excess RE, thereby maximizing the generation and utilization of solar energy, which is more cost effective (as against INR 7-8/ kWh incurred for conventional electricity consumption).
- Municipal utilities claim a significant share of the electricity consumption and expenditure in the ULBs. For instance, water supply facilities accounted for 61% of RMC's total electricity use in FY 2021-22. Therefore, ULBs in both Rajkot and Surat have prioritized minimizing of energy consumption and costs in municipal utilities. In Rajkot, 145 kWp of solar PV has been deployed at the Aji water treatment plant and 250 kWp at the Raiyadhar waste water treatment plant. Both cities have planned additional deployment of captive solar PVs on ULB plots and municipal utilities. It is suggested that the deployment of BESS along with RE is an opportunity for the ULBs to help maximize potential by storing surplus power (especially during the off-peak hours) and utilizing it in municipal utilities during night-time or peak hours.
- Similarly, residents who have installed rooftop solar PV are unable to access RE power and benefits for captive consumption due to a demand-generation mismatch. At times, day-time consumption is minimal as occupants are away at work. A large portion of the RE generation is being fed into the grid. The beneficiaries are receiving only INR 2.15/kWh for the RE power exported into the grid, as against the higher power tariff incurred during evening and night-time. The installation of RE with BESS may be explored in such instances.

- As wind generators are more challenging to schedule due to uncertainties regarding power generation, as compared to solar power, GUVNL and Gujarat Energy Development Agency (GEDA) suggested a solar-wind hybrid system, supported with BESS, as a potentially optimal solution to handle VRE.
- Stakeholders noted that the power supply systems in Rajkot and Surat have limited issues related to frequency or voltage. However, as additional distributed rooftop solar PV gets integrated into the grid in both cities, any fluctuations in RE generation can potentially impact the frequency or voltage at the grid level.

## 4.4. Electric Vehicle Scenario

Rising fuel prices, dependence on crude oil imports, high pollution levels, and commitment to reduce carbon emissions have been key drivers in the transition towards e-mobility in Indian cities. Rajkot and Surat are also making ambitious efforts to increase their EV fleet and put in place supporting infrastructure, including EV charging stations.

The SMC has notified a city-level EV policy to promote e-mobility locally, while a city-scale EV policy is under preparation for Rajkot. Surat aims to accommodate around 40,000 new EVs and develop 500 EV charging stations in the city by June 2025. With the average connected load for standard public charging stations varying from 100 kW to 150 kW, the targeted new charging stations can be expected to add a total load of about 50 to 75 MW for Surat.

Surat also plans to procure 300 e-buses for its public fleet, 49 of them already operational. Similarly, Rajkot plans to procure 150 public e-buses by 2023, 19 of them already operational. Approximately 12 DC chargers of 240 kW connected load each would be required per 50 e-buses, depending on the identified routes and charging intervals. One e-bus is estimated to consume around 250 kWh of electricity per day, amounting to 112 MWh electricity consumption for 450 e-buses across the two cities. The two cities are planning to integrate RE to meet part of the electricity requirements for charging the e-buses.

| Electric Vehicle Scenario | | |
|---|---|---|
| **Specifics** | **Surat** | **Rajkot** |
| **Private EVs and Related Infrastructure** | | |
| Status of city level EV Policy | Surat city Electric Vehicle Policy, 2021 is notified | Rajkot city Electric Vehicle Policy is under preparation |
| Total EVs (existing) | 6,699<br>• Two wheelers: 6,173<br>• Three wheelers: 146<br>• Four wheelers: 331<br>• Buses and others: 49 buses | 2,005<br>• Two wheelers: 1,778<br>• Three wheelers: 117<br>• Four wheelers: 110 |
| Total EVs (targeted) | • 40,300 by June 2025[32]<br>• Two wheelers: 20,000<br>• Three wheelers: 15,000<br>• Four wheelers: 5000<br>• Buses and others: 300 buses | Target to be outlined under the upcoming Rajkot City Electric Vehicle Policy |
| EV charging stations (existing) | 10 (approx.) | 3 (approx.) |

| Electric Vehicle Scenario | | |
|---|---|---|
| **Specifics** | **Surat** | **Rajkot** |
| EV charging stations (targeted) | 500 EV charging stations targeted by June 2025 (200 through SMC budget, 50 through FAME II, 150 based on PPP model, 100 with support from commercial buildings) | Target to be outlined under the upcoming Policy |
| **Public EVs and related infrastructure** | | |
| Total e-buses (operational) | 49 | 19 |
| Total e-buses (targeted) | A total of 300 e-buses are targeted (49 e-buses are operational. Additional 150 e-buses are proposed in municipal budget 2022-23.) | 150 e-buses are targeted by 2022 (50 e-buses by end of 2022, out of which 19 are operational) |
| EV charging stations for buses (existing) | i. 10 AC charging points (80 kW sanctioned load each)<br>ii. 12 DC charging points for 50 e-buses (180KW sanctioned load each) | i. 3.1 MW public bus charging station at Amul circle<br>ii. 12 DC charging points for 50 e-buses (240 KW sanctioned load each) |
| EV charging stations for buses (targeted) | For additional 250 e-buses | For additional 100 e-buses |

## Potential opportunities for BESS

- Surat's Electric Vehicle Policy 2021 promotes adoption of RE in EV charging infrastructure. Funds have been proposed for the purpose in the city's municipal budget for 2022-23. SMC has shown interest in examining the implementation of a pilot-scale BESS along with RE at an EV charging station. It may replicate the model upon success of the pilot project to help contribute towards its net-zero targets as a member of the Race to Zero initiative.
- Rajkot and Surat have plans to scale-up public e-buses. Most of the buses (about 75% as per RMC and SMC) are expected to be charged during night-time through dedicated charging infrastructure and will have significant power requirements. With both cities intending to integrate RE in charging infrastructure, this can be done in conjunction with BESS that can store RE and support overnight charging.
- BESS offers potential opportunities for peak-demand shaving, optimizing charging load, and reducing the sanctioned load demand for EV charging stations, as relevant. SMC has shown interest in checking the feasibility of BESS for EV charging stations to avoid the requirements for HT connections (>100 kW connected load), where the initial cost and monthly expenses will be higher.
- Rajkot City Electric Vehicle Policy is under preparation. With the city keen to integrate RE in its EV charging infrastructure, there is an opportunity to provide suggestions to enable BESS for efficient energy management at EV charging stations through the Policy.

## 4.5. Urban Development and Real Estate Growth to drive Energy Demand

**Rajkot**

A commercial, industrial and trade centre of the Saurashtra-Kutch region, Rajkot is rapidly expanding in all directions, especially along the highways. While the municipal area has increased to 161.86 sq km in 2020, from 129.21 sq km in 2015 and 104.86 sq km in 2011, the population rose from 1.28 million to 1.9 million during the 2011-2021 period. This expansion has impacted the demand for urban services, utilities and electricity.

The residential and commercial areas in the western part of the city are growing, while in the southern parts, residential areas are expected to develop due to industrial development in the surrounding areas. Areas in the western part of the city such as the Kalawad Road, Racecourse Road and Raiya Road house a significant proportion of high-income groups, and are rapidly developing. These areas are located close to the bus rapid transit system (BRTS) route and are witnessing high-density transit-oriented development.

A high-density transit-oriented zone (TOZ) spread over 34.5 sq km has been proposed around the city's Outer Ring Road, close to the BRTS corridor. The TOZ development will be fast-tracked by enforcing the Town Planning Scheme[33] or similar land development mechanisms in this zone. High-density development corridors, with a maximum permissible floor space index (FSI) of 4.0, have been proposed along all six highways in the city. Three growth centres, Shapar–Veraval, Khirasara–Metoda and Kuwadva–Gunda, have been identified around the industrial clusters to support the growing population in the coming years. Additional zones are being proposed on large tracts of land around existing industrial areas for the same purpose.

Mixed and compact land use is also proposed for area-based development (green field area development) in the west zone of the city under Rajkot's Smart City plan. In the proposed green field development area of 4 sq km, it is proposed that at least 20% of the total electricity requirements should be met through solar PVs. Eighty per cent of the total buildings in this area are proposed to be green buildings, and 20% of the total electricity demand in the area is proposed to be fulfilled by RE. An uninterrupted 24x7 electricity supply is also proposed. The total estimated demand load of this green field development area is 126 MW.

**Surat**

The Oxford Economics Global Cities Research 2018 identified Surat as one of the fastest growing cities in the world from 2019 to 2035.[34] The city's municipal area has grown from 326 sq km in 2011 to 462 sq km in 2021. Its importance as a diamond and textile hub with a large number of commercial and industrial activities is driving population growth.

Surat is also promoting compact city development. As in Rajkot, a TOZ has been proposed around the Outer Ring Road of the city, with FSI up to 4. As the development around the Outer Ring Road will be implemented in a phased manner, the demand for electricity may increase accordingly. The city has also proposed a higher FSI, ranging from 3.6 to 4.0, along roads with a width of 36 m or more in the city. It is therefore expected that the existing buildings will be redeveloped as high-rise buildings in the coming years, leading to an increase in the building footprint and electricity demand. Moreover, transit-oriented development has been proposed at 75 locations in the city, with a higher FSI of up to 4.

Under the impact of the upcoming Golden Quadrilateral highway, Ahmedabad-Mumbai bullet train and the Delhi-Mumbai industrial corridor, commercial and industrial activities in and around the city are expected to grow, particularly in the south-eastern areas. Currently, industries are being established in the southern part of the city, near Sachin Gujarat Industrial Development Corporation (Sachin GIDC) and Hazira. Industrial growth is spilling outside the dedicated industrial area of 38 sq km as per the City Development Plan of 2011. The industrial footprint is expected to expand to 136 sq km as per the City Development Plan 2035, leading to greater demand for industrial electricity and higher urban growth and energy consumption.

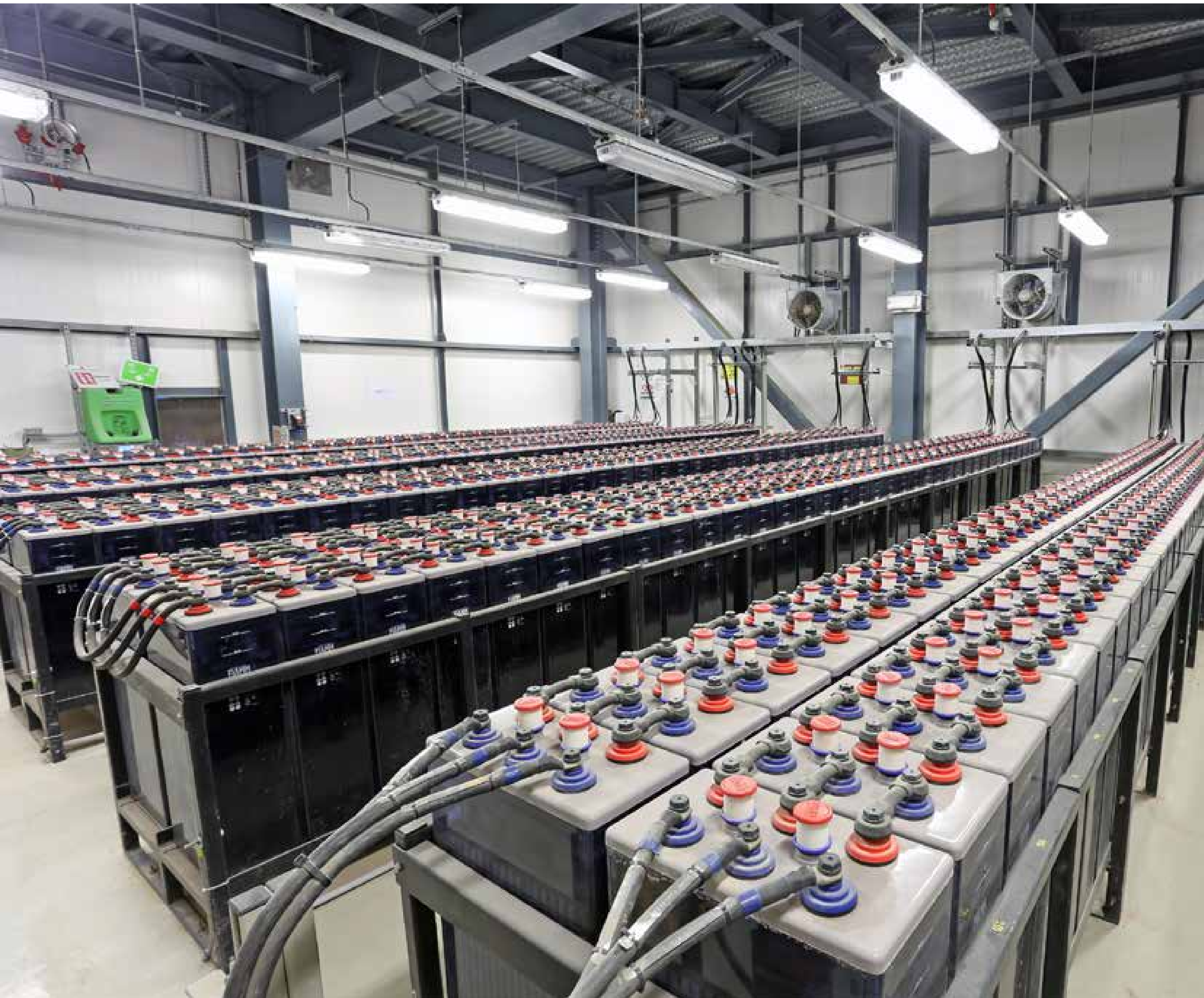
To encourage and promote activities related to the diamond industry and other mercantile activities, the state government has initiated the development of the Diamond Research and Mercantile (DREAM) city in Surat. It will be spread across 6.81 sq km in the southern part of Surat and will have an estimated demand load of 234 MW. Under the DREAM city project, the Surat Diamond Bourse (SDB) is being developed with more than 4,200 diamond merchant offices. The total estimated connected load of the SDB is 22 to 24 MW, with proposed centralized cooling, utility control room and a solar PV system.

**Implications on the demand for energy**

Rajkot's electricity consumption increased from 2016-17 to 2019-20 at an annual average growth rate of 3.1%. Residential, commercial and institutional buildings and facilities accounted for over 75% of Rajkot's electricity consumption in 2020-21. Given the planned development, and rising population and economic growth, both cities will continue to see a significant growth in the construction of residential and commercial buildings and industrial establishments in the next few years. The building footprint, and consequently, energy requirement in both cities can be expected to increase significantly. Rajkot and Surat have set city-wide climate targets and are pursuing ambitions for net-zero emissions. Both cities will need to deploy and integrate a significant scale of RE in private and public buildings, and municipal infrastructure, to meet these climate and RE targets.

## Potential Opportunities for BESS

- The dense urban development proposed with high FSI across different areas of Rajkot and Surat will increase the building footprint, and intensity of energy demand. Dense redevelopments in existing developed areas will similarly result in clusters of high-rise buildings with greater concentration of electricity consumption. A number of commercial developments, including hotels, shopping malls, leisure and retail spaces, and information technology companies (IT/ITes) have come up in growth corridors in both cities, with more expected to come up in future. Such mixed-use and high-density development will include consumers having a diverse energy demand. Given the current urban development trajectory and ambitious climate and RE related goals, there are potential opportunities for BESS to support the distribution infrastructure, assist RE integration, and offer improved energy management for different end-users.
- The anticipated increase in urban development will increase the demand for service utilities including water, wastewater, public transport, healthcare and emergency services. As noted earlier, both cities have significant RE deployment, to the tune of a planned 21 MW to meet the municipal energy demand in the near future, which is expected to be scaled up further. Both ULBs currently incorporate power backup through DG sets for utility services (such as water and wastewater) and emergency services (such as hospitals and fire stations). To this end, BESS can be a potential solution to manage municipal demand, maximize RE utilization, and provide reliable power in municipal utilities and public facilities.



# 5. Local Stakeholder Impressions on BESS

The project team engaged with stakeholders at the state level and in both cities, through one-to-one discussions, to gather inputs on opportunities to adopt BESS and the potential use-cases. The stakeholders were consulted over the course of the study to understand the prospects of enabling BESS, and the barriers and gaps for the same. Stakeholder inputs on entry points and opportunities have been captured in **Section 5.2** while their inputs with regard to gaps are reflected in **Section 9**.

## 5.1. Identification of Key Stakeholders

A mapping exercise was undertaken to identify the energy and urban sector institutions at the state and city levels, and the local stakeholders who could influence the promotion and adoption of BESS. The identified key stakeholders are listed below. A detailed mapping of stakeholders along with their specific roles and responsibilities is provided in Annexure 2. Stakeholders were subsequently engaged and consulted in relation to BESS.

**Table 3: List of Stakeholders at the State and City Level**

| Area of work | State or city level | Institution |
|---|---|---|
| Policy | State | Energy and Petrochemical Department, Gujarat Government |
| | | Ports and Transport Department, Gujarat Gov-ernment |
| | | Climate Change Department, Gujarat Govern-ment |
| | | GEDA |
| Regulation | State | GERC |
| | | Office of the Chief Electrical Inspector |
| Electricity generation | State | • GSECL<br>• GPCL<br>• Gujarat Industries Power Company Limited (GIPCL)<br>• Torrent Power |
| Electricity transmission | State | GETCO |
| | | Gujarat State Load Dispatch Centre |
| Electricity Distribution | State | GUVNL |
| | Regional/ City | • DGVCL<br>• Torrent Power (Surat)<br>• PGVCL |
| Urban development | State | Urban Development Department and Urban Housing Department (UD&UHD), Gujarat Government |
| | | Gujarat Urban Development Mission (GUDM) |
| | | Gujarat Urban Development Company (GUDC) |
| | Regional/ City | **Surat**<br>• Surat Urban Development Authority (SUDA)<br>• SMC<br><br>**Rajkot**<br>• Rajkot Urban Development Authority (RUDA)<br>• RMC |

| Area of work | State or city level | Institution |
|---|---|---|
| Other stakeholders | State Level/ Regional | EV infrastructure provider (Public charging stations) |
| | | EV fleet operators<br>● PMI Electro Mobility Solutions (Rajkot)<br>● Olectra Greentech Limited (Surat) |
| | Regional/ City | ● Commercial, industrial, institutional and residential consumers/prosumers<br>● Gujarat Chamber of Commerce and Industries (GCCI)<br>● Confederation of Real Estate Developers' Association of India (CREDAI)<br>● Confederation of Indian Industry (CII) |

## 5.2. Outcomes of Stakeholder Engagement and Consultation

Potential BESS use-cases identified through research were discussed with local stakeholders for their recommendations and to substantiate the use-cases. Through the consultations, specific BESS applications were prioritized based on interest of local stakeholders.

The RMC, SMC and a local DISCOM identified three priority use-cases: i) Load Management at EV charging station, ii) Peak load and power backup management at water pumping station and iii) Curtail peak load and deferral of upgrade at DT level. These priority use-cases were further evaluated in terms of BESS utility. The consultations also informed the preparation of the Assessment Framework, presented in Section 9, that was developed based on the need for ULBs and urban planning agencies to have a better understanding of the opportunities, benefits and applicability of BESS in different use-cases. The Framework is intended to guide stakeholders to undertake initial qualitative scoping for the five shortlisted BESS use-cases.

The key points from the stakeholder engagement and consultations in Rajkot and Surat are summarized below:

- **Increasing VRE penetration and its challenges** – The contribution of RE in the total electricity consumption is increasing, especially with the rising uptake of distributed and rooftop solar PV plants. However, the intermittency and variability in RE generation pose challenges in power demand and supply management. Possibility of encountering voltage and frequency fluctuation in the cities was noted, especially in Rajkot, due to increased grid-connected distributed RE penetration. The implementation of BESS can reduce the unpredictability of scheduled and weak power supplies and help the local load dispatch controller manage the supply efficiently.
- **Urban development driving energy demand and the need for reliable power supply with RE integration** – The intense urban development underway in Surat and Rajkot is expected to result in dense building clusters, greater energy demand and the need for reliable energy supply. With various urban development projects in the pipeline, including under the Smart City Mission, the two cities have ambitious plans for RE deployment and developing energy efficient green buildings. BESS can help deliver assured 24x7 uninterrupted electricity supply to consumers, and enable improved RE integration.
- **Relatively low tariffs and charges for grid power** – The TOU tariff has been introduced for commercial and industrial consumers and for municipal facilities in both cities, ranging from INR 0.45 to 0.85 per kWh in Rajkot and INR 0.45 to 1 per kWh in Surat. However, the current peak demand charges and electricity tariffs in Gujarat are relatively low compared to other states, inhibiting the financial viability of BESS deployment in BtM applications.
- **Feasible BESS applications**
  - → **Enabling energy time-shift** – The Gujarat Solar Policy 2021 requires that HT/Extra High Voltage consumers shall consume the solar energy generated for captive use between 7am and 6pm of the same day, with surplus energy to be sold to the DISCOM. By not limiting the capacity of solar PV installation by consumers with respect to their sanctioned load, the Policy promotes maximum utilization of the solar PV potential. BESS can be a suitable option for energy time-shift and for optimizing self-consumption of RE by end-customers.
  - → **BESS to support EV charging systems** – Surat and Rajkot have planned significant deployment of EV and charging infrastructure. Integrated BESS and solar PV for EV charging systems can be useful for the cities, as energy load demands will rise in the near future with the introduction of e-buses for public transportation as well as private EVs.

- **Contributing to smart city energy infrastructure** – Rajkot and Surat are designated Smart Cities under the Smart City Mission and need to be resilient to power outages and, therefore, demand reliable power supply. With both cities proposing to deploy significant RE capacity on-ground, BESS with RE can help ensure uninterrupted and low-carbon power supply.
- **BESS for BtM applications** – BESS can support RE integration and reliability of operations of utility services and essential end-uses such as water supply, wastewater treatment, hospitals and public buildings. It can be a viable option for HT commercial and industrial connections, where it can help in peak shaving, energy savings, maximizing RE utilization, and can serve as a clean power back-up source.
- **BESS for FtM applications** – BESS can support integration of variable RE generation and capacity firming, addressing uncertainties in RE generation (particularly for wind power), and help meet RPO targets. It can support in peak demand management and demand response in a cost-effective manner. In distribution grids, BESS can help in peak load management and capacity upgrade deferral for urban areas with overloaded DTs.
- **Specific use-cases of local interest for BESS evaluation** – Local stakeholders in Surat and Rajkot expressed interest in evaluating BESS applications specifically for EV charging infrastructure, municipal facilities such as water supply, and peak load management at DTs.

- **Advancement of BESS implementation**
  - State government mandates and provisions are required to drive promotion and deployment of BESS at the city-scale.
  - DISCOMs can include BESS proposals in their five-year plans submitted to GERC to accelerate BESS deployment.
  - DISCOMs and transmission companies (TRANSCOs) face uncertainties with respect to decisions on power tariff setting, which are cross-subsidized and often not reflective of the real cost of supply. Therefore, cost recovery will be a key factor for decision makers of DISCOMs and TRANSCOs to include BESS in their portfolio.
  - ULBs and DISCOMs coordinate for the expansion and upgradation of the power grid network to cater to the energy demand in new urban developments on an intermittent basis, as needed. Improved collaboration is needed between ULBs, DISCOMs and TRANSCOs to promote BESS deployment and realize the benefits at the city-scale. Coordination mechanisms and information sharing can help leverage opportunities to better align and influence planning and decision-making between the urban development, RE and power sectors.
  - Private participation is needed to support investment and push BESS deployment, given its high capital cost and limited BESS projects on the ground currently. In the current market scenario, viability gap funding would be required to support implementation of BESS projects. Policy initiatives such as inclusion of BESS in CERC's Ancillary Services Regulations 2021 can enable private investment and large-scale deployment in the state.
  - The implementation of BESS pilot projects can be prioritized to demonstrate techno-economic feasibility, benefits and value addition, and to disseminate implementation experiences in the local context.
  - ULBs do not require regulatory approvals for BESS deployment unless it is to serve as a generator.

**Highlights of key inputs from specific stakeholders**

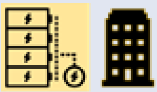
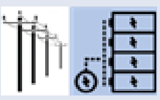
| | |
|---|---|
| **SMC** | ● Interest in evaluating BESS application for load management in EV charging infrastructure, given that 500 new EV charging stations are to be set up by 2025 in Surat. The potential reduction in the sanctioned load of an EV charging station can be assessed.<br>● Given its high-power consumption, the industrial sector can be prioritized for RE integration and demand reduction to contribute to Surat's net-zero GHG emissions target. Potential for BESS to support demand shaving and peak-load shifting and realize savings in energy bills for large industries with round-the-clock operations.<br>● Based on the results and outcomes of potential BESS pilots implemented for a specific use-case, SMC is willing to send recommendations to national line ministries and agencies such as the Ministry of New and Renewable Energy (MNRE). |
| **RMC** | ● Interest in examining BESS applications to support the operation of municipal facilities, especially water supply infrastructure.<br>● Water pumping stations in the city have large DG sets as backup (of around 500 kVA capacity). Data and inputs gathered from the RMC to support pre-feasibility analysis of BESS to be undertaken at a water pumping station (202 MLD capacity, monthly electricity consumption of 2 lakh kWh).<br>● Potential for exploring the integration of BESS in Rajkot's Raiya Smart city area. This greenfield area has received Indian Green Building Council (IGBC) Green Cities 'Platinum' certification at the planning stage and will entail application of sustainable planning concepts, policy initiatives and solutions to address energy use. Solar PV deployment of 3 MW is planned here.<br>● Coordinated planning and decision-making is needed between power DISCOMs and TRANSCOs, and ULBs for BESS deployment in the city.<br>● The implementation of pilot BESS projects will help beneficiaries, including ULBs, DISCOMs and TRANSCOs, and local end-customers understand the techno-commercial feasibility of BESS in the local context. |
| **DISCOMs (DGVCL, PGVCL, Torrent Power)** | ● Interest in evaluating pre-feasibility and cost-comparison of BESS deployment at the DT level in Surat, to reduce DTs' peak load and defer DTs' upgrade. Information shared on select DTs that are frequently overloaded due to increasing electricity connections and demand, to identify suitable ones for BESS evaluation. Given the limited space at such DTs, that can be in congested or densely populated areas, the availability of space for BESS deployment is a key parameter.<br>● Unscheduled interchange charges incurred by Torrent Power, Surat are not significant in relation to their overall operational costs.<br>● Grid power supply is reliable in Rajkot, with limited challenges encountered in load variation, voltage and frequency fluctuations. BtM applications for commercial and industrial consumers, emergency and essential services, and EV charging infrastructure can be assessed for BESS implementation in Rajkot.<br>● The tariff for charging of ESS's not being explicitly defined by the respective state electricity regulatory commissions yet, is detrimental for BESS uptake. |
| **GUVNL** | ● BESS can support capacity firming and integration of VRE generation.<br>● To meet unscheduled power and peak demand, DISCOMs need to procure power from exchanges, after utilizing their costliest generator, incurring a significantly higher cost for such power purchases.<br>● The inclusion of BESS in capital expenditure (CapEx) plans of DISCOMs can help in its higher penetration in the power system and its market development.<br>● The deployment of BESS pilot projects can improve understanding of their potential and implementation challenges, and help analyze the economic benefits of deploying BESS in the power system based on real-time data. GUVNL is willing to support and collaborate in techno-commercial studies and BESS pilot projects. |

| | |
|---|---|
| **GEDA** | • Uncertainties in RE forecasting, especially wind generation, pose challenges in meeting peak power demand in certain regions of Gujarat. BESS can help reduce deviation from scheduled generation and minimize generation curtailments. Analysis can be undertaken to evaluate reduction in UI charges for generators due to BESS deployment.<br>• DISCOMs can be provided an option to deploy BESS for meeting their RPO, along with solar and wind energy. Such a provision can benefit DISCOMs in the long run and enable them to consider BESS deployment which can further supplement and support effective integration and capacity utilization of rooftop solar PV.<br>• Collaboration between ULBs, DISCOMs and TRANSCOs is required to identify and tap into opportunities for BESS deployment at the city-scale in a coordinated manner.<br>• Private sector participation and PPP-based financing models can enable large-scale BESS deployment in the state. |
| **GERC** | • DISCOMs should integrate technical and CapEx proposals for BESS into their five-year proposals submitted to GERC to accelerate BESS deployment. FtM applications may be better suited for BESS deployments in the present market scenario and technology costs, as compared to BtM. In BtM applications, there is higher potential for BESS adoption for HT consumers that can leverage ToD tariffs to realize cost savings due to load time-shift through BESS.<br>• Availability of commercialized technology and price are the two major challenges for BESS deployment.<br>• ULBs do not require regulatory approvals for BESS deployment except when BESS serves as a generator, for which operational permissions would be required from the local DISCOMs and GERC. GERC is willing to support cities on technical and regulatory aspects for BESS deployment.<br>• Demand charges, based on connection capacity (kVA or kW), are set low for EV charging infrastructure at present, given the anticipated low volumes of EV and uncertainty in charging utilization. Therefore, cost savings from demand reduction may be lower at present and can potentially increase in the future as EV adoption and infrastructure evolves. |
| **GPCL** | • BESS will be a viable option for HT connections where ToD tariffs are higher and for micro-grid level applications, especially when loads are predominantly residential and commercial. There is potential to explore implementation of BESS in emergency services.<br>• The economics for BESS projects is expected to improve with expected reduction in battery costs (about 30% in 10 years). At present, BESS projects may require 20 to 30% viability gap funding.<br>• Given the expected increase in energy demand with an increase in the EV fleet, there are opportunities to deploy BESS in EV charging infrastructure, especially when integrated with RE. GPCL has tested the deployment of 50 kW solar PVs with 150 kWh BESS for EV charging.<br>• Energy costs incurred by major commercial and residential development projects and the contribution of RE-based power are key considerations to understand the feasibility of BESS at the city-scale. Funds available under urban programs such as the Smart City Mission can be leveraged for implementing BESS pilot projects.<br>• State-level policy mandates and targets, and private sector investments, are required to push BESS uptake. |
| **GETCO** | • With rapid increase in the installation of rooftop PV systems in the urban and metropolitan areas of Rajkot, load imbalance has become a challenge. Frequent voltage and demand fluctuation issues are experienced in some parts of the city, mainly in the industrial areas.<br>• The expansion of the power grid in urban areas is undertaken based on load demand forecasting, in coordination with DISCOMs and ULBs. For instance, RMC submits requests to GETCO for additional capacity to be deployed to cater to the forecasted power demand. Based on such requests, GETCO plans and undertakes deployment of new grid infrastructure.<br>• There is interest in examining the feasibility of BESS in supporting network augmentation. It is also suggested that a study can be undertaken to understand the long-term merits of integration of BESS at the power distribution-scale. |

# 6. BESS Use-cases identified for Rajkot and Surat

Use-cases for deploying BESS in the two urban areas were shortlisted based on stakeholder consultations and research. Five use-cases have been identified in total for Rajkot and Surat, across BtM and FtM applications, for further assessment, as noted in the Table below.

RMC, SMC and the local DISCOM in Surat were interested in examining the feasibility of BESS application in specific use-cases, including a) load management at EV charging infrastructure, b) peak load and power backup management in water pumping station, and c) peak load management at DTs, respectively. These stakeholders were engaged during the pre-feasibility technical and cost analysis undertaken for these specific use-cases.

| BESS use-case | Potential location | Beneficiary | Needs and opportunities for BESS |
|---|---|---|---|
|  **BtM applications** | | | |
| EV charging infrastructure management<br><br>**Specific application of local interest:** Load management at EV charging station, Surat | EV charging site | EV charging station operator,<br><br>ULB or public EV fleet operator | • Better integration and utilization of RE sources<br>• Peak power demand shaving (due to EVs)<br>• Reliable power/ Power back-up management<br>• Grid frequency and voltage regulation (before supplying to chargers)<br>• Addressing harmonic distortion introduced into the grid by chargers |
| End-use consumers (commercial, institutional, industrial and residential) | Consumer Premises | End-consumer | • Backup power for continuation of services<br>• Better RE integration<br>• Specific for the consumer commercial/industrial/ residential<br>• Peak load management<br>• Grid frequency and voltage regulation |
| Municipal utilities and services<br><br>**Specific application of local interest:** Peak load and power backup management at water pumping station, Rajkot | At specific municipal site | ULB | • Peak demand and energy charges reduction/ Load management<br>• Better integration of energy sources<br>• Backup power for continuation of services |
|  **FtM applications** | | | |
| DISCOM load management<br><br>**Specific application of local interest:** Curtail peak load and deferral of upgrade at DT level, Surat | Substation or feeder/ DT | DISCOM | • Deferral of distribution grid upgrade for peak load management<br>• Grid reliability improvement in terms of frequency and voltage regulation<br>• UI charges reduction<br>• Backup power for substation and ancillary services |
| Generation and transmission management | At power generation site and in transmission network | Generation and transmission companies | • Ancillary services management<br>• Optimizing utilization of RE in the power mix<br>• UI charges reduction |

# 7. Existing Policy Initiatives and Regulations for BESS

Policy and regulatory frameworks can help ensure implementation of use-cases identified for BESS and that these are attractive from a business perspective. This section provides a snapshot of policy and regulatory reviews relevant to BESS in India.

## 7.1. Key National Policies related to BESS

The national government has rolled out policy initiatives and guidelines to promote and support the installation of BESS in the country, especially in recent years.

i. **Guidelines for Procurement and Utilization of Battery Energy Storage Systems as part of Generation, Transmission and Distribution assets, along with Ancillary Services 2022**

The Ministry of Power (MoP) issued these Guidelines in March 2022 under the Electricity Act 2003 for the procurement of energy from BESS by the 'procurers', through competitive bidding, from grid connected inter-state and intra-state projects. Important business cases on the utilization of BESS for supplying energy and grid maintenance are also highlighted.

The objectives of the Guidelines are as follows:

- Improving the power supply – Facilitate procurement of BESS, as part of individual RE power projects or separately, for addressing the variability/increasing energy output from an individual RE project or a portfolio of RE projects; and augmentation of existing RE projects; and/or to provide ancillary, grid support and flexibility services for the grid
- Efficient utilization of T&D network – Facilitate procurement of BESS for optimum utilization of the T&D network
- Framework for power procurement through BESS – Ensure transparency and fairness in procurement processes, provide for a framework for an intermediary procurer as an aggregator/trading licensee/implementing agency for inter-state/intra-state sale-purchase of power
- Enhanced bankability of projects – Provide standardization and uniformity in processes and a risk-sharing framework between various stakeholders involved in the energy storage and storage capacity procurement, and hence encourage competition and enhanced bankability of projects

ii. **Scheme for Flexibility in Generation and Scheduling of Thermal/Hydro Power Stations through bundling with Renewable Energy and Storage Power 2022**

The MoP published this Scheme in April 2022, repealing previous schemes in this regard. As per the scheme, 'RE power with BESS' has been given the same meaning as application of 'standalone RE power'. Salient points under the Scheme are as follows:

- RE power plants may be established on a standalone basis or in combination with BESS, which is either co-located within the premises of a coal/lignite/gas/hydro station or at new locations.
- BESS, if applicable, should be established with a RE power plant through a competitive bid process under Section 63 of the Electricity Act.
- No transmission charge for use of Inter State Transmission System (ISTS) shall be levied if the RE power is being scheduled as replacement power, provided evacuation is being done from same switchyard.
- The RE procured by the beneficiaries under these guidelines shall qualify for RPO.

iii. **RPO and energy storage obligation trajectory till 2029-30, 2022**

The MoP prescribed a trajectory for energy storage obligations (ESO) in July 2022, on the same lines as the existing RPOs. The trajectory includes the following stipulations:

- RPO targets, in the form of ESOs, have been indicated till 2029-30, and it is stated that energy storage charged using RE shall be considered towards the RPO fulfilment:

| RPO targets through storage (on energy basis) (in %) | 2023-24 | 2024-25 | 2025-26 | 2026-27 | 2027-28 | 2028-29 | 2029-30 |
|---|---|---|---|---|---|---|---|
| | 1.0% | 1.5% | 2.0% | 2.5% | 3.0% | 3.5% | 4.0% |

- ESO shall be calculated in energy terms as a percentage of the total consumption of electricity and shall be treated as fulfilled only when at least 85% of the total energy stored in energy storage systems (ESS), on an annual basis, is procured from RE sources. ESO to be reviewed periodically, considering availability of capacity and to accommodate new commercially viable ESS and reduction in BESS cost.

iv. **National Mission on Transformative Mobility and Battery Storage 2019**

India launched a national mission to promote deployment of battery storage in e-mobility and to augment domestic manufacturing of battery storage. The mission includes a five-year phased manufacturing program to set up large-scale domestic battery factories by 2024.

While this policy initiative is primarily focused on the mobility sector, knock-on effects on stationary battery energy storage can be expected in the long-term, with reduced battery costs and a large stock of EV batteries that could be repurposed for second-life use as stationary energy storage. Efforts to expand this program to stationary energy storage applications could further accelerate the deployment of technologies such as BESS.

v. **Draft National Electricity Policy 2021**

The Draft National Electricity Policy (NEP) 2021 aims to promote clean and sustainable electricity, improve the transmission system to meet the grid demands, revamp the DISCOMs which are flailing due to financial burden, and develop efficient markets for buying and selling electricity and for grid services. The Draft NEP focuses on adding non-fossil sources of generation but also acknowledges that coal-based generation would still be needed for cost-effectiveness. It also focuses on hydro generation, hybrid models for renewables like wind, solar and hydro, need for micro-grids in remote areas, electricity storage, and development of a market and infrastructure for EVs.

## 7.2. Key National-level Regulations related to BESS

Several regulations rolled out for the power sector, with implications for BESS, include:

i. **Ancillary Services Regulations 2015**

In 2015, the CERC introduced the Ancillary Services Regulations for the tertiary frequency control requirement of the power market, which will be met by utilizing un-dispatched surplus capacity available with large inter-state generators. The regulation service requirement was implemented through the Reserve Regulation Ancillary Service (RRAS) mechanism. All inter-state generators whose full capacity tariff is determined or adopted by the CERC is mandated to be a RRAS provider.

National Load Dispatch Centre (NLDC) is the nodal agency for ancillary services which maintain the merit order for dispatch of RRAS providers based on their variable cost of generation. The triggers for dispatching ancillary services such as extreme weather, special days, generation, or transmission outage have been defined under the Regulations, based on which NLDC provides RRAS instructions (Up or Down service) considering transmission constraints (both inter-regional and intra-regional) during dispatch of RRAS.

The RRAS provider increases or decreases generation as per the instruction from NLDC, given through the respective regional load dispatch centre (RLDC) for Regulation Up and Regulation Down, respectively. The RRAS providers are paid both fixed and variable charges when Regulation Up service is required. However, during the Regulation Down service, the providers refund the fixed charges to the original beneficiary in proportion to the power surrendered. This settlement is handled by the nodal agency through the deviation settlement account under a separate account head of ancillary services, and the payment to the ancillary services provider shall be made from the Regional Deviation Pool Account Fund.

ii. **Ancillary Services Regulations 2022**

In January 2022, CERC notified the **Ancillary Services Regulations 2022, which allow entities capable of providing energy storage and demand response, to participate in the ancillary services market** to provide secondary and tertiary reserve ancillary services to the grid.

The regulation enables a market-based mechanism for procurement, deployment and payment of Tertiary Reserve Ancillary Services (TRAS) and will be facilitated by a nodal agency (NLDC) through power exchange(s). Meanwhile, the Secondary Reserve Ancillary Services (SRAS) will be procured directly by the nodal agency; a market-based mechanism is also possible. The NLDC, in coordination with RLDCs and state load dispatch centres (SLDCs), estimates the requirement of TRAS and SRAS at the regional level, factoring in the reserves readily available in each state's control area and based on the methodology specified in the grid code. The Regulations also stipulate that both SRAS and TRAS providers need to be connected to the inter-state or intra-state transmission system, and that the energy storage and demand-side resources can provide SRAS and TRAS to the grid.

The primary frequency response has been the responsibility of the generators to ensure system security as per the amended grid code, which ensures that generators maintain a primary reserve and respond promptly to system imbalance through governor control. However, the Regulations have an enabling provision to provide for procurement, deployment and payment mechanism for Primary Reserve Ancillary Services (PRAS) and other types of ancillary services, by amending these regulations based on the power market requirements and market reality.

iii. **Deviation Settlement Mechanism and Related Matters Regulations 2014**

These Regulations introduced the deviation settlement mechanism (DSM) based on the recommendations of the enquiry committee constituted in the wake of the 2012 grid failure events. They brought in improved grid discipline by introducing volume limits, progressive tightening of operational frequency band, and increase in deviation charges for underdrawal/overdrawal of power.

The DSM regulations were strengthened through five amendments, taking into consideration the prevailing power market conditions and recommendations from expert groups. In the 1st amendment, lower or increased power drawal/injection limits were added when the frequency is above 50.10 Hz or below 49.7 Hz, respectively. Through the $2^{nd}$ and $3^{rd}$ amendments, a framework for scheduling deviation for wind and solar generators and relaxation of volume limits for underdrawal/over-injection for renewable-rich states was extended, considering the high variability of RE sources, particularly wind and solar. These amendments also mandated a day-ahead forecast from solar energy generators with an interval of 15 minutes for the next 24 hours, when aggregated generation capacity is more than 50 MW. The solar generators being regional entities have the option of accepting the forecast of the RLDC concerned for preparing their schedule; or must provide the respective RLDC a schedule based on their own forecast, and any commercial impact on account of deviation from the schedule based on the forecast chosen by the wind and solar generator would be borne by it. In the $4^{th}$ and $5^{th}$ amendments, the administered DSM charges were indexed to the Area Clearing Price (ACP) of the Day Ahead Market (DAM) segment of the respective power exchange, with the objective of factoring in the geographical aspect of prices, effect of transmission congestion, and variations between peak and off-peak prices. This was done to incentivize participants to procure power from organized power exchanges, and to discourage entities from deviating substantially from their schedules because of higher charges, which will lead to improved forecasting, scheduling and grid discipline.

Discernible improvements in the stability of the power system, and the grid frequency staying within a small band over the recent years through amendments to the grid code and DSM mechanism implemented by the CERC, have resulted in the absence of large frequency excursions. This is because there is hardly any scope for frequency-linked price arbitrage at present, as the constituents are adhering to their schedule. Therefore, the linkage between system frequency and marginal price is no longer a correct indicator of the power generation being in short supply or surplus.

In 2015, the introduction of Ancillary Services Regulations made frequency-linked DSM counterproductive as ancillary services are deployed centrally by the system operator to restore and maintain the system frequency closer to 50 Hz. The frequency linked DSM is a decentralized tool for controlling frequency and their co-existence could lead to avoidable conflict in systems operation. Further, DSM prices have become predictable due to prevailing stability in grid, allowing for overdrawal of power by DISCOMS. The DSM prices can be very low or zero, especially during high frequency hours. Considering the fallouts of linkage of frequency to DSM rate, CERC has proposed a new framework for DSM under the Deviation Settlement Mechanism and Related Matters Regulations 2022.

### iv. **Deviation Settlement Mechanism and related matters Regulations 2022**

Notified by CERC in March 2022, these Regulations aimed at ensuring that entities connected to the grid do not deviate from it and adhere to their schedule of drawal/injection of power through a commercial mechanism in the interest of the grid's security and stability.

Regarding deviation in power injection by normal generators, there will be no charges for deviation up to 2% for over and under-injection, beyond which the charges will be 10% of the normal rate for over-injection and 120% of the normal rate for under-injection up to 10% of deviation. This is increased to 150% of the normal rate for under-injection beyond 10%.

Run-of-river (Ror) and MSW-based generators do not have to pay any deviation charges for over-injection. However, the Ror stations must pay for under-injection. The MSW based generators must pay only for under-injection beyond 20% at the normal rate for deviation.

In case of renewable generators such as wind and solar, the tariff is decreased by 10% in the event of over-injection of more than 5% and up to 10%, beyond which the renewable power suppliers will not be reimbursed. For under-injection, the wind and solar power sellers will not have to incur any costs up to 10%. However, if the deviation exceeds 10%, the seller must pay deviation charges at 10% of the normal rate.

For deviation in power drawal by power buyers, with schedule of more than 400 MW or from renewable rich states, there will be no charges for underdrawal. But for overdrawal, the entity must pay at the normal rate up to 10% of the deviation, at 120% for deviation up to 15%, and at 150% for deviation beyond 15%. The buyers with less than 400 MW schedule are not required to pay for underdrawal but need to pay the normal rate for overdrawal up to 20% and at 120% for deviation beyond 20%.

The Regulations define that the normal rate of charges for deviation for a specific time block is equal to the weighted average ancillary service charge (in paise/kWh). This is calculated based on the total quantum of ancillary services deployed by the system due to the deviations, and the net charges payable to the ancillary service providers for all the regions in that time block.

### v. **Promoting Renewable Energy through Green Energy Open Access Rules 2022**

The MoP notified these Rules with the aim to ensure access to affordable, reliable, sustainable and green energy for all, in line with ambitious national RE programs. The key eligibility limit for OA transaction has been reduced from 1 MW to 100 kW and the key provisions for cross-subsidy surcharge, additional surcharge and standby charge, have been added to incentivize the common consumers. Further, there is no capacity limit on RE generation by captive consumers.

As per the Rules, DISCOMs are obliged to procure and supply green energy upon request by eligible consumers for a minimum of one year on payment of an additional charge, the Green Energy Tariff. The green energy consumed by a consumer in excess of its RPO obligation is counted towards RPO compliance of the DISCOM. The rules state that there shall be a uniform RPO on all obligated entities in the area of a distribution licensee and that Green Hydrogen/Green Ammonia can be included for fulfilment of the RPO.

The Rules also clarify that banking of unused power will be provided on a monthly basis at least, which is a critical provision for the green OA market. Commercial and industrial consumers can purchase green power on voluntary basis and can be rated and rewarded green certificates.

The Rules also aim to provide a standardized framework for OA deployment, to streamline the overall approval process for granting OA, including time-bound processing by bringing uniformity and transparency in the application, as well as approval of OA through a mandated national portal. Further, approval for green OA, if not granted in 15 days, will be deemed to have been granted by default.

Load dispatch centre (LDC)/state transmission utility (STU)/central transmission utility (CTU) have been appointed as the nodal agencies for green OA to reduce the influence of DISCOMs in the OA approval process and to implement the OA application clearance window of 15 days (as specified in the Rules).

### vi Grant of Connectivity, Long-term Access and Medium-term Open Access in inter-State Transmission and Related Matters (Seventh Amendment) Regulations 2019

The CERC notified these Regulations in January 2019 with the objective of promoting large grid connected wind-solar PV hybrid systems to optimize the utilization of transmission infrastructure and land, and to reduce the variability in renewable power generation to achieve better grid stability.

The Regulations support a range of energy storage solutions based on mechanical, electrochemical and thermal technologies, and allow grid-connectivity of energy storage asset as a stand-alone asset or as part of renewable hybrid projects. For stand-alone storage assets, inter-state connectivity will be granted only for facilities with more than 50 MW capacity. Smaller capacity storage assets must be either tied to a renewable or hybrid power plant or can aggregate and operate with one asset acting as the lead generator.

### vii Draft Indian Electricity Grid Code 2022

In June 2022, CERC notified the draft of the revamped Indian Electricity Grid Code (IEGC) 2022. The Draft Code bodes well for energy transition as it has provisions related to testing, trial runs and commercial operation of RE generators and storage technologies. It also provides for long-term integrated resource planning for resource adequacy.

As per the Draft Code, successful trial run of a standalone ESS shall mean one cycle of charging and discharging of energy, as per the design capabilities with the requisite metering, telemetry and protection system being in service. For declaration of commercial operations, the documents and tests required by an ESS include a certificate confirming compliance to the CEA Technical Standards for Connectivity, power output capability in MW and energy output capacity in MWh, frequency response of the storage system, and ramping capability as per design.

Further, the operating, schedule and dispatch code of the Draft IEGC 2022 includes extensive provisions regarding operation and dispatch of ESS's connected to the power market.

# 8. Analysis of Barriers and Gaps for BESS Deployment in Gujarat

In order to drive the integration of BESS in India's power sector and cities, it is important to address existing gaps that inhibit its implementation. The gaps have been identified through secondary research and stakeholder consultations in Rajkot and Surat, and in consultation with state-level institutions in Gujarat. Key gaps assessed towards policy and regulation; and institutional, technical and financial aspects are noted in this section.

<table>
<tr><th colspan="2">Barriers and Gaps for BESS</th></tr>
<tr><td>Policy and Regulation</td><td>Long-term vision, roadmap and provisions for enabling interventions for battery storage deployment lacking at national or state level<ul><li>A comprehensive policy/roadmap at the national and state-level, to guide deployment of BESS under both FtM and BtM applications from an urban context, is needed.</li><li>GT&D utilities, end consumers and third-parties in the market and other stakeholders should be incentivized under national or state policies to encourage investing in BESS and facilitating proliferation.</li></ul>Lack of adequate policy impetus on BESS in existing state-level policies (solar/wind/hybrid RE/EV) and urban development programs<ul><li>Gujarat's Solar Policy and EV Policy, both notified in 2021, do not include provisions to promote energy storage. BESS is not included as a solution to meet energy demand and enable RE integration for built infrastructure in current urban development programs such as the Smart Cities Mission and the National Mission on Sustainable Habitat 2.0.</li><li>Missing thus far, the opportunities to link BESS with RE plans notified in the state are expected to enable higher penetration and market development in the energy storage space. Further, DISCOMs may integrate technical/CapEx proposal for BESS with their five-year plans (i.e., multi-year tariff [MYT] petition) submitted to GERC, also endorsed by GUVNL, to accelerate the deployment of BESS.</li></ul>Ambiguity/lack of support regarding BESS in existing national policies and regulations<ul><li>Lack of clarification on tariff structure (tariff for charging BESS through grid connection, transmission and distribution), which is important to develop business cases</li><li>While BESS is considered an option for SRAS and TRAS, the Ancillary Service Regulations ignored BESS as an asset for primary frequency response, which is the responsibility of the generators currently, despite it being one of the fastest response systems prevalent.</li><li>Lack of policy and regulatory impetus for fast responding assets such as BESS to provide grid services</li></ul></td></tr>
<tr><td>Institutional</td><td>Urban energy (including energy storage) not addressed in the urban infrastructure and land use planning process in Indian cities<ul><li>ULBs and urban development agencies typically have a limited role in planning and decision making in the energy sector. Given their authority in planning, they are well-placed to promote energy efficient urban design, including adoption of BESS for effective RE integration and peak power management. However, they are often not sufficiently equipped and are hampered by resources and funding.</li><li>Lack of adequate coordination, particularly between ULBs and DISCOMs, is leading to unsynchronized urban and energy planning, and missed opportunities to effectively leverage solutions such as BESS in sustainable energy management at the urban scale. Early-stage coordination in infrastructure planning can help tap into opportunities offered through significant RE-scale up (projects of 17.3 MW capacity in total are proposed in FY 2022-23 by Surat and Rajkot) and EV charging infrastructure (installation of 500 EV charging stations is targeted by Surat).</li></ul>Institutional framework and capacity for integrating BESS deployment into urban planning lacking (at various levels of horizontal and vertical governance)<ul><li>Given the lack of policy emphasis, promotion of BESS is not on the agenda of the state energy department or state nodal agencies. An enabling institutional structure is important for handling aspects of policy, regulation, technical know-how, and co-ordination with multiple actors at the state and local level regarding BESS promotion. In the absence of an institutional structure with clearly defined roles and responsibilities of the various departments involved, it is difficult for stakeholders to coordinate and approach the right department for implementation of BESS.</li></ul></td></tr>
</table>

| | Barriers and Gaps for BESS |
|---|---|
| | **Inadequate coordination and knowledge sharing between various stakeholders including DISCOMs, ULBS, and other concerned state departments**<br>● Multiple stakeholders would be involved for the successful implementation and optimum utilization of BESS in various RE, EV infrastructure, energy supply and demand services, including ULBs, urban development authorities, DISCOMs, GETCO, GERC and end-consumers.<br>● A platform or mechanism for disseminating information and developing collaborative relationships among stakeholders regarding BESS, is lacking. Such platforms can enable access to operational data, information of performance, and knowledge from implementation and operation of any existing commercial or near-commercial BESS projects such as the Modhera project (6MWp solar PV with 15MWh BESS), and hence help decision-making for promotion and replication of BESS. |
| **Technical** | **Lack of standardization in BESS and associated technology**<br>● BESS, and its associated technology available in the market currently, does not adhere to a standard that has been approved for deployment by any authorized entity in India. This means any consumer/developer installing BESS may not meet appropriate requirements for voltage, frequency and other technical parameters. An approval system for BESS technology to be implemented in India is missing.<br>**Understanding and expertise on planning, operating and maintenance practices for BESS not well-established**<br>● Apart from the battery, BESS is comprised of electronic and other devices and hence needs specific technical guidelines or protocols to guide its deployment. In the absence of such technical guidelines, BESS deployment may result in harmonics and other challenges in the system.<br>● An interconnection guideline, which clarifies the factors to consider while connecting BESS with the grid, is lacking. GPCL has cited instances of grid disturbances such as DT failure while testing the grid connectivity of BESS.<br>● There have been a few instances of Li-ion batteries catching fire globally. Existing guidelines lack details on safe installation and operation of BESS systems. Given that India is yet to install a substantial number of BESS projects, this gap should be addressed before the BESS scale-up.<br>**Unavailability of data and reliable estimates on energy demand and load profiles for different applications, to assess BESS feasibility**<br>● Information, for analysing and estimating the benefits with BESS, on daily and hourly load profiles and peak demand is either not available or not being recorded, particularly for BtM end-uses such as EV charging stations, commercial buildings, healthcare, municipal facilities and emergency services. Reliable benchmarks for energy demand and load profiles for different types of buildings and infrastructure are limited, posing a challenge for early-stage modelling and planning of BESS for new buildings and greenfield development, as well as in existing ones.<br>● The data gap also poses a challenge to assessing peak demand, hourly energy requirement, distributed RE generation from different buildings and end-uses at the city-scale to identify high potential opportunities for BESS. State-level studies and analysis on the BESS potential in urban areas to support evidence-based decision-making are lacking.<br>**Limited knowledge and information on benefits of BESS projects and best practices to enable replication**<br>● Technical know-how and exposure to BESS technologies is limited among decision-makers, investors and stakeholders, restricting efforts to evaluate BESS suitability and subsequent implementation in FtM and BtM applications.<br>● There is a lack of published information on BESS costs, benefits and operation for different use-cases in the Indian urban scenario. While stakeholders showed interest on pilot-scale BESS implementation across use-cases during consultations, evidence and knowledge of successful implementation is insufficient. Sharing of operational data, system performance, benefits accrued, and business models from existing BESS projects, in Gujarat and other Indian cities, is necessary to build stakeholder and market confidence.<br>**Lack of focus on BtM application of BESS**<br>● BtM applications for BESS can be highly beneficial to the consumer and can alleviate peak load complaints of the DISCOM. Emergency or essential services such as hospitals, municipal facilities and emergency shelters require rapid response technology to maintain performance in the event of grid outages. RMC has installed a DG set of 500 kVA capacity in its water pumping stations to ensure uninterrupted operations, in the event of disruption in grid power. Water pumping stations and other municipal facilities are further integrated with solar PV systems in Rajkot and Surat to reduce their dependency on the grid. Further, large-scale consumers will have high power demand and may require solutions for energy cost management to prevent penalties for excess power consumption. Policy level push and support for such applications may help eliminate the cost of network upgradation and reduce the peak load power purchase cost. |

<table>
<tr><th colspan="2">Barriers and Gaps for BESS</th></tr>
<tr><td rowspan="1">Financial</td><td>
High capital cost<br>
● Despite a significant reduction in the capital cost of a BESS,[35] it continues to be high in comparison to solutions that would have been otherwise implemented viz. DT replacement. In such a scenario, investment for BESS proliferation can only be spurred through incentives or viability gap funding.<br>
● A targeted capital support programme to provide grants, loans or guarantees to support BESS projects is not in place. Funding for urban and energy decision-makers and planners to undertake potential assessment studies, feasibility projects and support in project commercialization costs, is not available.<br>
Lack of options in local procurement of Li-ion batteries and high import duty<br>
● Given the lack of domestic battery manufacturing, large portions of BESS equipment are imported from overseas, with import duty and taxes applicable, resulting in additional financial burden for implementers and investors.<br>
Lower financier or investor confidence due to lack of evidence on successful projects, business models and funding mechanisms<br>
● There is a lack of published results around financial returns and commercial viability of BESS projects in the local context, impacting investor confidence and inhibiting funding of BESS projects.<br>
● Electricity tariffs and peak demand charges for commercial, industrial and municipal consumers in Gujarat are relatively lower than in other states, posing challenges to realization of business cases for BESS,[36] particularly for BtM applications. Further, tariffs are cross-subsidized (as in other Indian states) and not reflective of the costs incurred to supply electricity, especially during high demand periods and exigencies/shortages. The average monthly market clearing price in the Indian energy exchange was INR 10.06 per kWh in April 2022[37] that reportedly spiked to INR 20 per kWh,[38] before regulatory interventions capped spot prices at INR 12/kWh. The mismatch in supply-demand costs along with inherent challenges in supply and distribution of electricity has also contributed to more efforts on BESS implementation in FtM systems, than in BtM.
</td></tr>
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Photo by Sungrow EMEA on Unsplash

# 9. Assessment Framework for BESS Use-cases and Applications

As noted in previous sections, there exist various opportunities to integrate BESS to cater to the rising energy demand, changing load profiles and increased RE generation at the city-scale, particularly in relevance to a large increase expected in RE generation, e-mobility and infrastructure development in urban areas. BESS can be deployed across various applications and use- cases in cities, either as an FtM or BtM solution. BESS use-cases specifically identified for Rajkot and Surat under this study are presented in Section 6. However, battery energy storage is still a relatively novel technology in India and understanding of the opportunities and applicability of BESS in different use-cases is still evolving among planners, decision-makers and stakeholders.

With this rationale, an **Assessment Framework has been developed to guide and underpin preliminary scoping of BESS deployment for specific use-cases identified at the city-level, before going into technical pre-feasibility studies. This guiding Assessment Framework can provide a structured conceptual map of the learning and mapping steps that will lead to useful outcomes and decisions, helping assess and understand the challenges, opportunities and feasibility of BESS adoption for specific applications at the urban scale**. An Assessment Framework improves the validity and reliability of such an initial examination, allowing early movers deploying a novel technology to develop robust assessment instruments to evaluate feasibility with greater ease.

Assessment Frameworks have been developed, specific to the five shortlisted priority use-cases in this study, including BtM and FtM applications.

| BESS for BtM applications | BESS for FtM applications |
|---|---|
| 1. EV charging infrastructure | 4. Generation and transmission management |
| 2. End-use consumers (commercial, industrial and residential) | 5. DISCOM load management at power distribution side |
| 3. Municipal utilities and services | |

The Assessment Framework for preliminary scoping of BESS deployment is presented for each of the five use cases in sections 9.1 and 9.2 through the following structure:

| | | |
|---|---|---|
| | Opportunities and needs relevant to BESS | An overview of requirements and services that BESS can provide in the specific use-case |
| | Decision flowchart for scoping of BESS | Intended to support qualitative check on BESS prospects and decision-making on proceeding with a pre-feasibility check for BESS |
| | Framework with indicators | Includes key indicators and data points, corresponding to specific opportunities and energy related needs, to help users gather relevant data and information to eval-uate BESS suitability |

The Assessment Framework is especially relevant for city level stakeholders such as urban planners, local policymakers and practitioners who may not be conversant with the challenges arising in the power sector due to growing energy demand, RE integration and e-mobility transition, especially at the local distribution level and the opportunities therein for BESS systems. The overall approach proposed by the Assessment Framework will allow intended users to examine prospects and undertake a preliminary scoping of BESS for specific applications, to understand the inherent opportunities and requirements that BESS can address, and to do an initial check for BESS deployment in their urban context. However, it should be noted that this Framework is not intended to replace or substitute detailed technical assessments that would follow such an initial screening.

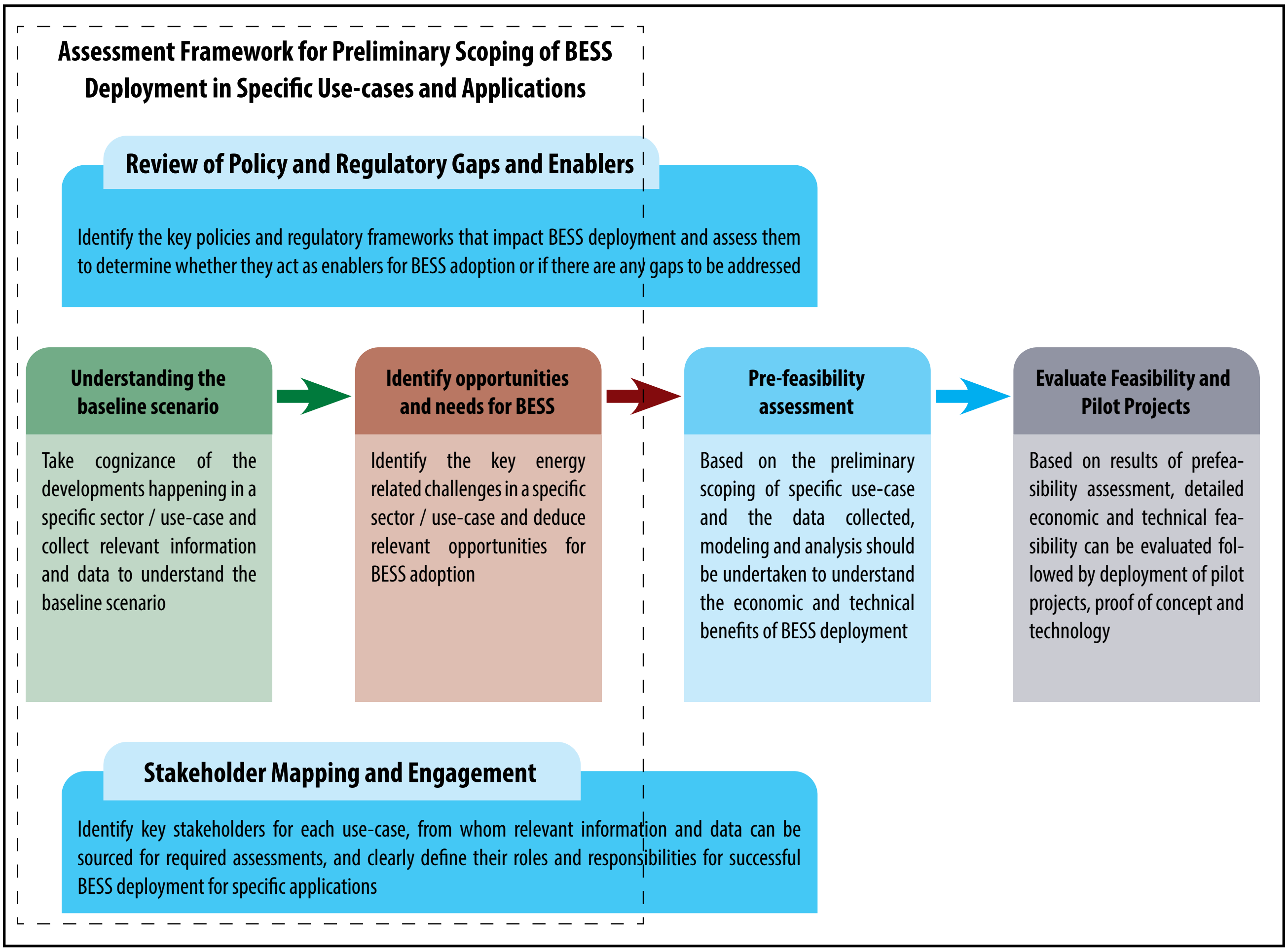



**Figure 13: Overall Approach of the Assessment Framework**

As depicted above, the Assessment Framework for preliminary scoping of BESS has a step-by-step approach and includes the following elements:

- **Understand the baseline scenario:** The first step involves taking stock of current status and developments taking place, through apprehension of targets, plans, entry points and drivers that would have implications on how and where BESS potentially fits in for the specific use-case. This also includes screening of sites or locations with relatively better prospects of BESS. For example, ULB targets to integrate RE systems in facilities/infrastructure for municipal services or municipal plans to make large-scale water pumping stations more energy efficient.
- **Identify the key opportunities and needs for BESS:** The next step is to help identify and narrow down on the key energy related opportunities and needs or applications requiring intervention and which can be catered to by BESS. For instance, a need to reduce high energy bills through peak load management and a potential to maximize the amount of on-site RE generation for self-consumption in commercial and industrial facilities. In case of FtM applications, seasonal peak electricity requirements and increasing consumer end-connections may cause frequent overloading of DTs, wherein BESS can support shaving of peak demand of the DT and hence help postpone investments for upgradation. This step would also entail gathering of relevant information to understand and evaluate which energy related requirements are critical and can be served by BESS.
- **Stakeholder mapping and engagement:** Along with the two steps above, it is imperative to conduct a stakeholder mapping and engagement exercise. This entails an initial identification of key stakeholders and engaging with them for gathering information and data to support the assessment. For example, when assessing municipal utilities for BESS, ULBs can provide information about the operational patterns, energy bills, and plans for future expansion, while DISCOMs can help understand implications of electricity loads on the power distribution network and capacity available in the feeder/DTs serving such municipal facilities.

- **Review of existing policy and regulation:** A review of the existing policy and regulatory frameworks is necessary to understand whether the current landscape, frameworks and mechanisms act as enablers or barriers to BESS deployment. For instance, CERC/SERC regulations on deviation settlement and penalties/charges levied on DISCOMs when deviating from scheduled drawal of power.

Depending on the outcomes of the preliminary scoping and evaluation of BESS (which is primarily qualitative), pre-feasibility studies and detailed feasibility assessments can follow, both technical and financial. Some elements of the policy and regulatory review that require deeper evaluation (for example, BESS safety standards, regulations and plan for decommissioning and safe disposal of BESS at the end-of-life) can extend beyond the preliminary scoping into pre-feasibility assessments. Similarly, stakeholders or prospective consumers for BESS will need to be engaged for information gathering and consultations during the pre-feasibility evaluation stage.

**Supporting Elements and Enablers for BESS adoption – Policy, Regulation and Stakeholder Coordination**

The first impetus to innovative technologies and processes primarily comes through the right policy initiatives, be it at the national or sub-national level. Policies being put forth by the national, state, and local governments with respect to RE, EV and power sector transition, and the market reaction to such initiatives, are key to enabling deployment of novel technologies like BESS. At the urban level, the policies and targets surrounding RE and EV deployment are largely based on state and national level policies. Local governments set energy transition and e-mobility targets at the city level in line with the state policies, with support stemming typically from state and national level schemes and programs.

In the case of BESS deployment for urban applications, for instance, local and sub-national policies linking incentives to energy-efficient operation of EV charging stations and integration of RE for powering EV charging, would be a key enabler for BESS, since an RE plant combined with BESS would be better able to meet the EV charging loads effectively. Further, ambitious local policies or targets on net-zero emissions, RE, e-mobility, and EV charging infrastructure would greatly increase opportunities for BESS.

National targets and policies for the power sector, such as the Revamped Distribution Sector Scheme of GoI, aim to reduce the aggregated technical and commercial (AT&C) losses and will provide DISCOMs with the required financial support and incentives for upgrading the distribution infrastructure, implementing smart metering systems, reducing technical and financial losses, and deploying novel technologies such as BESS to improve the efficiency of DISCOM operations. Such schemes and targets would play a key role in including BESS deployment as part of the DISCOMs' CapEx plans, enabling large scale deployment of BESS for various applications.

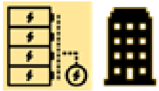
Regulatory frameworks surrounding the power sector are key to enabling at scale deployment of BESS. The current costs of BESS pose a challenge for its financial viability across most applications. However, new (or amendments to) power sector regulations will greatly influence the power market dynamics, leading to opportunities for BESS with better prospects to improve or achieve feasibility.

Regulations and guidelines for BESS including grid interconnection; remuneration model for various applications either with RE plant, DISCOM or as standalone system; large-scale procurement; and safety standards are required to support and regulate BESS deployment. Recent regulations by the CERC on developing an ancillary services market (with provision to allow BESS to participate) and DSM are examples of regulatory interventions that will support development of new opportunities and potential for BESS deployment.

Stakeholder co-operation and coordination are important to tap into potential opportunities for BESS adoption, both at the city-wide scale as well as in specific use-cases. Urban development and planning agencies can coordinate with DISCOMs/utilities at an early stage of the urban planning process. DISCOMs can provide inputs to ULBs in their spatial planning and zoning process regarding RE, building clusters and EV charging infrastructure to enable deployment of BESS. Local RE developers, large consumers, DISCOMs and ULBs can work together to promote the adoption of BESS along with RE systems.

## 9.1. Assessment Framework for BESS in Behind-the-Meter Applications

BESS, when connected to the grid behind the meter by end consumers, is referred to as BtM BESS. Deployment of BESS at BtM can generally range from small to large scale depending on the type of end-use consumer or application that can directly benefit from using BESS, including large commercial buildings, industries, hospitals, EV charging stations and public utility infrastructure. The assessment framework for BESS for the following BtM applications is described in the sections below:

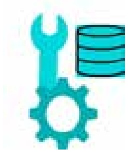
| | |
|---|---|
|  **BtM applications** | • BESS for EV charging infrastructure<br>• BESS for end-use consumers (commercial, industrial and residential)<br>• BESS for municipal utilities and services |

### 9.1.1. Electric Vehicle Charging Infrastructure

Accessible, reliable and affordable electricity is a prerequisite for adequate charging infrastructure for e-mobility. BESS has multiple uses and applications in EV charging infrastructure. It can help support power distribution and defer the need for network upgrades, improve the output of the chargers to charge the EV batteries, enable peak demand shaving, harness the maximum potential of on-site RE, optimize costs and reduce GHG emissions.

#### 9.1.1.1 Key Energy related Opportunities and Needs relevant to BESS

**Support power distribution infrastructure**



- Rapid EV transition in a city will add significant energy demand to the local distribution grid within a short period, potentially leading to operational challenges for the grid network. While most DISCOMs are well-prepared to serve new EV related energy demand from a system-level generation standpoint, there is a greater need for readiness at the distribution network level. DISCOMs would have to increase their CapEx and operational expenditure investment for distribution capacity augmentation and procure additional power to cater to the peak demand patterns arising from EV charging infrastructure. In case the capacity utilization of the nearest feeder exceeds the threshold (generally 70 to 80% of its total power capacity), an upgrade of the distribution network is required, which can be an expensive and time-consuming exercise.

  Power infrastructure costs are observed to be the largest cost component for setting up EV charging networks, based on experiences from India and international cases. Civil works and securing power connection from the nearest distribution point may be challenging and expensive in congested areas or where connections need to be drawn across busy roads. With charging station operators required to bear the costs of any upgradation in the electricity network, power connection and network costs can significantly impact the economics of charging stations.

  BESS can help decongest the distribution network, reduce capacity requirement and overloading of DTs, and hence help defer distribution network upgrades and lower the costs of establishing power infrastructure for charging. BESS deployment can help deliver reliable and quality power, as per technical standards, in locations such as urban outskirts or in congested or busy city areas where interconnection and distribution network upgrade is a challenging, costly and time-consuming process.

**Minimize energy charges**

- **Peak demand charges and load management:** Electricity demand charges incurred during peak periods can significantly impact operational costs for charging stations. Energy demand from EV charging can peak and increase power consumption at the city-scale in a short period. High concentrations of EV charging can overload the local power grid. BESS can help reduce peak demand and optimize charging load where energy demand is consistently high and frequently exceeds contractual/sanctioned load of the charging station connection.

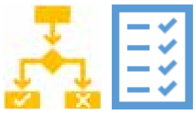
  For example, Gujarat's EV tariff levies demand charges of INR 50 per kVA for billing demand in excess of contract, which is two times the base demand charges. BESS can help EV charging stations take optimal advantage of ToD tariffs. BESS can be charged from the grid during off-peak hours at lower costs and be used to deliver energy and effectively manage charging loads during peak demand periods. This capability of BESS can suit EV charging catering to commercial vehicles or aggregator fleets that need to be charged during the day. BESS adoption can also help effectively restrict additional load and energy demand where future expansion and increased utilization of charging stations is anticipated.

- **Possibility of reducing sanctioned load viz. shift from HT to LT category:** HT connections (generally required for sanctioned load >100 kW, limits vary across states) add additional burden of high demand charges as compared to LT connections. An HT connection attracts higher installation and monthly demand charges and requires more time for energization. For instance, the costs of getting power infrastructure and connection in place for a 20 kW load in Delhi range from INR 3 to 4 lakhs and increase to around INR 11 lakh for a charging station with 100 kW load.[39] BESS provides an opportunity for operators to reduce the sanctioned load requirements for EV charging stations, helping confine them to low tension electricity connection. This helps leverage the LT distribution infrastructure and incur lower energy costs.

**Enable captive use of RE installation**

- EV charging operators may set up captive RE generation systems to meet the energy requirement for EV charging, partly or in full, especially at locations where the quality and availability of power supplied by the DISCOM is a challenge. BESS can serve as a reliable power source in conjunction with RE generation to ensure seamless operations in the event of grid outages. For effective integration and maximum utilization of on-site RE such as solar PV, BESS can store additional RE generation and support overnight charging. Such a system can cater to charging stations that serve vehicles during the day-time and public and commercial fleets during night-time. BESS can use off-peak power to charge itself, ultimately freeing up more available power for the electricity system to use alternatively. It can also help stabilize the variable power available for EV charging when the solar irradiation is intermittent.

#### 9.1.1.2 Decision Framework for Scoping of BESS in Electric Vehicle Charging Infrastructure



The decision framework presented below is intended to guide and support city officials, urban and energy planners, decision-makers, charging service providers, and local stakeholders in identifying opportunities and scoping of BESS in EV charging infrastructure. The process will need involvement and inputs from stakeholders and decision-makers, including DISCOMs, ULBs, EV charging service providers, EV fleet operators, state nodal energy agency, and state departments such as transport and urban development.

A first step in this process entails taking cognizance of the baseline scenario and understanding the current and planned EV related development in the city (refer Figure 14). Identifying state and city-level plans, policies and targets that will influence the rate of EV adoption and charging infrastructure deployment can help comprehend the scale and timeline of e-mobility transition and its associated energy demand. Early phases of EV growth in Indian cities are expected to come from the commercial sector fleet owners and operators, bus transit agencies, and from commercial EV charge network operators serving both commercial and private vehicle segments. Depending on the scale and type of vehicles, these new loads can range from several hundred kW to several MW.[40] Information and any assessments on current and anticipated energy demand from EV charging is helpful to ascertain implications at the city-scale.

Understanding the existing status and anticipated scenario can further help identify entry points and opportunities for potential BESS integration in the local e-mobility space. Local priorities and targets may focus on specific vehicle segments, with corresponding implications on energy requirements and presenting specific possibilities and challenges. For instance, electrification of the public bus fleet, as targeted in Rajkot and Surat, will result in high power requirements given the large batteries of e-buses and fleet size. Charging such e-bus fleets will require dedicated charging infrastructure with significant loads and night-time charging requirements. Similarly, local plans and policies that promote adoption of RE with EV charging can enhance prospects for BESS adoption.

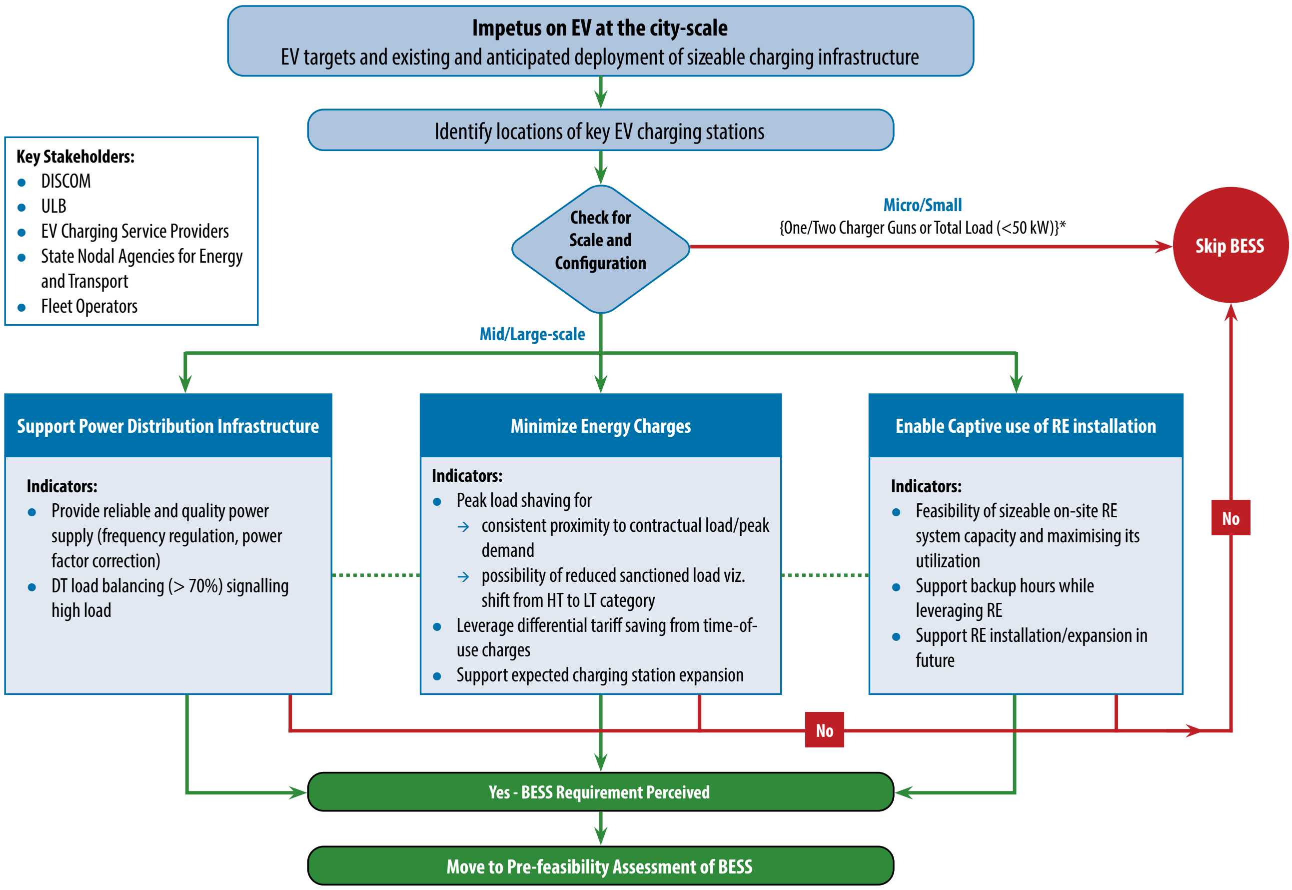
Once the baseline scenario at the larger urban-scale has been reviewed, the next step can be to screen EV charging stations to prioritize stations and locations with appropriate scale and opportunities to examine the suitability of BESS. It may not be suitable for micro and small-scale stations with one to two chargers and low electricity load and power demand. Other criteria and considerations in the screening may include:

- location and unavailability of quality reliable power supply (relevant for charging infrastructure in peripheral areas or near highways and for public charging at bus depots away from the city centre),
- charging characteristics/patterns (commercial charging with high loads coincident with peak demand hours or fleets with significant night-time charging load),
- high captive RE generation on-site, and
- significant future expansion and utilization of the charging station.

Post screening, the decision framework can be used to conduct a qualitative evaluation of suitability of BESS for the identified EV charging station(s). To begin with, additional site-specific details can be collected including sanctioned load, monthly electricity consumption, EV segments served and specific charging patterns. At this stage, the scoping framework aims to help users identify and evaluate three specific opportunities and energy related needs, as noted earlier, that can potentially be served by BESS for the identified site(s) (refer Figure 14)

- Support power distribution infrastructure
- Minimize energy charges
- Enable captive use of RE installation

These three opportunities and needs are interlinked. For example, reducing peak load or integration of RE will help reduce energy costs, while also reducing the requisite energy flow and line losses in the local distribution network. Depending on site-specific conditions and opportunities, BESS can meet more than one of these requirements and deliver multiple benefits concurrently. **Therefore, in the scoping evaluation, sites where BESS can potentially cater to multiple requirements and opportunities, rank higher for prospects for its adoption**. If specific opportunities and scope for BESS to meet needs are determined (i.e., affirmative), users can move ahead with pre-feasibility assessment for BESS for the EV charging site(s). If the requirement for BESS is not perceived, other load and demand management measures such as standalone RE installation, and reconfiguration of the charging plan and technology, can be looked at instead of BESS.




* Reference values identified for screening from field information and may differ from case-to-case basis

**Figure 14: Decision Chart for Scoping of BESS for Electric Vehicle Charging Infrastructure**

| Component | Steps |
| --- | --- |
| **Understand the baseline scenario and identify specific sites for examination** | **Identify the impetus on e-mobility and the scenario of related energy demand at the city level**<br>Apprehend targets, current status and future plans for deployment of EV and new charging infrastructure to support EV targets; ascertain the existing and anticipated increase in energy demand and load on grid due to EV charging infrastructure<br><br>**Suggested data points, dependent on data availability**<br>● Status of EV uptake and penetration in private (2W, 3W, 4W, buses) and public transport (buses), and in freight transport (3W, 4W, trucks)<br>● Identify prevalent charging patterns[41] (morning, afternoon, evening, night-time) of EVs for different categories of vehicles<br>● Identify any local level projections/assessments undertaken for future EV scenario and any studies undertaken to assess the increase in city's energy demand due to EV<br><br>**Screen and prioritize EV charging stations to examine BESS prospects**<br>Undertake screening and identify priority charging stations with appropriate scale and opportunities for BESS<br><br>**Suggested data points, dependent on data availability**<br>● Determine total number of EV charging stations (public and private)<br>● Determine current power demand and usage statistics of EV charging infrastructure at the city-level<br>● Identify location of charging stations (within city/dense neighbourhood/highway/public space/commercial or private space/residential complex)<br>● Screen and prioritize charging stations with multiple charges, excluding micro/small-scale charging stations with 1 or 2 chargers and low electricity load and charging energy demand; understand charging requirements and patterns at the station to determine energy and load demand<br>● Identify scale and configuration and power supply for the prioritized charging stations in terms of number of chargers, charging technology, target end-user type, charging capacity (kW or kWh), status and plans for use of RE to supply power (fully grid-powered/RE + grid-powered/wholly RE powered)<br>● Identify connected load, monthly electricity and energy consumption, and energy bills incurred for the prioritized charging station |
| **Scoping of BESS for applications in EV Charging Infrastructure** | **For selected EV charging stations (prioritized or ones of interest), identify and assess following key opportunities and energy related needs**<br><br>**Minimize energy charges**<br>● Daily and monthly load profile and peak demand[42] of the charging station to determine whether energy demand is high and in proximity to sanctioned contractual load/peak demand<br>● Applicable power supply tariff rates for charging stations, load requirements and charges for connection types (high-tension, low-tension)<br>● Applicable differential tariffs such as peak demand tariff rates, ToU charges<br>● Plans and scope for future expansion of charging station<br><br>**Enable captive use of RE installation**<br>● Status and plans for RE system installation on-site and capacity of RE system<br>● Plans and scope for future expansion of RE installation on-site<br>● Determine the reliability of grid power supply and requirement of significant hours of power backup due to frequent outages and interruptions<br><br>**Support power distribution infrastructure**<br>● Determine power load availability and capacity loading of nearest distribution transformer/ feeder[43]<br>● Any challenges faced in availability of reliable quality power (required frequency, power factor) |

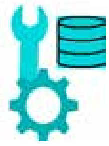
### 9.1.2. BESS for End-Use Consumers (Commercial, Industrial and Residential)

BESS installed at BtM works as an on-site storage system, which provides energy for self-consumption without passing through an electricity meter and interacting with the grid. BESS deployed at the consumer end (residential, commercial and industrial) can store electricity that is either produced from on-site RE systems or drawn from the grid (generally when electricity prices are low) and whenever needed, discharges the stored energy to meet on-site energy demand.

BESS has a variety of applications when it comes to BtM operations, with acquisition theme and requirements varying for different types of consumers. For instance, emergency or essential services such as hospitals, public buildings and emergency shelters require rapid response to continue operations in the event of grid outages, while large-scale consumers demand more power and hence need solutions for energy cost management.

#### 9.1.2.1 Key Energy related Opportunities and Needs relevant to BESS

**Reduce energy bills**



Mid to large-scale consumers, especially commercial and industrial entities, often demand more power and incur high electricity costs for their facilities and buildings due to their higher power charges. ToD tariffs are often implemented to reduce consumption of electricity and for load management during peak hours, with higher tariffs for electricity levied during peak hours. Commercial and industrial consumers are also levied demand charges based on the highest amount of power drawn during any interval over the billing period.

In Gujarat, HT consumers are required to pay additional ToU charge, ranging from INR 0.45 to 0.85/kWh for HT consumers, for consumption during peak hours (07.00 am to 11.00 am and 06.00 pm to 10.00 pm). A concession of INR 0.43/kWh is provided for consumption during night-time (10pm to 6am). Further, under HT load categories, the excess demand is billed at almost double the cost of normal rates (viz. charge of INR 360 per kVA for excess demand) and the energy charges for higher demand categories are also significantly higher than base rates. Thus, BESS implemented at BtM scale can provide significant energy cost savings to consumers by offering capabilities including peak shaving, energy time-shift and differential tariff saving from ToD charges, and lower demand charges by reducing load requirements from the grid.

**Optimize RE installations for captive use and beyond**

Cities are witnessing significant growth in solar and wind systems, with RE generation being prioritized across existing and new greenfield developments. However, these RE sources cater to only a part of the energy demand of consumers. While maximizing the potential for RE systems by storing the surplus energy generation (especially during the off-peak hours) and helping utilize this stored energy during the night or peak hours, BESS systems support sizeable RE deployment by removing barriers such as limitations on size, generation and compensation.

For instance, the Gujarat Solar Policy 2021 includes requirements that HT/EHV consumers shall consume solar energy generated for captive use between 07:00 am to 06:00 pm of the same day, with surplus energy to be sold to DISCOMs through gross-metering mechanism at a tariff of INR 2.15 per kWh. The Policy also promotes tapping of full solar PV potential at the consumer's premises, by removing the previous ceiling which required that solar PV projects cannot exceed 50% of the sanctioned load or contract demand of the said facility. BESS can be a suitable option to address opportunities and challenges in such cases and to maximize RE generation and utilization, especially when there are no restrictions on the installed capacity for RE systems with respect to the sanctioned load of buildings or consumers. RE systems installed along with BESS offer a reliable source of power supply for designing mini-grid or off-grid systems, where required, such as in peripheral urban areas, new greenfield developments, and for isolated industrial units.

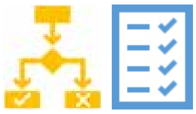
**Provide power backup/resilient power**

Frequent power outages can have significant impacts on consumers, especially for end-users such as hospitals, hotels and public buildings. Unlike DGs, BESS can provide reliable, clean, instantaneous, low-maintenance and silent backup power supply during grid disruptions and outages until complete power restoration. BESS thereby delivers benefits in terms of time and money as it eliminates downtime. Integration of BESS with RE sources enables backup energy for longer periods. BESS can serve as an environment friendly[44] power backup solution to support cities in their carbon mitigation strategies and net-zero targets.

**Support power distribution infrastructure**

BESS also supports power DISCOMs by reducing congestion in the feeder lines and DTs (especially where there are large loads connected), thereby offering deferral in system upgradation investments.

### 9.1.2.2 Decision Framework for Scoping of BESS for Commercial, Industrial and Residential Consumers



The framework outlined below will support in determining opportunities and needs for BESS for distinct BtM consumers based on the applications identified. Gathering information and inputs for the framework will involve key stakeholders such as DISCOMs, state nodal agency, ULBs, respective consumers groups (residential, commercial and industrial, institutional end-users) and their associations.

As a pre-requisite to the process, apprehend state and city goals for deployment of BtM applications including low carbon and carbon neutral plans of the private sector, net-zero or climate action plans and targets for buildings, and norms for DG set usage as a power-backup system. This will help understand the scenario and potential avenues for BESS to support energy transition in commercial, industrial and residential sectors. BESS-backed BtM systems can cater to various applications across commercial, industrial and residential consumers. The scale of applications would vary based on the energy requirements of the consumers.

Understanding the existing status and anticipated future scenario would help analyse requirements and benefits of BESS-backed BtM systems and also assist in screening and shortlisting consumers based on the scale of applicability. Table 4 below illustrates how BESS suitability for BtM applications can be assessed for different opportunities and needs across different consumer types.

**Table 4: BESS Suitability under Various Applications for End Consumers**

| Consumer category | Require power back-up for long hours | Sizeable RE installed in premises | High energy bills | BESS suitability |
|---|---|---|---|---|
| Industrial/ Commercial | X | ✓ | ✓ | **High** (to reduce energy bills and maximize RE potential) |
| Industrial/ Commercial | ✓ | X | ✓ | **Moderate** (in absence of RE, prospects for standalone BESS are lower) |
| Residential | ✓ | ✓ | X | **High** (to fulfil power back-up requirements and maximize RE potential) |
| Residential | X | ✓ | X | **Moderate** (due to low energy requirements) |
| Residential | X | X | ✓ | **Low** (due to high existing cost of BESS) |

The next step, post screening and selection of the consumers, is to conduct a qualitative evaluation for feasibility of BESS. Key indicators presented in the three opportunities and energy related needs (as mentioned below) will assist in determining the use-case and corresponding prospects for BESS for BtM applications. Pre-requisites to the scoping for BESS include gathering information on connected load, monthly energy consumption, energy bills incurred by the consumer, frequency and duration of outages/grid failures, capacity of RE installed on-site (if applicable) and operational challenges towards deployment of RE systems (limitations on size/generation/compensation). Opportunities and energy related needs to be potentially served by BESS for BtM applications for commercial, industrial, residential and institutional end-users are categorized into four types:

- Reduce energy bills
- Optimize RE installations for captive use and beyond
- Provide power backup/resilient power
- Support power distribution infrastructure

BESS can be suitable for one or multiple applications across these four opportunities, depending on the specific needs of the consumers. If the outcome of the scoping evaluation confirms the potential for more than one application or need to be met by BESS, the prospects for BESS are better since it can help deliver multiple benefits. Once the specific opportunities and applications are identified for BESS using the decision framework below, users can move ahead with pre-feasibility assessment for BtM BESS. If the requirement for BESS is not perceived, other energy efficiency and energy demand management measures can be looked at instead of BESS.

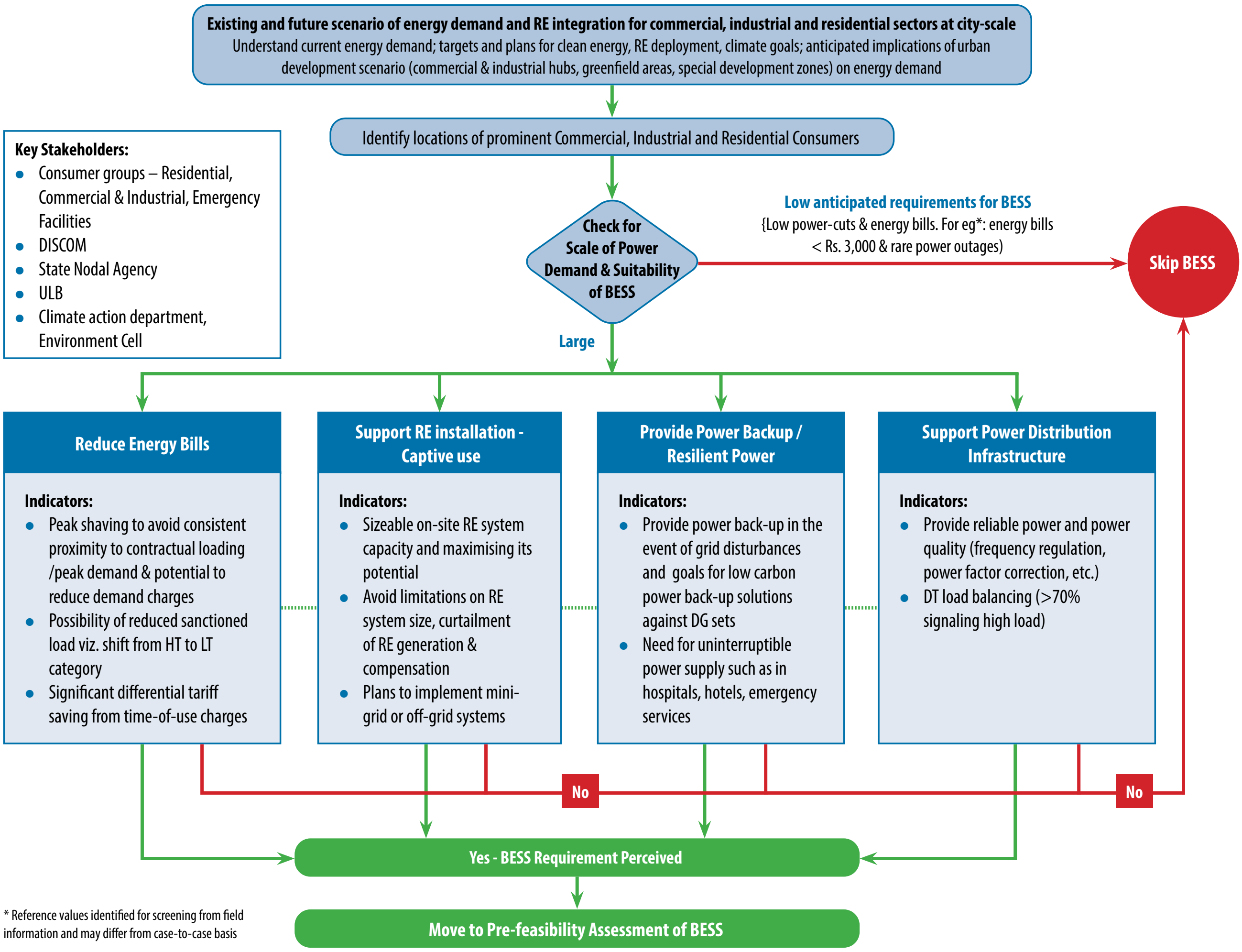



**Figure 15: Decision Chart for Scoping of BESS for BtM Applications for Commercial, Industrial and Residential Consumers**

| Component | Steps |
|---|---|
| **Understand the baseline scenario and identify specific sites for examination** | **Understand the scenario and potential avenues for BESS to support energy transition in commercial, industrial and residential sectors**<br>Take cognizance of the state/city plans around clean energy, RE, climate/net-zero targets, including for the private sector; understand the urban development scenario and new developments planned such as special developmental plans, new greenfield areas, commercial hubs, and IT zones: this will help establish an understanding of the future scenario of energy demand and RE integration<br>**Suggested data points, dependent on data availability**<br>● Collect information on state/city considerations and plans regarding RE integration including RE policies and targets, net-zero/climate action targets and plans, annual budget announcements<br>● Plans for setting-up mini-grid systems, especially RE based mini-grids – as BtM ESS's can help smoothen VRE generation, provide energy management support to meet consumer demands, and replace DGs to provide back-up power when renewable generation is not available |

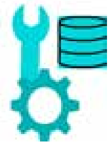
| Component | Steps |
|---|---|
| | **Assess and select consumers based on the scale of power requirements and potential for BtM applications using the screening matrix (refer Table 4)**<br><br>**Suggested data points, dependent on data availability**<br>● Gather data related to power requirements at the consumer end, excluding cases where there are low anticipated requirements (refer to Table 4 with the screening matrix for BESS suitability); identify connected load, monthly electricity consumption and collect energy bills of mid to large scale consumers with significant energy intensity to select consumers for scoping<br>● Understand the building stock of the city and collect energy-use data through the DISCOM on samples of buildings across different areas of the city: this will help better assess the location specific future demand of power and trend of decentralized RE deployments (rooftop PV)<br>● Check for the requirements of power back-up and reliability – frequency and duration of outages/grid failures; emergency service facilities like hospitals, fire-stations, key public buildings require uninterruptible power supply<br>● Identify the capacity of RE installed (if applicable) and scrutinize if there are any operational challenges towards deployment of RE such as curtailment of VRE generation, limitations on size/generation/compensation for RE plants |
| **Scoping BESS for commercial, industrial and residential consumers** | **For selected sites/buildings (prioritized ones or those of interest), identify and assess following key opportunities and energy related needs**<br><br>**Reduce energy bills**<br>● Gather data on daily and monthly peak demand, energy requirements, load profile, demand charges and surcharges incurred for exceeding sanctioned load<br>● Applicable power supply tariff rates, requirements and demand charges for connection types (HT, LT) based on load category<br>● Applicable differential tariffs such as peak demand tariff rates, ToU charges<br>● Any future renovation/expansion/upgradation of buildings or facilities that can impact energy bills and power demand<br><br>**Optimize RE installation for captive use and beyond**<br>● Status and plans for RE system installation on-site and its capacity<br>● Plans and scope for future expansion of RE installation on-site<br>● Any restrictions with deployment of RE viz. limitations on size/generation/compensation<br>● Plans for implementing off-grid/mini-grid systems, including providing energy access to off-grid households when combined with RE systems<br><br>**Provide Power Backup/ Resilient Power**<br>● Record of monthly power and requirements for corrective maintenance – understand durations and frequency of such events to determine the reliability of grid power supply<br>● Quantify power back-up requirements for critical energy systems like in hospitals, hotels, public buildings and determine the CapEx and operational expenditure of DG set based on capacity required[45]<br>● Apprehend norms/guidelines for emission control and permissible noise levels for operation of DG sets, especially in 'silent zones' which lie within 100 metres of premises of schools, colleges, hospitals and courts and examine the actual records; check penalties on high noise pollution and emissions limits<br><br>**Support power distribution infrastructure**<br>● Determine capacity loading of nearest DT/feeder and the spare capacity available for expansion/upgradation of infrastructure<br>● Any challenges faced in availability of reliable quality power (required frequency, power factor) |

### 9.1.3. Municipal Utilities and Services

Most of the municipal services that cater to the daily basic needs of the citizens are critical in nature, such as water supply and wastewater pumping stations, headworks, and sewage treatment plants. These facilities, being energy intensive, also need to ensure continuous operation. Thus, the power demand of these facilities is critical and must met at all times. Considering the various municipal services and the energy-intensive infrastructure within the ULB's purview, that are bound to expand or grow in line with the needs of the growing urban population, there are several applications and opportunities for deployment of BESS as a complementary system supporting energy efficient municipal utilities.

#### 9.1.3.1 Key Energy related Opportunities and Needs relevant to BESS

**Minimize energy charges**



- **ToD tariffs and load management**: Municipal services are required to be operational round the clock to cater to citizens, making it difficult to manage load and take advantage of ToD tariffs established by the DISCOMs. High demand, especially during peak hours, leads to high electricity costs. BESS has the ability to reduce these costs, by shifting the peak load to off-peak hours, and thereby incurring lower ToD tariffs. BESS can complement grid supply during peak hours and get charged during off-peak hours. This reduces the municipal utilities load burden during peak hours leading to electricity cost savings.
- **Reduction of demand charges:** As municipal services are generally billed under commercial or near-commercial LT/HT tariff category by DISCOMs, demand charges are applied to electricity bills based on peak demand during the billing period. BESS can help in peak demand shaving that will reduce demand charges which can lead to significant cost savings from electricity bills. For instance, in Gujarat, the per kVA demand charges increase with higher contract demand, and the demand exceeding the contract is billed at Rs. 360 per kVA (for high-tension power [HTP II] category consumer) which is significantly higher than the base demand charges. Further, the per unit cost of energy increases based on the category of billing demand. Therefore, peak demand shaving by BESS will help reduce the contract demand category and stay within the contract demand, and hence achieve significant cost savings especially for large municipal facilities.

**Enable captive use from RE installation**

- ULBs are increasingly deploying solar and wind power plants for captive consumption in their efforts to transition towards cleaner energy sources. For instance, RMC is deploying solar PV plants in its municipal facilities such as the Aji water treatment plant with 145 kWp solar PV system deployment and the Raiyadhar wastewater treatment plant with a 250 kWp solar PV system installed on-site. Ahmedabad Municipal Corporation is also deploying wind generators in the Kutch region to offset consumption from its utilities. However, renewable sources are intermittent and deploying BESS will help store and utilize renewable generated energy during peak demand periods when electricity costs are higher, instead of feeding to grid at lower or normal energy tariffs (depending on state-level net-metering and solar policies). Thus, BESS enhances the efficiency of RE systems by storing the excess energy generated and enabling its utilization at any time of the day for captive consumption by municipal facilities. Further, with the help of BESS, RE generation potential can be maximized and excess energy generated beyond captive requirements can be stored and sold to the power market during favourable periods.

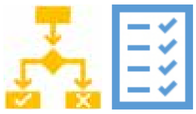
**Provide power back-up**

- Municipal utilities/services require reliable power back-up solutions to ensure continuous operation in the event of grid outages or scheduled maintenance. For critical facilities such as water supply pumping stations, it is often necessary to have power back-up with sizeable capacity to the tune of the connected load. BESS can provide power back-up services more efficiently and can save significant costs incurred from operating large DGs. Cities can evaluate deployment of BESS to improve energy efficiency of municipal operations and to replace polluting DGs, as a strategy to support their clean energy policies and emission targets. Further, BESS offers fast response time and reacts instantaneously to on-site power disturbances, and supplies required power to sustain operations, making it an ideal power back-up solution for critical municipal facilities.

**Supporting power distribution infrastructure**

- BESS, when deployed with an energy intensive infrastructure or facility, reduces the demand on the local DT/feeder station, thus avoiding congestion and limiting incidences of critical loading in power distribution infrastructure. Alternatively, DISCOMs can also deploy BESS at critical distribution nodes serving large and multiple municipal utilities, to help ease congestion and load on the local power network.

#### 9.1.3.2 Decision Framework for Scoping of BESS in Municipal Facilities and Services



In this assessment framework for municipal facilities and services, the key energy related needs of ULBs and the opportunities therein for BESS are identified based on stakeholder interactions and the information collected. This is followed by a decision tree that sets the outline to understand the baseline scenario regarding municipal services and to screen specific locations or infrastructure for preliminary scoping of BESS. The process will assist ULBs to arrive at a decision on the applicability and suitability of BESS for relevant sites and applications.

In the first step of baseline scenario assessment, the development plans of the city need to be understood, especially with respect to large energy intensive facilities for municipal utilities (existing or being built) and plans for RE installations in such facilities. Documents such as the master plan, city development plan, municipal infrastructure plan, and climate action plan will provide an understanding of the vision and development plans of the city. This understanding of the city's infrastructure plans, including the development of large service infrastructure and integration of RE, would help understand potential entry points where BESS could come in. A review of these documents would also help identify locations and infrastructure with significant energy requirements.

Along with the baseline assessment, it is important to assess the relevant policy frameworks that guide and influence new developments, such as requirements and targets for captive RE plants. It is necessary to collect requisite information needed through engagements with relevant stakeholders to undertake an initial qualitative evaluation. Local stakeholders and decision makers such as ULBs, urban planners, regional/metropolitan development authorities, and state municipal administration departments have a significant role in shaping the development of cities. A preliminary identification, mapping and engagement of stakeholders would also help better understand the city's baseline scenario.

Given the current cost of BESS, deploying BESS for LT connections, especially non-critical ones, is not feasible. Therefore, locations and the projected power demand of critical energy intensive infrastructure should be identified from the baseline assessment and through interactions with local DISCOMs and ULBs. After the baseline assessment, and identification and screening of priority sites with potential for energy efficiency interventions, the decision tree should be used to evaluate the four opportunities and applications for BESS:

- Minimizing energy charges
- Enabling captive use of RE installation
- Providing power backup
- Supporting the power distribution infrastructure

The evaluation is done against specific indicators listed in the decision framework that correspond to the specific opportunities and needs for BESS (refer Figure 16).

The four opportunities and needs depicted in Figure 16 are interlinked. For example, deploying BESS to reduce the peak demand and energy costs incurred by the ULB will also benefit the local power distribution infrastructure serving the municipal facility. Depending on the application, and site-specific conditions, BESS can cater to more than one energy related requirements. Therefore, sites where BESS can potentially provide multiple services and deliver multiple benefits at the same time, have higher prospects for BESS adoption.

If specific opportunities and the scope for BESS are determined and established at the end of the evaluation, users can move ahead with carrying out pre-feasibility assessments for BESS. However, if the requirement for BESS is not perceived, other energy management measures through alternative technologies and solutions have to be explored.

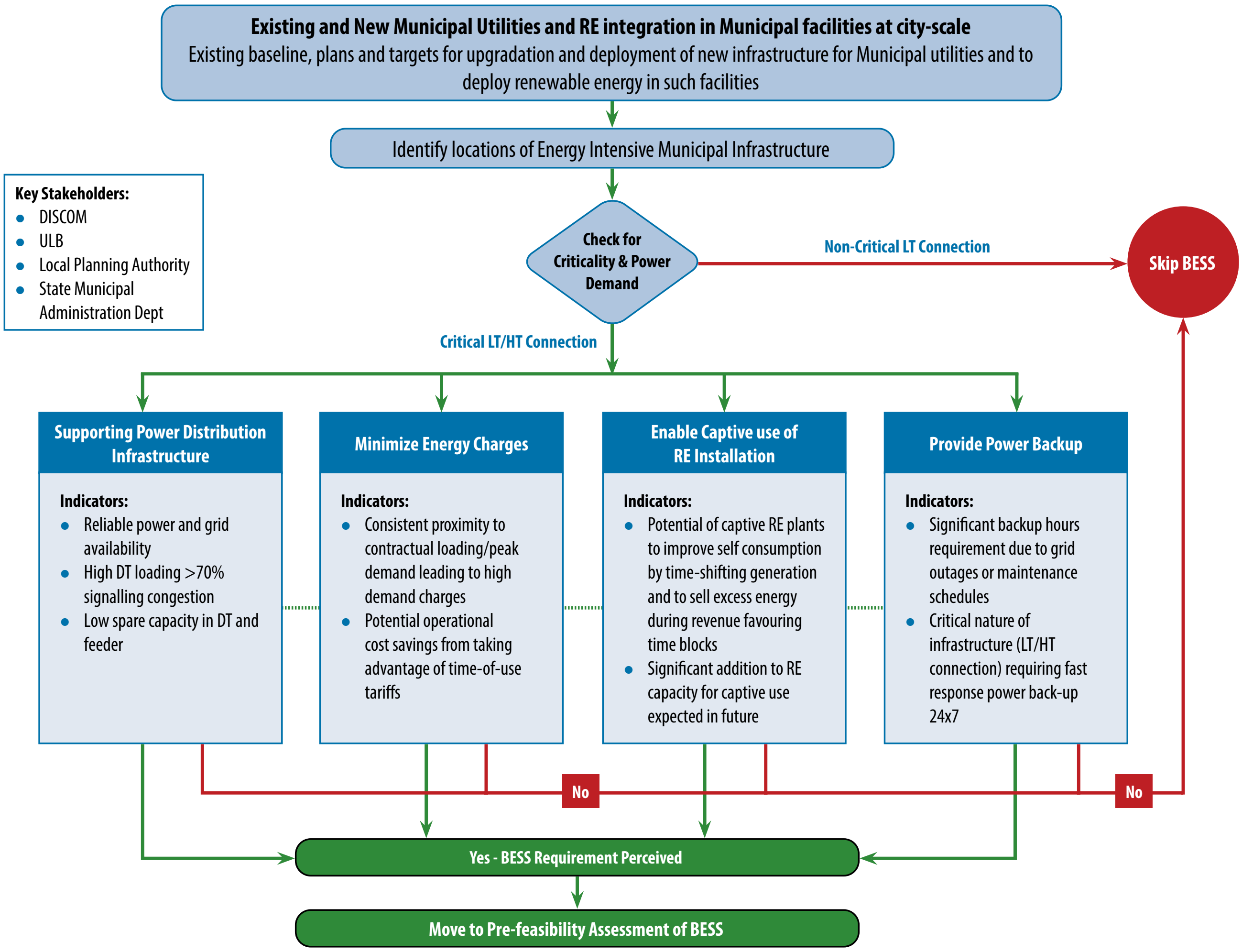



**Figure 16: Decision Chart for Scoping of BESS for Municipal Facilities and Services**

| Component | Steps |
|---|---|
| **Understand the baseline scenario and identify specific sites for examination** | **Understand the developmental plans for municipal facilities and services in the city**<br>Collect information on the baseline scenario and targets, and plan to develop new infrastructure for municipal services and integration of RE<br><br>**Suggested data points, dependent on data availability**<br>● Collect and check documents such as master plan, city development plan, municipal infrastructure plans and climate action plans<br>● Local policies on deployment of RE systems in municipal and public amenities<br>● Identify if there are any local level projections and assessments undertaken for future energy demand and RE integration in municipal service facilities<br><br>**Identify locations of energy-intensive and critical municipal infrastructure along with their power demand to check if they are suitable to examine BESS opportunities**<br>Undertake screening and identify priority municipal facilities that are energy intensive or are expected to have high power demand in the future<br><br>**Suggested data points, dependent on data availability**<br>● Collect information of total connected load of ULBs and of individual municipal facilities<br>● Collect data on current power demand, use of RE for power supply, and profile/usage statistics of the specific critical/energy intensive infrastructure to be screened for assessment |

| Component | Steps |
|---|---|
| | ● Screen and prioritize critical and energy-intensive infrastructure and facilities<br>● Identify the location of energy-intensive or special developments such as commercial areas, new neighbourhoods and residential complexes that will increase the demand for municipal service facilities in the future<br>● Identify connected load, monthly electricity, and energy consumption and energy bills for the prioritized facilities/ sites<br>● Understand the operational patterns and service delivery requirements for these municipal facilities to correlate with energy demand |
| **Scoping of BESS for applications in municipal facilities and services** | **For selected municipal facilities/sites (prioritized or ones of interest), identify and assess the following key opportunities and energy related needs**<br><br>**Minimize energy charges**<br>● Daily and monthly load profile and peak demand[46] of the municipal facility to determine whether energy demand is high and close to the sanctioned contractual load/peak demand<br>● Applicable power supply tariff rates, load requirements and charges for connection types (HT, LT)<br>● Applicable differential tariffs such as peak demand tariff rates, ToU charges<br><br>**Provide power back-up**<br>● Determine the reliability of grid power supply and requirement of significant hours of power backup due to outages and interruptions; collect information on scheduled power shutdowns per year for maintenance, and the frequency and period of outages due to grid disturbances<br>● Capacity of DG deployed at the facility for power back-up and its associated diesel use, operational expenditure and CapEx<br><br>**Enable captive use of RE installation**<br>● Status and plans for RE system installations on-site and their capacity<br>● Identify challenges in captive RE plants, such as demand and supply gaps especially during peak hours, percentage of generated RE power utilized for self-consumption vs sold to grid (determine such cost as per solar policies and energy tariffs) when supply exceeds demand, especially during the daytime and the percentage of RE curtailed due to power evacuation challenges<br>● Plans and scope for future expansion of RE installations for captive consumption<br><br>**Support power distribution infrastructure**<br>● Determine capacity loading of nearest DT/feeder and the spare capacity available for expansion/upgrade of infrastructure<br>● Any challenges faced in availability of reliable quality power (required frequency, power factor) |

**Supporting elements and enablers for BESS adoption in BtM applications – Policy, regulation and stakeholder coordination**

Deployment of BESS for BtM applications will mainly be driven by the business perspective of benefits that BESS can bring into the energy system of an end consumer. In such cases, rather than independent deployment of BESS, integrated deployment of RE with BESS will rake in multiple benefits and make it more viable. This can also enable consumers to better manage the loads, especially in EV charging infrastructure and energy intensive end-use energy systems such as those of municipal service facilities and industries.

The deployment and scale-up of BESS in BtM applications needs policy and regulatory support that will enable and encourage implementation of BESS in such applications, handling safety concerns related to grid interconnection and end-of-life safe disposal. Strong stakeholder engagement and coordination also includes private-sector stakeholder participation is important.

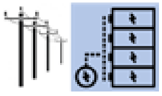
From a policy perspective, the city's environment or climate-related policies, RE and EV plans and targets, mandate requirements for environment-friendly power back-up solutions, and restrictions on emissions and incentives for energy efficiency in municipal facilities and buildings, will help promote the deployment of BESS for BtM applications. Further, clear guidelines on the business aspects of BESS, along with stringent regulations in place to ensure safety in installation, maintenance and disposal of BESS systems, will go a long way in alleviating the barriers with respect to end-consumers.

BtM BESS adoption requires public and private stakeholder engagement and coordination, as mass promotion and awareness among the consumer groups/associations and communities is key to the deployment and scale-up of BESS for BtM applications. A stakeholder engagement plan to engage the private sector, and active promotion by an alliance of ULBs, DISCOMs and other stakeholders from the urban development and power sectors is needed to create awareness, build strategies, implement and manage BESS deployments in BtM applications.

| | Enablers and Considerations |
|---|---|
| **Policy** | ● Goals, targets and plans in the city, which may significantly raise the demand for power and need for load management in the future: This includes e-mobility and setting up EV charging stations, developing necessary infrastructure for municipal services (especially energy intensive services), development of greenfield or new areas, special zones, redevelopments with high building footprint and energy demand.<br>● Ambitious climate and RE goals and policy, net-zero GHG emission targets, clean air action plans at the city-scale<br>● If there are any plans, requirements and incentives in place at the city level/state level for RE deployment in EV charging, municipal services infrastructure, and by consumers; whether the city has explored RE + BESS for enhanced integration of RE into the BtM end-uses<br>● If there are any plans for BESS deployment for operations of EV charging stations, municipal facilities, and by commercial and industrial consumers; if there are any mandatory obligations in applicable policies (BESS, EV, RE) for deployment of energy storage for such energy intensive applications<br>● Whether there are any assessments undertaken to understand the potential and challenges in deploying BESS<br>● Whether efficient operation, load management and low-carbon footprint in end-uses such as EV charging stations, municipal facilities, and commercial and industrial consumers/buildings is incentivized<br>● If there are any plans for deployment of environment friendly power back-up solutions (specifically where there are large requirements), for e.g., in commercial buildings, emergency services and industrial units<br>● Consideration of BESS in mini-grid plans<br>● If there are any guidelines and mechanisms in place to promote re-purposing of decommissioned EV batteries for BESS |
| **Regulation** | ● If the technical and operational guidelines are in place at the state/city level, for powering EV charging stations[47]<br>● If the grid interconnection approval process (state level) for ESS's is framed<br>● If the DISCOM has any guidelines or process developed for deployment of BESS in BTM applications for large consumers<br>● If the State regulations are in place for setting up fair valuation for BESS along with RE systems; if the tariff has been announced or special tariff been offered for charging BESS<br>● What, if at all, are the guidelines and mechanisms for promoting and ensuring safety standards for BESS technologies at the local level; if not, whether nationally or state approved guidelines for such procedures are being recommended<br>● If there are regulations or a plan[48] in place or approved for decommissioning and safe disposal of BESS at the end-of-life |
| **Stakeholder Coordination** | ● If there is a coordination mechanism set up and functioning for local authorities and stakeholders to coordinate the urban and energy planning for EV charging infrastructure, large municipal facilities, and energy-intensive private buildings; coordination mechanisms should include ULBs and corresponding authorities such as DISCOMs, public transport authority, urban planning/regional development departments, energy regulatory and planning agencies and state nodal agencies.<br>● If urban development and planning agencies coordinate with DISCOMs/utilities at an early stage of the planning process<br>● If there are communication mechanisms in place for coordination between ULBs, utilities and other stakeholders (consumer groups/associations) on city-level urban planning and sharing of data with respect to the deployment of EV charging, municipal facilities and infrastructure, large building developments<br>● Whether processes encompassing permissions and regulations for BESS deployment and operation are discussed among ULBs, urban planning agencies, DISCOMs, consumer groups and associations, and are streamlined |

## 9.2. Assessment Framework for BESS in Front-of-the-Meter Applications

BESS, when directly connected into the power grid (distribution or transmission networks) or with power generation assets, instead of being used for the captive consumption, is referred to as FtM BESS. FtM battery energy storage is generally larger in scale as compared to that in BtM end-uses. BESS deployed at FtM has various applications, ranging from providing ancillary services support and optimizing RE generation to deferral of investments in grid infrastructure upgrade. The assessment framework for BESS for following FtM applications is described in the sections below:

| | |
|---|---|
|  **FtM applications** | • BESS for generation and transmission management<br>• BESS for DISCOM load management |

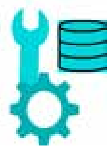
### 9.2.1. Generation and Transmission Management

BESS can play a key role in transition to clean energy in the generation and transmission system, especially with the rising share of VRE in the energy mix. BESS has a wide scope of applications, ranging from short-time power quality improvement to long-term power management. It can provide ancillary services support (essential for the functioning of the system) and act as reserve power to meet or reduce the gap on the committed quantum of power supply by generators. It can also defer requirements for transmission network upgrade.

BESS provides significant value to RE operators by providing a stable electricity supply, thus avoiding RE generation curtailment and increasing their revenue. High power demand (especially during the summer months) can overload the transmission systems, leading to the need for network upgrades, which can entail significant costs. By reducing the loads on the transformers, BESS can help postpone such transmission network upgrades.

#### 9.2.1.1 Key Energy related Opportunities and Needs relevant to BESS

**Support grid integration for VRE (Capacity firming)**



- RE generators are required to supply committed amount of power. In case the VRE power generation is lower than as scheduled (due to weather conditions or system break-down), BESS can support generators by supplying reserve power to meet and reduce the gap in their committed quantum of power, and hence eliminate or reduce the penalty that such generators may otherwise have to pay.

  Further, the Draft DSM Regulations[49] floated by CERC propose that solar and wind generators will not be paid for generation that they inject in the grid over and above the scheduled generation quantum. Currently, this limit is set up to 15% of additional injection, with no implications on revenue payment to generators. If the draft is notified, it would result in reduction of revenue in case RE generation is more than scheduled generation, which is quite possible due to the intermittent nature of solar and wind energy. Deploying BESS can enable absorbing such surplus VRE generation to charge the BESS, instead of feeding the grid (i.e., without realizing these extra units of power) and the charged energy can then be fed back to the grid at a later time when revenue can be realized.

**Manage the power demand and grid infrastructure**

- **Aid in evolving energy-mix** – Integration of cleaner and smart energy technologies like RE and EV in the electricity system, and replacing the traditional power plants, demands greater flexibility to manage increased operational complexity. By providing flexibility and stability in the energy network, BESS offers a reliable power supply, thereby becoming a critical part of the energy mix.

- **Deferral of investments in grid infrastructure upgrade** – By storing power during off-peak periods and supplying it during periods of peak demand, BESS provides load-levelling by reducing the load and stress on the power system infrastructure and hence offers postponement of investments in grid upgrades.

- **Supporting RE powered distributed generation system (mini-grids)** – BESS is an important component in a distributed generation system and mini-grid, especially where the load requirements are desired during non-generation hours of RE systems (viz. during night time in case of a solar-powered system).

**Provide Ancillary Services support**

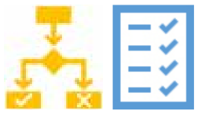
- Ancillary services are value-added services that support and improve the reliability and quality of power. In a matured energy market where the power supply tariffs are defined on the basis of market forces, BESS can find novel business opportunities to be used as a high-quality energy capacity alternative. Because of its capability to ramp up and down quickly, BESS can provide emergency capability to neutralize grid imbalances quickly. Ancillary service capabilities offered by BESS include:

  → **Frequency regulation and voltage support** – Voltage and frequency are two main parameters that ensure the reliable operation of the power grid. Frequency variations in a power system occur because of an imbalance between generation and load. Intermittent power generation from RE and other sources, along with increasing variable loads, cause frequency fluctuations in the grid. BESS can support in maintaining frequency within pre-set limits by providing fast response to power imbalances. Further, it can support in maintaining the grid voltage by injecting or absorbing both active and reactive power as required.

  → **Black start operation** – Large generators need an external power source to perform vital functions before they can start generating electricity (known as black-start). Generally, this power is supplied by the grid, but in an event of grid failure, BESS can provide this necessary support service.

  → **Spinning reserve** – Spinning reserve is required to maintain system stability especially during the unexpected deviations by generating units from their production schedules. The spinning reserve allows system operators to compensate for the unexpected imbalance between load and power generation. BESS can respond quickly (within milliseconds or minutes) and supply power in such events.

### 9.2.1.2 Decision Framework for Scoping of BESS in Generation and Transmission System



This framework aims to support policy and decision makers in the power sector, public and private generators, state TRANSCOs, state nodal agencies, load dispatch centres, and local stakeholders (city planning officials, ULB) for preliminary screening and identifying of opportunities for BESS in the power generation and transmission system. Scoping of BESS for the generation and transmission system requires knowledge of various aspects including the dynamics of increasing VRE penetration and their integration in the electricity system, ancillary services management – the prevailing procurement process, applicable regulations, and associated penalties. Information on state and city plans for RE (with or without BESS), RPO obligations, and plans for establishing mini-grid systems and managing grid infrastructure is also required. The corresponding datapoints related to various parameters for assessing BESS requirements are also highlighted in this framework.

To start the process, it is necessary to apprehend the state plans and targets for the deployment of large-scale RE systems (solar, wind and others) aiming to increase the contribution of RE in the energy-mix. In the case of VRE plants, the challenges related to supply of a committed amount of power and the requirement of reserving power for capacity firming can be ascertained by consulting the state and local generators.

The state and city plans for implementation of mini-grids, which are often an economically viable option for electrifying peri-urban communities, can be looked at. RE along with BESS offers a reliable solution to meet the energy requirements of such communities and new greenfield areas.

It is also necessary to understand the process of estimating the requirement of ancillary services.[50] In this regard, the nodal agency NLDC carries out SRAS and TRAS after factoring in the reserves for each state control area. The quantum of requirement of SRAS and TRAS on a day-ahead basis and incremental requirement (if any) on real-time basis are updated on the NLDC's website.[51]

This decision framework encapsulates the following opportunities wherein BESS can provide the necessary support/services:

- Support grid integration for VRE (Capacity firming)
- Manage the power demand and grid infrastructure
- Provide ancillary services support

BESS provides a range of services and support to the generation and transmission system. Therefore, to maximize its benefits, a combination of value streams that can be dynamic, varying by season, region and the time of day, should be selected. However, if the requirement for BESS is not perceived, other load and demand management measures and ancillary services resources, such as generating stations, can provide the demand response.

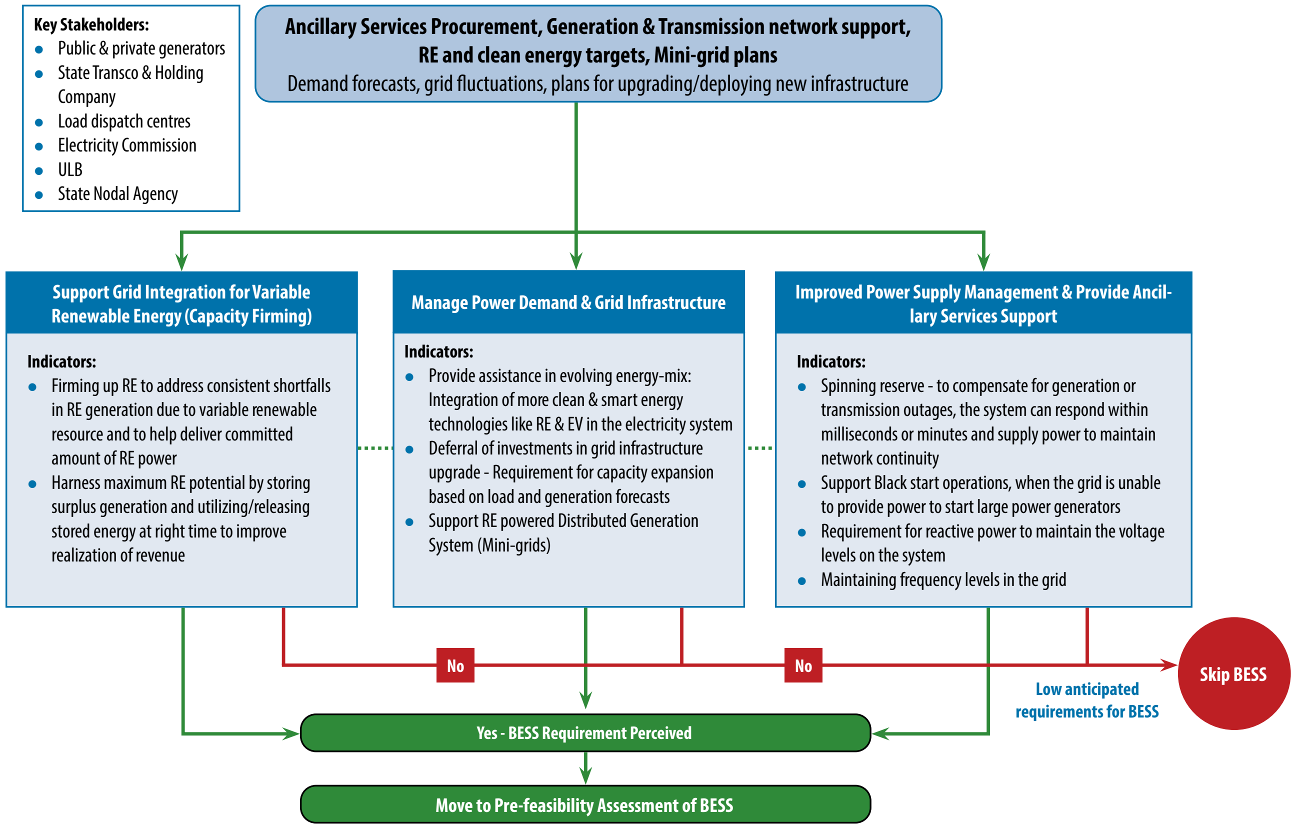



**Figure 17: Decision Chart for Scoping of BESS for Power Generation and Transmission Applications**

| Component | Steps |
|---|---|
| **Understand the baseline scenario** | **Understand the state and city plans and targets for RE, RPO obligations, setting-up mini-grid systems, grid infrastructure upgrade; understand the requirements and market mechanism for procurement of ancillary services**<br><br>**Suggested data points, dependent on data availability**<br>● RE goals and targets – Check the state RE policy, generation companies' (GENCOs) plans for large scale installation of RE system, city RE targets and plans<br>● Setting-up mini-grid systems – State/city policies, DISCOMs or state nodal agency's (SNA) plans and targets for mini-grids<br>● Procurement of ancillary services through BESS – Check NLDC/RLDC plans for procurement and associated compensation and incentives based on performance<br>● Grid Infrastructure upgrade plans– TRANSCOs' plans for capacity expansion based on load and generation forecasts |

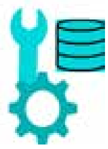
| Component | Steps |
|---|---|
| **Scoping BESS for generation & transmission system applications** | **Identify key opportunities and energy related challenges**<br>Based on the requirements, screen and shortlist a range of services and support functions BESS can provide.<br><br>**Support grid integration for VRE (capacity firming)**<br>● Quantify the generation losses or gaps in the committed quantum of power and associated penalties paid by the generators. Further, analyse the average reserve amount of RE power required to meet commitments and reduce the gap.<br>● Check the restrictions on capacity of RE deployment, RE curtailment and compensations – whether the existing policy limits the capacity, utilization and compensation for RE generation. Further, check if the regulations offer benefits in case RE generation is more than the scheduled generation.<br><br>**Manage the power demand and grid infrastructure**<br>● Changing the energy mix and its impact on grid stability – addition of new loads and variable energy generators in the grid system, leads to increased challenges with regard to ensuring stability and flexibility in the network. On the transmission level, flexibility can come from the ESS's<br>● Requirements of grid infrastructure upgrade – check the monthly load profile of the power transformer (PT); whether the transformer faces congestion or the loading is consistently higher than set thresholds. Further, check for spare capacity to address seasonal variations and demand forecasts of the local region.<br>● Supporting RE powered distributed generation system (mini-grids)- Check state level policies, DISCOM or SNA plans and RE targets, and city budget announcement for setting-up mini-grid systems.<br><br>**Provide ancillary services support**<br>● Check the power quality issues and reactive power requirements - Monitor the voltage and frequency levels. LDC monitors these operations in real-time on the grid. Voltage dips occur with fluctuations in the generation connected loads. Assess the requirements for reactive power to maintain the voltage levels on the system.<br>● Requirements for fast dispatch - Check the fixed schedules for the quantum of power supply and variability in generation. For faster dispatch, load and generation levels are to be more closely matched.<br>● Ascertain reserve management requirements –NLDC estimates requirements for SRAS and TRAS.[52]<br>● System restoration after black-outs - Generators require black start service to restart operations after a black-out event. An on-site auxiliary generator is needed to provide necessary support in case of grid outages.<br>● Requirements for upgradation of transmission grid infrastructure – check the records of overloading/congestion (quantum and duration) in the high-power transformer – to assess the additional capacity required for optimum operation. |

### 9.2.2. DISCOM Load Management at Power Distribution side

DISCOMs, with their ever-complicated local distribution network, have to expand rapidly at times when VRE and EV are given a greater push to meet climate goals, and encounter highly varying load and demand. Addressing the inherent challenges in load management is key to ensuring reliability and quality in power supplied by DISCOMs to the end consumers. Distribution infrastructure such as DTs and feeder stations require optimized load management measures that will also optimize the operational expenditure of the DISCOM. This presents several applications and opportunities for BESS to be deployed as load management asset in FtM by DISCOMs.

#### 9.2.2.1 Key Energy related Opportunities and relevant to BESS

**Support Distribution Load Management**



- **Peak load management:** During peak hours, if the demand is more than the scheduled generation, DISCOMs are forced to secure supply by procuring power at high procurement charges from peaking plants or generating reserves. However, when demand is low during off-peak hours, DISCOMs are forced to procure a minimum amount of power or pay for it to keep generators online, thereby adding to their financial stress. BESS can provide cheaper power during peak demand periods and can be charged with cheaper power during off-peak period, and hence alleviate the strain on local grid and the financial implications for DISCOMs.

- **Demand response:** Responding to inordinate demand conditions has been a major issue for load dispatchers in India, especially in emergency situations due to faults or unplanned events. The availability of fast load responders like BESS provides a necessary remedy for grid controllers in such situations.

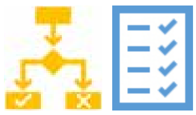
**Provide Ancillary Support**

- **Frequency and voltage regulation:** Availability of BESS, which is an extremely fast responder for power requirements, provides an option to the distribution and transmission system to efficiently regulate its frequency and voltage level, and minimize the risk of equipment failure.
- **Supplement infirm power:** The most popular RE sources such as solar and wind, despite the availability of better forecasting systems, are still unreliable due to their intermittent nature, and BESS can help firm the capacity of RE plants by playing the role of an operating reserve, and supplement RE generation as necessary.

**Assist in Operational Expenditure Management**

- **Energy arbitrage:** BESS provides a business opportunity in terms of the revenue generation and helps in self-sustainability of the DISCOM. DISCOMs can utilize BESS to store energy and trade it subsequently for revenue or use the energy stored for banking purposes with other utilities or users.
- **Minimizing deviation charges/penalties:** DISCOMs are subjected to regulatory penalties and charges due to overdrawal/underdrawal of power due to various reasons. The availability of BESS can help the DISCOM not only avoid these penalties, but ably serve important customers.
- **Deferral of system upgrade:** BESS helps in peak load management and hence the immediate upgrade of the distribution and transmission system can be deferred, freeing up necessary funds for other upgradation and infrastructure works.

### 9.2.2.2 Decision Tree for scoping of BESS in DISCOM Load Management



In this assessment framework for DISCOM load management, the key opportunities and needs for BESS are discussed. The decision chart provides an outline to support the understanding of the baseline scenario of the DISCOMs and the factors that greatly influence or impact the operation of the DISCOMs in the foreseeable future, and support decisions on gauging applicability and prospecting of BESS.

This decision chart for preliminary scoping of opportunities for BESS in DISCOM operations, starts with the process of understanding the various plans and targets of DISCOMs with respect to its operation, RE integration and AT&C loss reduction. The CapEx plans of a DISCOM, power sector targets such as RPOs, AT&C loss reduction targets, state and local policies on RE and EV, and interaction with DISCOM level stakeholders will help users clearly understand the investment plans of the DISCOMs and the impending challenges they face due to RE and EV proliferation. This will require deploying new technologies and infrastructure or upgrading the existing distribution infrastructure.

Along with baseline assessment, it is important to conduct a preliminary assessment of the relevant policy and regulatory frameworks in the power sector and to collect key information required to do initial qualitative evaluation from relevant stakeholders. Power sector stakeholders at the state level such as the SERC, TRANSCOs, DISCOMs/state electricity board, intra-state generators, SLDC would be able to provide enough data and information for initial screening or evaluation to understand the baseline scenario better.

For example, information such as the range of peak power procurement charges and UI charges paid to the SLDC, and typical load and frequency profiles of power distribution infrastructure for at least one day in each season, would be necessary for a qualitative screening evaluation of the suitability of BESS for specific applications and opportunities pertaining to the key technical and commercial challenges faced by DISCOMs, load management, and operational expenditure of the DISCOM.

Post screening of the baseline scenario of the DISCOM's operations at the city level, the decision framework can be used to conduct a qualitative evaluation of three opportunities and requirements for BESS:

- Support distribution load management
- Provide ancillary support
- Assist in operational expenditure management

The evaluation is done against specific indicators (refer Figure 18) corresponding to the specific opportunities identified for BESS.

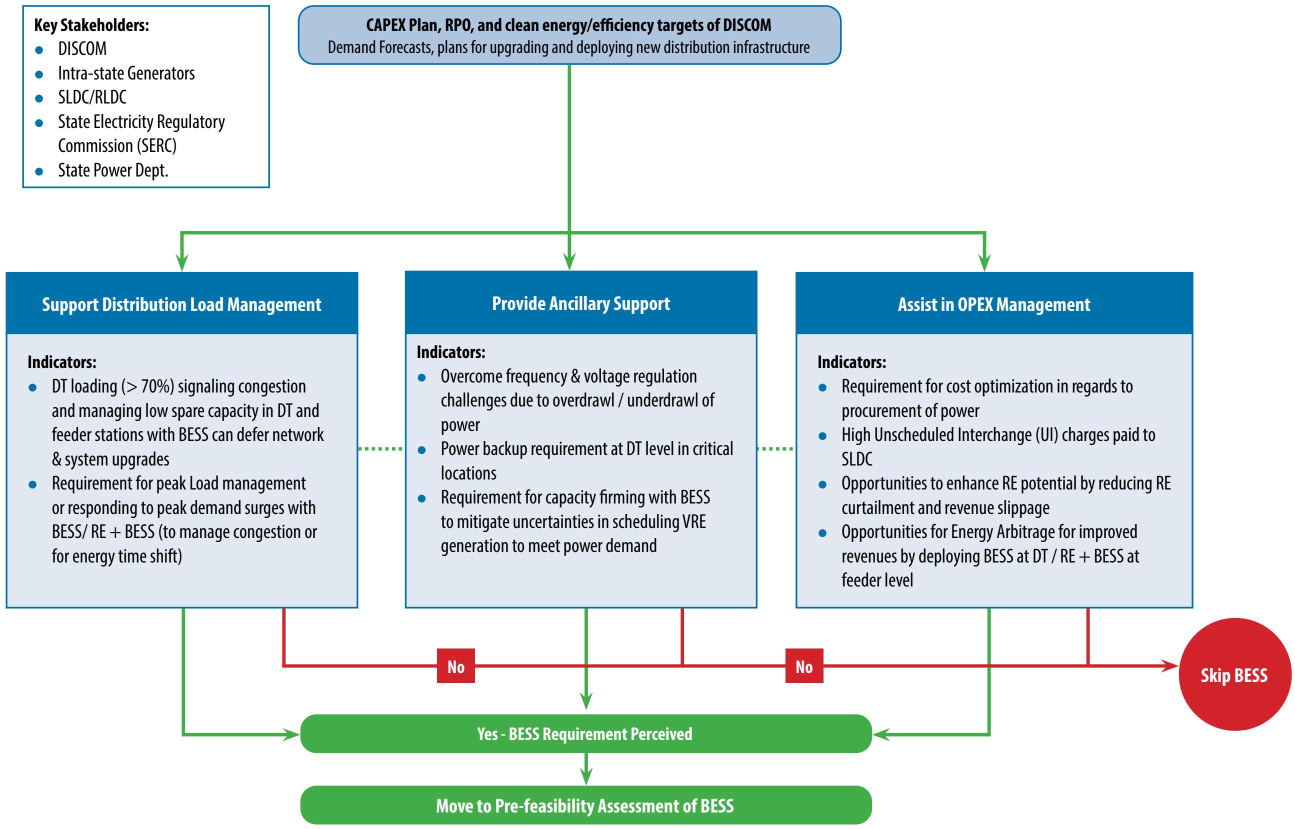



**Figure 18: Decision Chart for scoping of BESS to support Power Distribution Operations**

The three areas of opportunities and requirements depicted in Figure 18 are interlinked, as deploying BESS, for example, to help in frequency regulation will also reduce peak loading or to supplement infirm RE power will help to optimize the operational costs of the DISCOM. Depending on site-specific conditions and the opportunities based on which BESS is sized and deployed, it can meet more than one of these requirements and deliver multiple benefits concurrently. Therefore, opportunities where BESS can potentially cater to multiple requirements have higher prospects for BESS adoption.

If specific opportunities and the scope for BESS to meet the requirement are determined, users can move ahead with pre-feasibility assessment for BESS. However, if the requirement for BESS is not perceived, other load and demand management measures such as upgradation of distribution transformers and network capacity or local RE installation can be looked at instead of BESS.

| Component | Steps |
|---|---|
| **Understand the baseline scenario** | **Identify the local DISCOMs' plans and targets**<br>Through the CapEx plans of the DISCOM and stakeholder interactions, understand the current and planned distribution infrastructure and RE-related development plans of the DISCOM<br><br>Take cognizance of any targets set at the state or national level on operational efficiency and on transitioning to a clean energy-based power mix<br><br>**Suggested data points, dependent on data availability**<br>● What is the current level of AT&C losses reported by the DISCOM for the local grid? Are there any specific plans or targets to improve efficiency?<br>● What is the RPO target of the DISCOM? Status of RPOs and plans for RE system installation or procurement from GENCOs |

| Component | Steps |
|---|---|
| | **Future scenario for RE and EV in the city, and requirement of utility scale BESS at FtM**<br>● Identify any assessments/pilot projects undertaken by DISCOM for BESS deployment to support its operations<br>● Information on RE and EV trends/targets of the city that can potentially impact the grid stability and DISCOM operations in the future, which can be supported by BESS<br>● Information on large-scale developments in the city such as new commercial areas, residential neighbourhoods and expansion/improvement of infrastructure, leading to significant increase in power demand that can burden the local distribution network and require infrastructure upgrade. |
| **Scoping of BESS for applications in EV charging infrastructure** | **Identify key opportunities and energy related needs**<br><br>**Distribution Load Management**<br>● Based on the daily and monthly load profile of DTs or feeder stations, check if they face congestion or if the peak demand[53] loading is consistently higher than set thresholds; identify and prioritize the infrastructure that are due for upgrade<br>● Collect information on spare capacity of DT/feeder station available at all times, considering seasonal variations in the power demand, and the demand forecasts of the local region by the DISCOM<br>● Check if RE + BESS or standalone BESS can be explored as a potential solution for enhancing efficiency of DT/feeder station and the capacity available with it, especially when there are challenges due to space constraints, requirement of spare capacity at the infrastructure being critical.<br><br>**Provide Ancillary Support**<br>● Identify the challenges faced in maintaining frequency and voltage levels within set thresholds. Collect daily and monthly frequency and voltage profile of specific DTs/feeder stations<br>● Identify the critical distribution nodes and requirement of significant hours of power backup to ensure grid reliability at critical distribution nodes<br>● Evaluate the energy and fuel cost associated with DG (power backup), and deduce the operational cost of DG (in INR/kWh)<br><br>**Assist in Operational Expenditure Management**<br>● Evaluate the current applicable peak-demand tariffs and the average monthly deviation from scheduled load (in MWh)<br>● Calculate the monthly average of unscheduled power purchased and the cost paid to procure the unscheduled power from short-term markets<br>● Evaluate the average monthly deviation charges paid to the SLDC and RLDC as per current regulations<br>● Identify the applicable differential tariffs such as peak demand tariff rates, ToU charges, and the opportunities for energy arbitrage in different applications such as RE+BESS |

**Supporting Elements and Enablers for BESS adoption in FtM applications – Policy, Regulation and Stakeholder Coordination**

Deploying BESS for FtM applications can be challenging due to the nexus of various regulations and policies at the national, state and local levels with respect to optimizing the power sector, while moving towards a rapid transformation in the energy mix and mobility. However, such applications are critical to scaling-up of the BESS deployment as an energy management asset.

Given the complexity involved in the Indian power system, the national-level regulations and policies should guide state-level stakeholders in developing clear implementation plans, considering the opportunities for BESS at all verticals of the power system. The coordination between a multitude of stakeholders that directly or indirectly impact the operation of a power system is crucial to deploy BESS for optimization of the power system.

State level regulations; and a state level implementation plan for BESS deployment for various applications and value stream, which can be commoditized; mandates, and incentives for generators and transmission companies will support in its large-scale uptake. Consideration in RE policies, RPOs etc. will ensure high penetration for BESS along with helping overcome several challenges related to large-scale grid integration of renewables.

Strategic coordination and communications mechanisms are required to push the adoption of energy storage across the power system value chain. Stakeholder groups including generators, state TRANSCOs, LDCs, Electricity Commission, SNA, DISCOMs and ULBs can jointly explore all potential energy storage needs at the state/city level and subsequently, if the requirements are perceived, the next steps are to select applications, assess feasibility, remove/mitigate barriers and plan deployment in a timely manner.

| | **Enablers and Considerations** |
|---|---|
| **Policy** | ● Consideration for BESS in RE policies, RPOs for DISCOMs, any local mini or micro-grid plans and whether there are any plans for deployment of round-the-clock RE projects<br>● Will DISCOM's RPO be considered if RE-based BESS is procured or deployed?<br>● Ambitious net-zero policy at the city-scale, local RE and EV policies and targets<br>● Has the government notified facilitative measures for BESS (with or without RE) deployment by DISCOM via incentives/ financial support in gazette or through any scheme?<br>● Is there any revenue framework set for tariff calculation, incentives etc. for BESS developers?<br>● Check state/city's policies and plans for deployment of BESS for generation and transmission systems (targets and incentives for deployment) |
| **Regulation** | ● Regulations on participation of BESS in the ancillary services market (Ex: CERC Ancillary Services Regulations 2022 allowing BESS to provide SRAS and TRAS)<br>● What are the regulations with respect to DISCOMs deviating from scheduled drawal of power from the GENCOs? (Ex: CERC Regulations on Deviation Settlement Mechanism 2022 making deviation charges dependent on cost of bringing AS onboard for stabilizing the grid)<br>● Are there regulations in place for all potential revenue streams for BESS with respect to DISCOM?<br>● Are there technical and operational guidelines in place for safe installation and operation of BESS?<br>● What, if at all, are the guidelines and mechanisms for promoting and ensuring safety standards for BESS technologies at the local level?[54] If not, are nationally or state approved guidelines for such procedures being recommended?<br>● Are regulations and a plan in place or approved for decommissioning and safe disposal of BESS at the end-of-life?[55]<br>● Aggregation of distributed RE and energy storage projects at the substation level can improve the reliability of VRE generation from distributed systems and enable faster adoption of ESS's. Is such aggregation facilitated via regulations?<br>● Promotion of BESS can be facilitated through multi-year tariff regulations which can provide avenue to DISCOM/ TRANSCO to incorporate such interventions<br>● Are there regulations (at state level) in place for setting up fair valuation for BESS? Is the tariff announced/special tariff offered for charging BESS?<br>● Is the grid interconnection approval process (state level) for ESS's framed? |
| **Stakeholder coordination** | ● Is a coordination mechanism set up and functioning for generators, transmission companies, DISCOMS, SNA, SERC, load dispatch centres – NLDC, SLDC, RLDC etc.?<br>● Are there communication mechanisms in place for coordination between local stakeholders regarding planning and sharing of data with respect to the deployment of BESS at the city level, especially between the ULB and DISCOM?<br>● Are processes encompassing permissions and regulations for BESS deployment and operation discussed among stakeholders and streamlined?<br>● Is the DISCOM responsible for all activities or does it need permissions from some other authority?<br>● DISCOM to communicate installation data/operation data to designated agency<br>● Chief Electrical Inspector to approve the design of BESS systems. |

# 10. Cost Analysis and Evaluating Preliminary Feasibility for BESS Use-cases

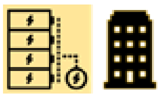
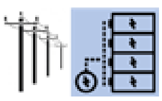
In the Indian context, BESS deployments have predominantly been in large grid-scale facilities and pilot-scale projects primarily undertaken by DISCOMs to assess the complex technical implications, financial requirements and benefits accrued. At the urban level, BESS deployment or its scale-up would involve a multitude of relevant stakeholders from both the urban sector and the power sector. Therefore, it is important for stakeholders to understand the various use-cases and opportunities for BESS deployment during the concept phase of a project aimed at deploying BESS.

During the concept and development phase of such an initiative, undertaking a prefeasibility assessment to scan a series of options or use-cases and determining the most suitable one for further detailed feasibility study is crucial. A qualitative screening or scoping of the opportunities of various use-cases, using tools such as the Assessment Framework presented in Section 9, can narrow down the options based on the baseline scenario of such use-cases. Subsequently, it is also important to conduct a preliminary feasibility and financial check, to evaluate and identify a suitable technical opportunity of BESS that can be explored further. These will invariably be subjected to a detailed feasibility assessment that would provide the optimal combination of the most suitable technical BESS solution for which financial bankability can be ensured.

## 10.1. Analysis undertaken for BESS Use-cases

In this study, a pre-feasibility level analysis was undertaken across four of the shortlisted BESS use-cases (see Table 5). The intent of this analysis was to evaluate the preliminary feasibility of BESS deployment in a use-case by comparing the total costs of ownership (TCO) for the baseline (without BESS) against TCO with implementation of BESS in each use-case. The TCO analysis accounts for prevalent capital and operational costs over the period of the service of BESS. The TCO analysis was carried out for different scenarios, and primarily looked at different combinations of grid-based power, RE and BESS deployment. The analysis has been carried out by using use-case specific data templates and excel spreadsheet tools developed for 3 BtM and 1 FtM use-cases. As this study is focused on urban areas of Rajkot and Surat, the analysis was carried out for four shortlisted BESS use-cases relevant to the local context. Given the absence of large generators in both cities and resulting limited access in procuring local data, an analysis for the use-case of deploying BESS for generation and transmission was not carried out.

**Table 5: Use-cases included in the Cost and Pre-feasibility Analysis for Rajkot and Surat**

| |
|---|
|  **BtM applications** |
| **EV charging infrastructure management**<br>● BESS for a mid-scale commercial EV charging station<br>● BESS for a large-scale e-bus charging station |
| **End-use consumers (Commercial, institutional, industrial and residential)**<br>● BESS for a large-scale hotel<br>● BESS for a mid-scale hospital |
| **Municipal utilities and services**<br>● BESS for a water pumping station |
|  **FtM applications** |
| **DISCOM load management**<br>● BESS for distribution transformer load management and deferral of upgrade |

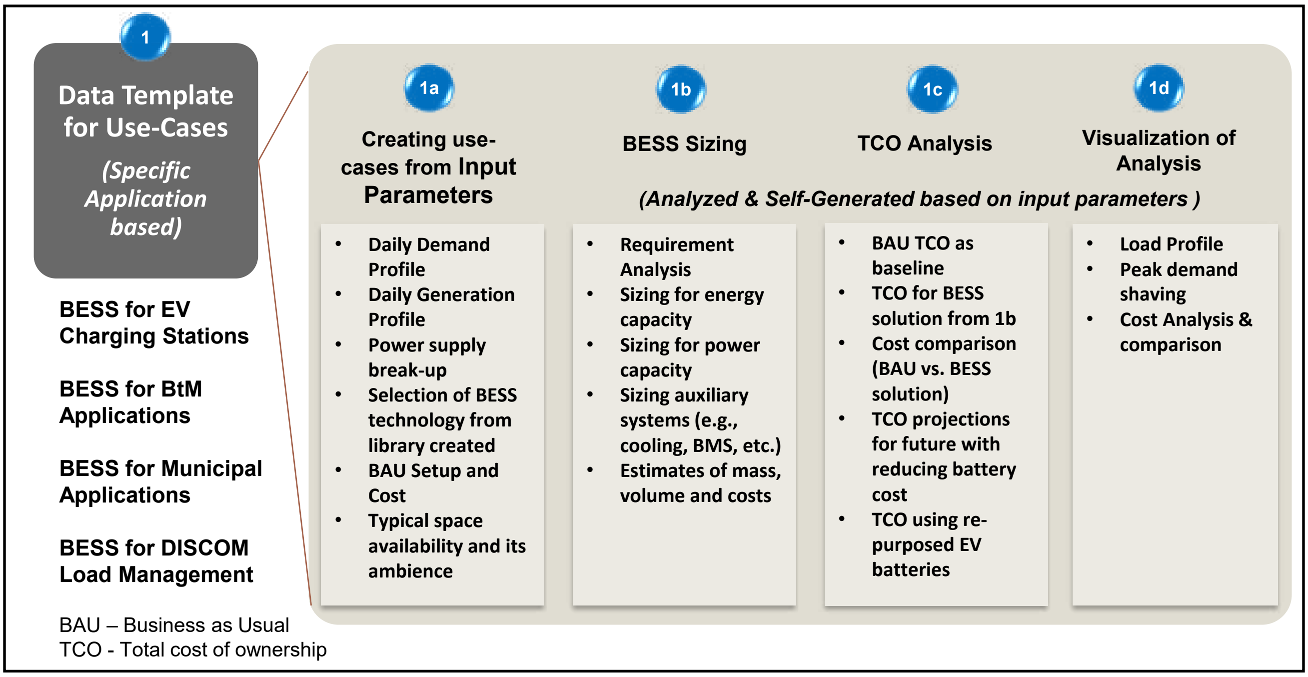



**Figure 19: Technical Approach of Use-Case Analysis Using Excel Tool Developed**

The technical approach of the analysis, based on an excel spreadsheet tool, is depicted in Figure 19.

- **Input parameters: T**he spreadsheet analysis tool builds a use-case for assessment based on an input parameters module, which sets the required boundary conditions, including the cost and technical parameters for developing the business-as-usual (BAU) case through inputs fed-in by the user. This module is also used to build various scenarios for analysis against the BAU by using different input parameters that can conduct the iterations based on user inputs.
- **BESS sizing:** The input module is directly linked to a BESS sizing module within the tool, that can estimate BESS sizing, specifications, and the system costs, based on a library of Li-ion BESS modules offered by select manufacturers (with specifications primarily sourced from product datasheets).
- **TCO analysis:** This is based on the outcomes of the two modules from which the cost values and technical parameters for all different scenarios are derived. Apart from undertaking TCO analysis for various scenarios for each use-case, a sensitivity analysis was undertaken to understand the impact of future variations in the cost components such as battery costs and energy costs on the TCO. Existing power costs and demand charges have been sourced from GERC tariff order for relevant DISCOMs in Surat and Rajkot.

For these analyses, the data and information required as per the data templates were sought from relevant local stakeholders, specifically SMC, RMC and a local DISCOM. Potential site or location to identify primary requirements that BESS could serve, energy related data including monthly electricity consumption and bills, contracted load, daily operational and power demand patterns, daily load, power factor and frequency profiles, specifications of RE systems, and backup power on-site, were among the data and information gathered from the stakeholders. Any data gaps such as daily load profiles and RE generation have been plugged by using representative data and assumptions from secondary sources.

The TCO analysis conducted provides a metric to allow for the comparison of capital and operational costs for various scenarios across use-cases incurred over the service life of BESS. It is to be noted that the analysis does not include parameters needed for a more detailed financial analysis such as financing and discount considerations, future replacement or degradation costs, recovery of cost from battery disposal, among others. When performing a detailed feasibility study, the financial analysis should also include a detailed cost-benefit analysis that takes into consideration all the monetary and technical benefits in deploying BESS, especially from multiple revenue streams possible when a particular use-case is assessed. This is required to arrive at a more accurate optimization of the technical solution and financial bankability.

A summary of the outcomes for the technical analyses is presented below.

## Outcomes of TCO analysis – Understanding feasibility for BESS deployment

As noted in the section above, a preliminary feasibility analysis for BESS deployment for four use-cases (3 BtM and 1 FtM) was done by comparing the TCO for the BAU case (without BESS) against TCO with implementation of BESS in each use-case. The analysis was carried out for multiple end-uses in some use-cases (such as mid-scale commercial EV charging station, public e-bus charging station, hospital and hotel) to further understand the impact of scalability on feasibility for BESS implementation. Additionally, sensitivity analysis was done to correlate the impact of reduction in BESS costs and increasing energy costs on the feasibility of BESS deployment.

- As deduced from the analysis, BESS is technically a viable solution to reduce the peak demand of the facilities and for power factor correction. It also helps maximize the self-consumption from RE generation and provides reliable power-backup during grid outages. BESS deployed along with RE in BtM applications such as EV charging, commercial and industrial facilities, and municipal utilities also reduces the loading of the local DT, thus, deferring the requirements for augmentation to certain extent and providing co-benefits to DISCOMs.
- A cross-comparison of TCO analysis for BtM applications indicates that large facilities with high load demands such as industrial units, large hotels and municipal facilities are likely to benefit more with BESS implementation. Such consumers commonly face challenges with peak load management and low power factor, and hence BESS is likely to become feasible sooner for such cases as compared to consumers with low to medium load demand.
- RE plays an important role in improving the viability of BESS in end-uses with large demand. As the cost of BESS is expected to decline significantly in future as energy costs from the grid will increase, the feasibility of BESS coupled with RE systems will improve. It was observed that RE in the gross-metering model further improves viability of BESS coupled systems as compared to the net-metering model (comparison reflected in the table below). In a future scenario, the TCO for a case where BESS is deployed with RE (gross-metering) comes at par with the TCO for BAU.

| Comparison of TCO (average difference for all BtM use-cases) | |
|---|---|
| **BESS deployed with net-metered RE and grid supply vs. BAU/ Base case** | **BESS deployed with gross-metered RE and grid supply vs. BAU/Base case** |
| • Current scenario: +18.4% | • Current scenario: +16.1% |
| • Future scenario: +9.2% | • Future scenario: +5.4% |

- From the FtM use-case analysis, BESS deployment for load management at DT level was assessed against BAU scenario of upgrading or deploying new DT based on their respective annualized cost of deployment. It was evident from the analysis that deploying BESS's primarily load shaving application was viable only when the peak loading occurs for shorter intervals and requires only low load-shaving requirements or demand.
- BESS deployed at the distribution scale can be utilized to cater to multiple applications. Evaluating benefits from the multiple value streams delivered by BESS is important and can help improve viability.
- Electricity tariffs and peak demand charges in Gujarat are relatively lower as compared to other states. The viability of BESS deployed with the RE system would improve, and the total cost of operations would be significantly lower and closer/at par with baseline costs for states where the power and fixed charges are higher (such as Uttar Pradesh, Rajasthan) as compared to grid power charges currently applicable in Gujarat.
- By using repurposed batteries, the viability of BESS improves significantly. The analysis shows that BESS deployed with re-purposed batteries and the RE system has a relatively lower cost of operations than the base case. However, a market is likely to be developed in future, where existing EV batteries will be retired at the end of first-life and a regulatory regime for re-purposing those batteries would be in place.

The following sections include the TCO analysis, comparison and estimates of BESS sizing for the energy requirements, key findings and recommendations for each use-case.

## 10.2. BESS for Electric Vehicle Charging Infrastructure Management

Based on the expected utilization, target vehicle segment and location, EV charging stations include commercial space charging and public fast charging, among others. The non-linear nature of charging of EVs, especially during the peak demand periods, puts a burden of high energy bills on the station operators and increases stress on the distribution grid. Cost analysis has been undertaken for BESS deployment for a medium-scale e-car charging station and a large e-bus public charging station.

For the analysis, site parameters such as power consumption profile (load profile) and power supply mix (energy consumption from the grid and captive RE plants) were developed based on the operational patterns of the charging stations and intent to integrate RE systems such as solar PV in the two project cities.

The tariff and demand charge values considered for the analysis are obtained from the tariff schedules released by GERC for FY 2022-23 for the consumers of the distribution licensees in Gujarat.[56]

Preliminary feasibility of BESS is assessed with regard to the potential benefits such as peak shaving and maximizing RE utilization.

### 10.2.1. Use-case #1 – BESS for a Medium-scale Commercial Electric Vehicle Charging Station

**Site details**

The case considers an EV charging station with five Type-2 EV chargers, with day-time and night-time operations. The power and energy requirements for the site along with a representative daily load profile (developed based on the charging requirements) are presented below. A solar PV system of 40 kW is considered to be deployed on-site and meets 5% of the total energy requirements.

**Site details and input parameters: Commercial EV charging station**

| | |
|---|---|
| Chargers | 5 x type 2 EV chargers (each of 60 kW capacity) |
| Sanctioned load | 300 kVA |
| Average load | 145 kW |
| Maximum load | 270 kW |
| Daily energy requirements | 3,489 kWh |
| Charging requirements | Day operation from 6-8 AM and 4:30 – 10 PM. Night operation from 10 PM – 6 AM |
| Power supply | 100% grid |

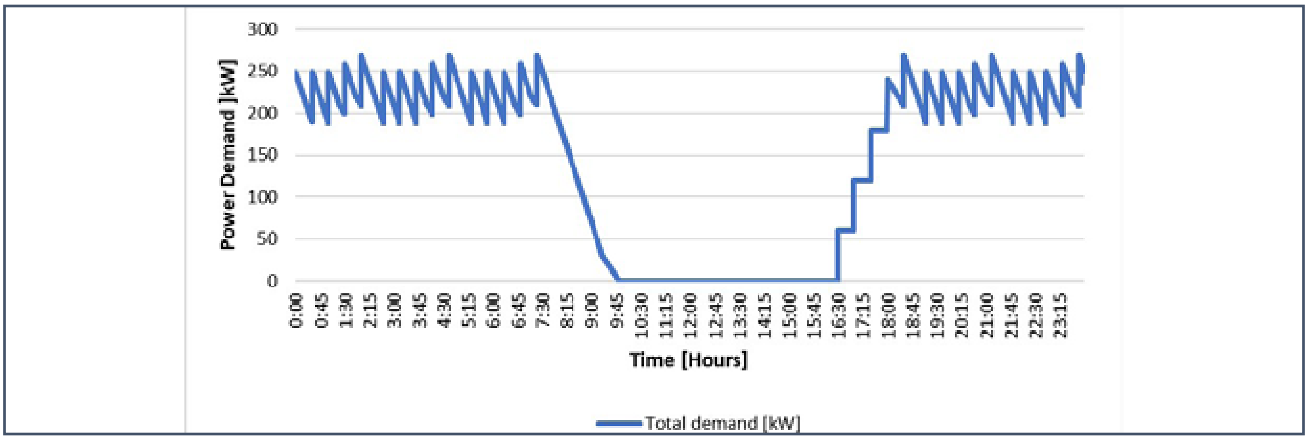



**Figure 20: Power Demand of the Electric Car Charging Station**

**BESS Requirement and Sizing**

**Key objective of BESS deployment:** BESS is intended to reduce the peak demand by 20%, curtailing the load from 270 kW to 216 kW. It will thereby offer savings in energy bills to the charging station operator.

| | |
|---|---|
| Peak shaving target | 20% |
| Energy storage requirement from BESS | 190 kWh |
| BESS charging source | Primarily through the captive RE plant and supple-mented with grid power as necessary |
| BESS design capacity | 491 kWh/319 kW |

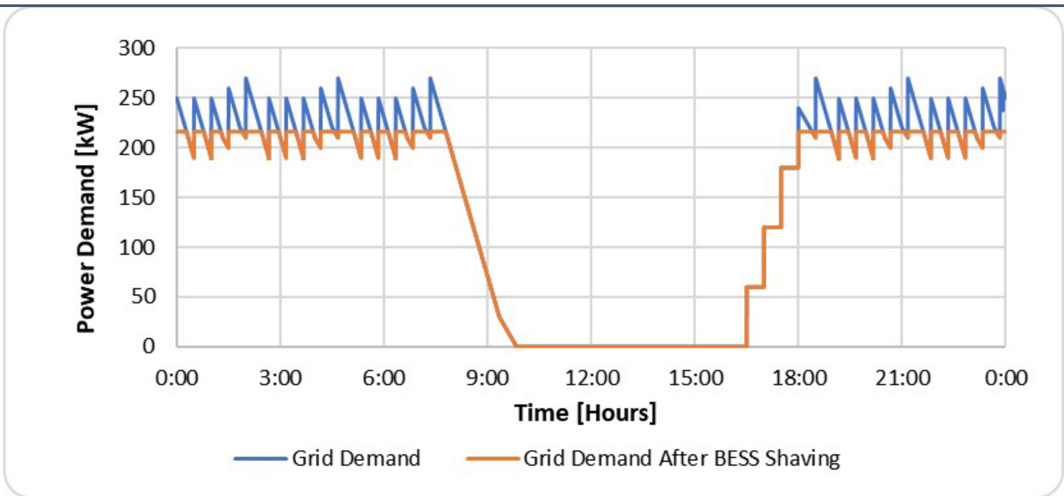



**Figure 21: Potential Load Shaving achieved with BESS Deployment**

**Cost Analysis**

The purpose of the analysis is to understand and compare the estimate of the cost of operations (energy related) of using BESS as against the base-case without BESS. The cases are based on different combinations of energy mix for the EV charging station and BESS. Analysis was undertaken for four cases as listed below:

- BAU case: 100% grid supply
- Case I: Grid + BESS
- Case II: 95% grid supply + 5% RE supply (with net-metering) + BESS
- Case III: 95% grid supply + 5% RE supply (with gross-metering) + BESS

Additionally, the four cases have been assessed for different scenarios to understand the impact of increasing power costs and decreasing capital costs of BESS, as anticipated in the future:

- Base scenario: Considering current cost of BESS and applicable energy charges
- Future scenario: With estimated projections for cost of BESS and energy cost after 5 years

(Refer to "Assumptions" below for more details on scenarios)

| Total cost of operations (INR/kWh) | BAU Case | Case I | Case II | Case III |
|---|---|---|---|---|
| Base scenario | 4.07 | 5.04 | 4.83 | 4.98 |
| Future scenario | 4.96 | 5.62 | 5.41 | 5.46 |

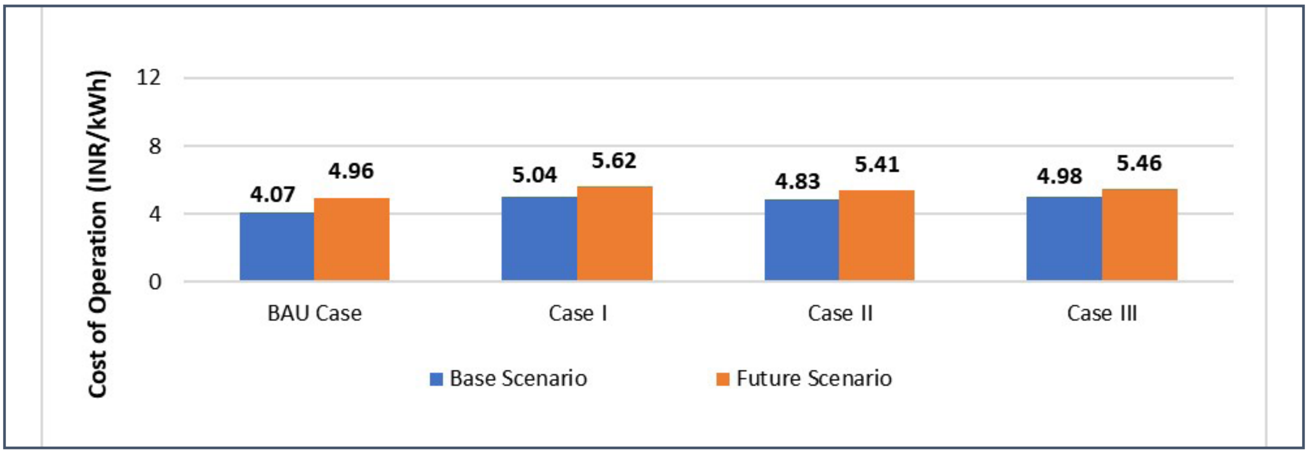



**Figure 22: Comparison of Operational Costs in Baseline against BESS Deployment Cases**

### Results and Findings of Cost Analysis

- **Impact of introducing BESS on total cost of operations** –In case of base scenario, with Grid + BESS (Case I), the cost of operations increases by 23.8% as compared to the BAU case. In the future scenario, the cost of operations with BESS deployment converges with the BAU across all cases with BESS deployment due to reducing capital costs of BESS and increasing grid energy costs in the future. In the future scenario, TCO in Case I is higher by 13.3% as compared to the BAU.

- **RE system optimizes the cost of operations** – Deploying BESS along with on-site RE system reduces the cost of operations when compared to only Grid + BESS (Case I), as RE is used to charge BESS which effectively displaces 5% of grid consumption. This is observed in both types of metering arrangements for RE i.e., net-metering (Case II) and gross-metering (Case III). However, the TCO remains higher as compared to the BAU case because of the high capital cost of BESS.

**BESS Cost Estimates**

| | |
|---|---|
| Capital cost of BESS (Existing scenario) | ₹85.4 Lakhs |
| Capital cost of BESS (Future scenario) | ₹67.2 Lakhs |

**Feasibility for BESS**

| BESS for commercial EV charging station | For Surat and Rajkot |
|---|---|
| Savings in energy bill | Implementation of BESS reduces peak load of the charging station. However, it increases the cost of operations in both exist-ing and future scenarios due to the high cost of technology. |
| Maximizing RE utilization | An on-site captive RE plant optimizes the operations of the charging station. It provides charging to the BESS as well as re-duces energy requirements from the grid. |

## Key Findings

**BESS is a technically viable solution to reduce the peak demand of the EV charging station. However, the TCO incurred on integrating BESS is higher than that in BAU case.**

**Assumptions**

| Parameters | Base scenario | Future scenario |
|---|---|---|
| Grid shaving target | 20% | 20% |
| Cost per unit energy capacity (USD/ kWh)[57] | 220 | 173 |
| RE Capacity (kW) | 40 | 40 |
| Power cost (INR/kWh) (excludes taxes and surcharges)[58] | 4 | 4.87 (assuming escalation of 5% per year) |
| Demand charge (INR/KVA) | 25 | 30.42 (assuming escalation of 5% per year) |
| RE per unit generation cost (INR/kWh) | 3.5 | 3.5 |

**BESS Technical Specifications**

The specifications of the BESS module considered for the analysis are as follows:

| | |
|---|---|
| BESS technology | Li-ion LFP liquid cooled |
| Battery DoD | 100% |
| Acceptable battery degradation | 80% |
| Nominal voltage [V] | 25.6 |
| Number of cells in series | 8 |
| Number of cells in parallel | 2 |
| Unit cell voltage [V] | 3.20 |
| Nominal charge capacity [Ah] | 200 |
| Nominal energy capacity [kWh] | 5.1 |
| 1-C current [A] | 200 |
| Max continuous charge C-Rate [1/hr] | 0.65 |
| Max continuous discharge C-Rate [1/hr] | 0.65 |
| Life @ 1C, 25°C, 100% DoD and 80% residual capacity [Cycles] | 6000 |

### 10.2.2. Use-case #2 – BESS for a High-power Electric Bus Charging Station

**Site details**

A representative load profile for an e-bus charging station was developed, taking into consideration that the station holds 12 DC fast charges of capacity 180 kW, maximum load considered is 3,003 kW and the average load is 1,281 kW, while the average daily energy requirement is 29,246 kWh. The installed RE capacity at the site in the existing scenario is envisaged as 325 kW, which meets 5% of the total energy requirements.

**Site details and input parameters: Commercial EV charging station for e-bus**

| | |
|---|---|
| Chargers | DC fast chargers (12 chargers each of 180 kW capaci-ty) |
| Sanctioned load | 3,100 kVA |
| Average load | 1,281 kW |
| Maximum load | 3,003 KW |
| Daily energy requirements | 29,246 kWh |
| Charging requirements | Day operation from 11:30 AM - 3:30 PM; Night op-eration from 9:30 PM – 5:00 AM |
| Power supply | 100% grid |

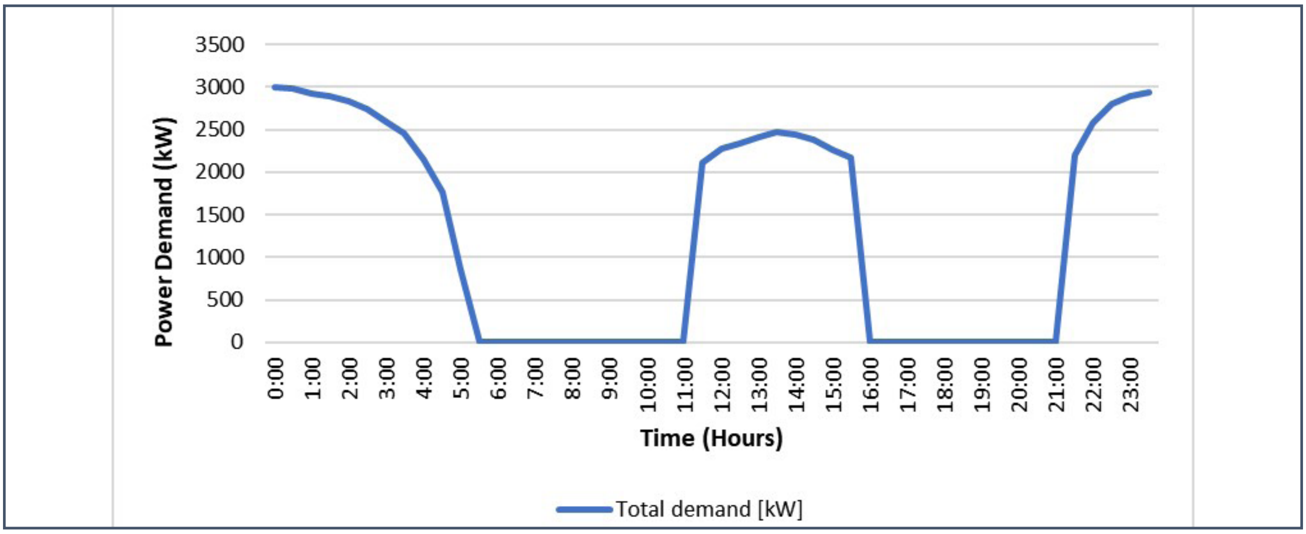



**Figure 23: Power Demand of the Electric Bus Charging Station**

### BESS Requirement and Sizing

Key objective of BESS deployment: BESS is intended to reduce the peak demand by 20%, curtailing the load from 3,003 kW to 2,402 kW. The charging station operator will thereby realize savings in energy bills and maximize captive RE utilization by storing the surplus RE generation during the day and supplying the RE during peak demand intervals.

| | |
|---|---|
| Peak shaving target | 20% |
| Energy storage requirement from BESS | 3,300 kWh |
| BESS charging source | Primarily through the captive RE plant and supplemented with grid power as necessary |
| BESS technology | Li-ion LFP liquid cooled |
| BESS design capacity | 4,751 kWh/3,088 kW |

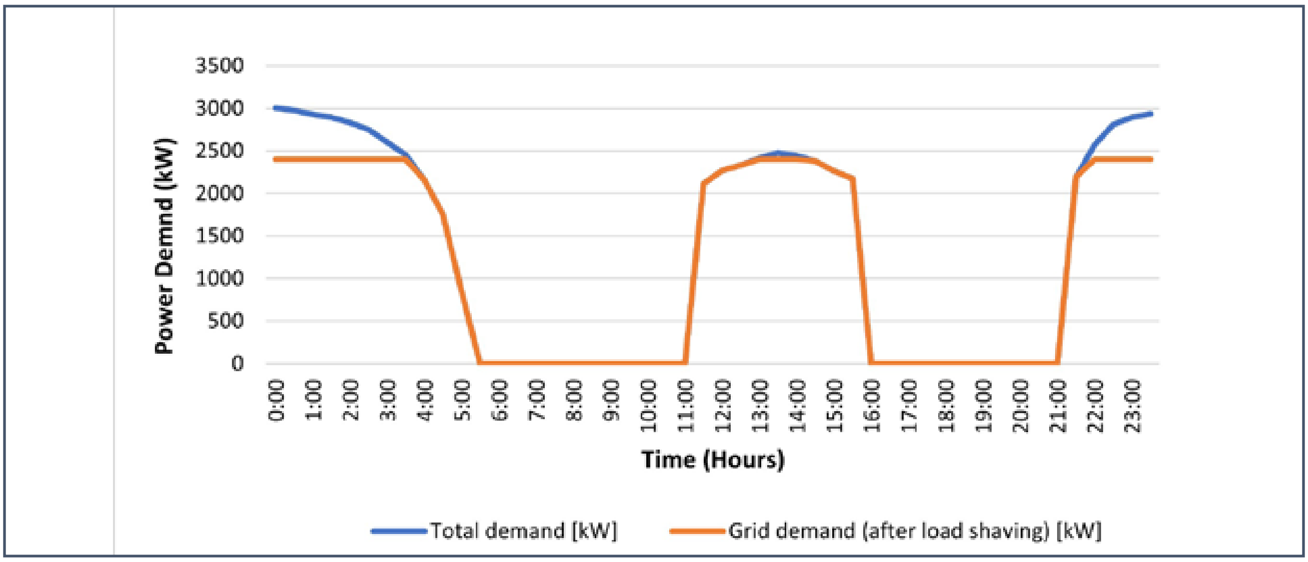



**Figure 24: Potential Load Shaving achieved with BESS Deployment**

### Cost Analysis

The purpose of the analysis is to understand and compare the estimate of the cost of operations (energy related) for using BESS as against the base-case without BESS. The cases are based on different combinations of the energy mix for the EV charging station and BESS. The analysis was undertaken for four cases as listed below:

- BAU case: 100% grid supply
- Case I: Grid + BESS
- Case II: 95% grid supply + 5% RE supply (with net-metering) + BESS (for base and future scenario 1)
- Case III: 95% grid supply + 5% RE supply (with gross-metering) + BESS (for base and future scenario 1)

Additionally, the four cases have been assessed for different scenarios to understand the impact of increasing energy costs and decreasing capital costs of BESS, as anticipated in the future:

- Base scenario: Considering current cost of BESS and applicable energy charges
- Future scenario 1: With estimated projections for cost of BESS and energy cost after 5 years
- Future scenario 2 (with RE supply increased to 10% instead of 5%): 90% grid supply + 10% RE supply + BESS deployment in Case II and Case III (with estimated projections for cost of BESS and energy cost after 5 years)

(Refer to "Assumptions" below for more details on scenarios)

| Total cost of operations (INR/kWh) | BAU case | Case I | Case II | Case III |
|---|---|---|---|---|
| Base scenario | 4.10 | 5.16 | 4.96 | 5.10 |
| Future scenario 1 | 4.99 | 5.69 | 5.49 | 5.54 |
| Future scenario 2 | 4.99 | 5.69 | 5.28 | 5.39 |

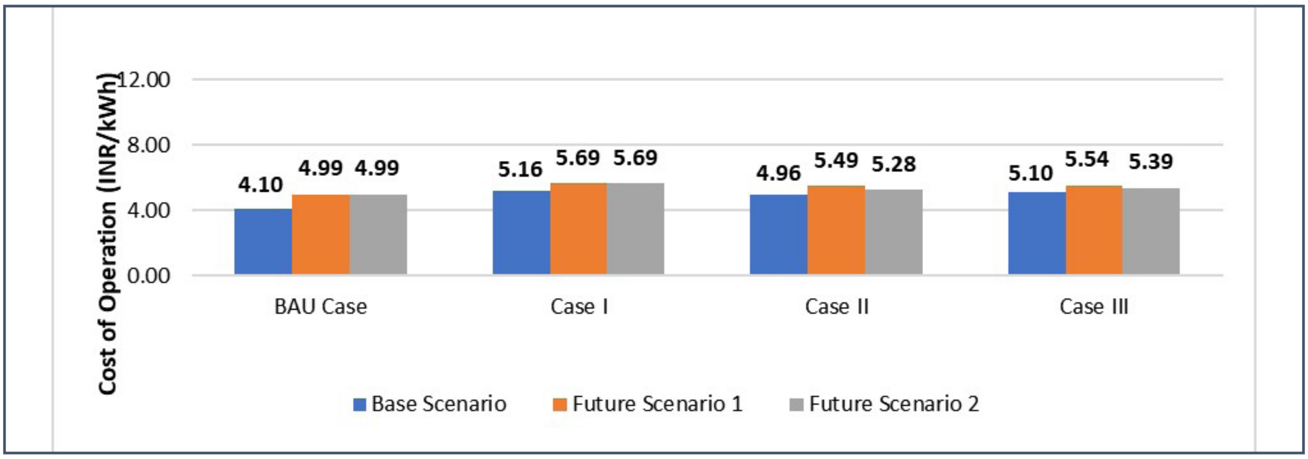



**Figure 25: Comparison of Operational Costs in Baseline against BESS Deployment Cases**

### Findings and Results of Cost Analysis

- **Impact of introducing BESS on total cost of operations** – In the base scenario, the TCO increases by 26% for deployment of BESS with 100% grid supply (Case I) as compared to BAU. In the future scenario, the TCO for Case I is 14% higher in comparison to BAU, given lower capital costs of BESS and rising grid energy costs.
- **RE system optimizes the cost of operations** – Deploying BESS in conjunction with on-site RE system reduces the TCO when compared to only Grid + BESS (Case I), with a relatively lower difference to the TCO in the BAU case. This is observed for net-metered RE (Case II) as well as gross-metered RE (Case III). However, the TCO remains higher as compared to the BAU case because of the high capital cost of BESS.
- **Increasing the RE contribution in the energy mix (future scenario 2)** – Based on future costs, deploying BESS with a higher RE capacity makes the TCO fall further as seen in Case II and Case III, moving significantly closer to the BAU costs. Integrating a higher RE capacity, while recommended, should be evaluated based on site parameters such as land availability and budget.

#### BESS Cost Estimates

| | |
|---|---|
| Capital cost of BESS (existing scenario) | ₹825.8 Lakhs |
| Capital cost of BESS (future scenario 1) | ₹649.36 Lakhs |

#### Feasibility for BESS

| BESS for commercial EV charging station for e-bus | For Surat and Rajkot |
|---|---|
| Savings in energy bill | Implementation of BESS reduces peak load and grid consumption of the charging station. However, the cost of operations is observed to increase in both existing and future scenarios, due to the high cost of technology. |
| Maximizing RE utilization | An on-site captive RE plant optimizes the operations of the charging station, providing charging to the BESS as well as reducing grid energy consumption. |

### Key Findings

**The viability of BESS increases with higher RE proportion in the power-mix. BESS helps reduce the peak demand of the large EV charging station along with maximizing the utilization of RE. However, the TCO of BESS integrated system remains higher than that in the base case without BESS.**

#### Assumptions

| Parameters | Base scenario | Future scenario 1 | Future scenario 2 |
|---|---|---|---|
| Grid shaving target | 20% | 20% | 20% |
| Cost per unit energy capacity[59] (USD/ kWh) | 220 | 173 | 173 |
| RE Capacity (kW) | 325 | 325 | 650 |
| Power cost[60] (INR/kWh) (excludes taxes and surcharges) | 4 | 4.87 | 4.87 |
| Demand charge (INR/KVA) | 25 | 30.42 | 30.42 |
| RE per unit generation cost (INR/kWh) | 3.5 | 3.5 | 3.5 |

#### BESS Technical Specifications

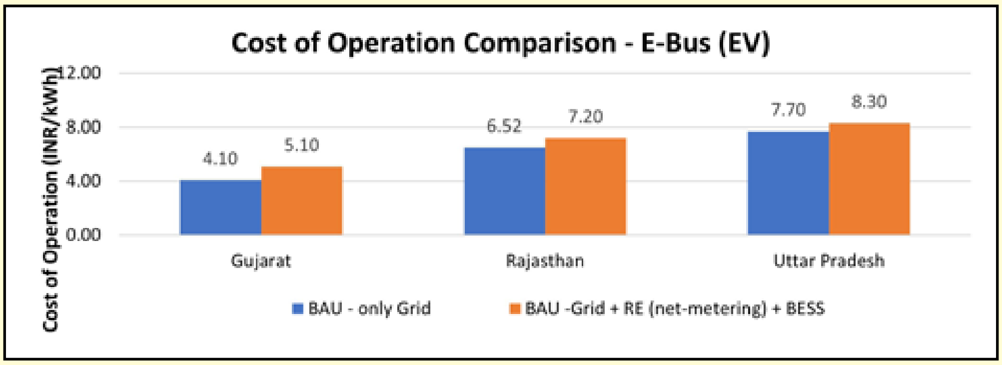
The specifications of the BESS module considered for the analysis are as follows:

| | |
|---|---|
| BESS technology | Li-Ion LFP Liquid Cooled |
| Battery DoD | 100% |
| Acceptable battery degradation | 80% |
| Nominal voltage [V] | 25.6 |
| Number of cells in series | 8 |
| Number of cells in parallel | 2 |
| Unit cell voltage [V] | 3.20 |
| Nominal charge capacity [Ah] | 200 |
| Nominal energy capacity [kWh] | 5.1 |
| 1-C current [A] | 200 |
| Max continuous charge C-Rate [1/hr] | 0.65 |
| Max continuous discharge C-Rate [1/hr] | 0.65 |
| Life @ 1C, 25°C, 100% DoD and 80% residual capacity [Cycles] | 6,000 |

## Prospects of BESS Implementation for Electric Vehicle Charging Infrastructure Management

To optimally design the system, a captive RE system for BESS charging and running other operations during the day is recommended.

- Other services BESS can provide in addition to load shaving are:
  - → **Power back-up system** – A power back-up system provides required energy in the system at the time of failures/outages.
  - → **Power quality (frequency regulation, total harmonic distortions etc.) –** Frequency regulation ensures balance of electricity supply and demand over seconds/minutes' time frame. BESS can improve frequency excursion and the settling frequency. Minimizing total harmonic distortions (THD) ensures the supply side of AC waveform stays very close to sinusoidal and protects converters and other equipment running on same AC supply. BESS can also help with voltage regulation.
- Electricity tariffs and peak demand charges for EV in Gujarat are relatively lower as compared to other states. The viability of BESS deployed with RE system would improve and the total cost of operations with BESS would be significantly lower and closer/at par with baseline costs for states in which the power and fixed charges are higher (such as Uttar Pradesh, Rajasthan) as compared to grid power charges currently applicable in Gujarat. For illustration, the TCO comparison for an e-bus station (use-case no. 2) for 95% grid + 5% RE with BESS vs the BAU case (only Grid) in the current scenario for Gujarat, Rajasthan and Uttar Pradesh is reflected below, along with the percentage increase:




| State | Percent increase in TCO for 95% grid + 5% RE with BESS case vs BAU |
|---|---|
| Gujarat | 24.3% ↑ |
| Rajasthan | 10.4% ↑ |
| Uttar Pradesh | 7.8%↑ |

- BESS could be a viable option for minimizing the energy bills of EV charging stations with the utilization of repurposed batteries[61] for which the capital cost incurred is about 25% of that of new batteries.[62] Cost analysis with re-purposed batteries and RE system showed the cost of operations to be lower than the BAU case (100% grid). However, a market is likely to be developed in future where the existing EV batteries will be retired at the end of first-life and a regulatory regime for re-purposing those batteries would be in place.

## 10.3. BESS for End-use consumers (Commercial, Institutional, Industrial and Residential)

The primary drivers for customer adoption of BtM BESS are opportunities for peak shaving and demand charge management, power quality management and improvement of energy resilience. Surat and Rajkot are major commercial and industrial hubs. In Rajkot, the commercial and industrial sectors were responsible for over 60% of the city-wide electricity consumption in year 2020-21.[63] The commercial sector accounted for 59% of Surat city's electricity use in the same year. The application of BESS in the commercial and industrial spaces with large power demands in both cities will offer advantages in terms of peak load shaving, savings in electricity costs, increased RE utilization and a reliable power supply.

Cost analysis for BESS deployment has been performed for a mid-size hospital and a large-scale hotel. The input parameters, including the power consumption profile (load profile) were developed based on sample load profiles for a medium-scale hospital and a large hotel located in conditions similar to Rajkot and Surat (retrieved from OpenEI).[64] Preliminary feasibility of BESS is assessed with regard to the potential benefits such as power factor correction, peak shaving, power back-up requirements and maximizing the utilization of RE.

### 10.3.1. Use-case 1 – BESS for a Large-scale Hotel

**Site details**

The maximum and average load of the hotel being considered in the use-case analysis are 2,277 kW and 1,931 kW, respectively. The average daily energy requirement is 46,180 kWh. The installed RE capacity at the site in the existing scenario is considered to be 500 kW.

**Site details and input parameters: Large hotel**

| | |
|---|---|
| Sanctioned load | 2,300 kVA |
| Average load | 1,931 kW |
| Maximum load | 2,277 KW |
| Daily energy requirements | 46,180 kWh |
| Power supply | 100% Grid |
| On-site power backup | • DG of 750 kW<br>• Average power backup requirement of 4 hours per month |

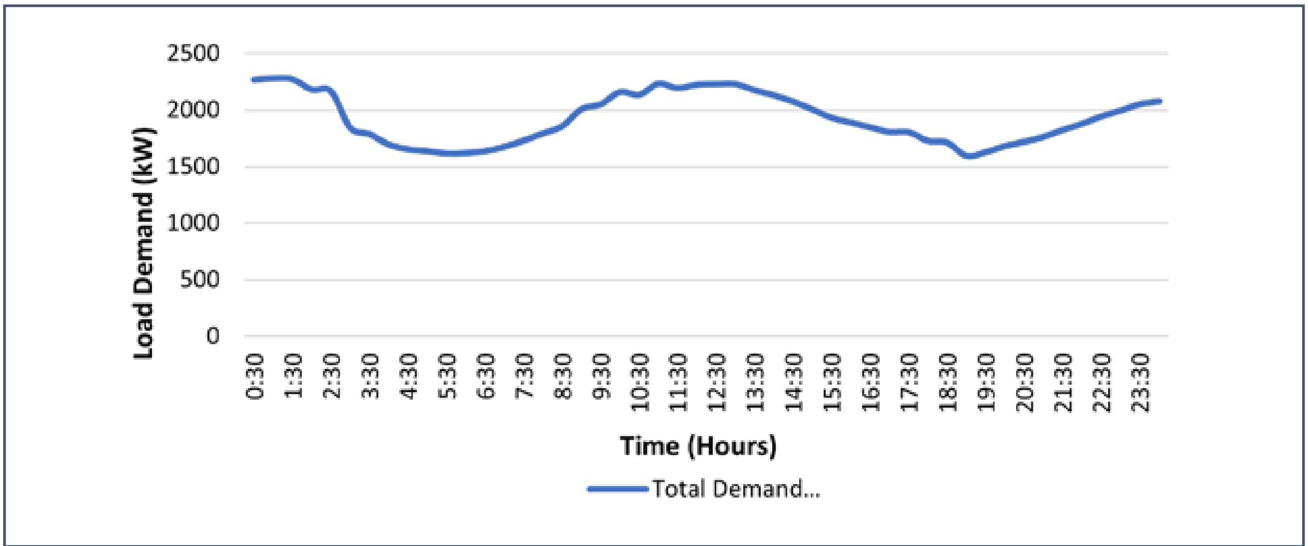



**Figure 26: Load Demand of the Hotel**

### BESS Requirement and Sizing

**Key objective of BESS deployment:** BESS is intended to reduce the peak demand (by 20%), curtailing the load from 2,277 kW to 1,822 kW, and improve the power factor. BESS will thereby offer savings in the energy bills of the hotel, while supporting increased RE self-consumption.

Concurrently, BESS deployed can also provide power back-up for up to four hours on a monthly basis for running loads of capacity > 750 kW.

| | |
|---|---|
| Peak shaving target | 20% |
| Energy storage requirement | 6,033 kW |
| BESS charging source | Primarily through the captive RE plant and supplemented with grid power as necessary |
| BESS design capacity | 7,557 kWh/4,912 kW |

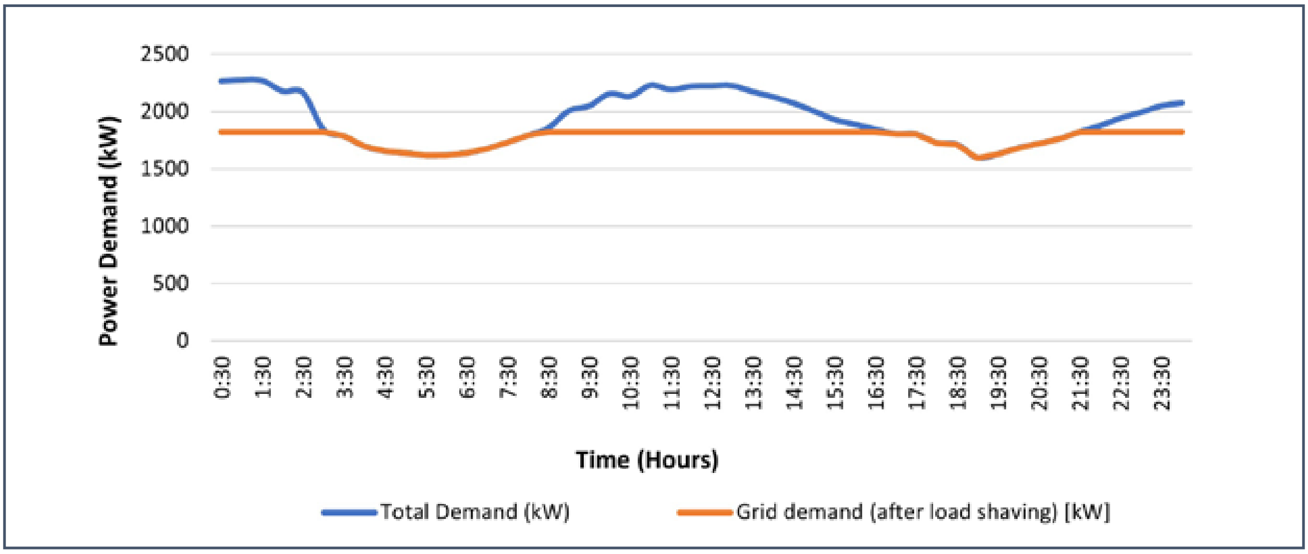



**Figure 27: Potential Load Shaving achieved with BESS Deployment**

### Cost Analysis

The purpose of the analysis is to understand and compare the cost of operations (energy related) estimated with deployment of BESS, as against the base-case without BESS. The cases are based on different combinations of the energy mix for the hotel and BESS. Analysis was undertaken for three cases as listed below:

- BAU case: 100% grid supply
- Case I: 95% grid supply + 5% RE supply (with net-metering) + BESS
- Case II: 95% grid supply + 5% RE supply (with gross-metering) + BESS

Additionally, the three cases have been assessed for different scenarios to understand the impact of increasing energy costs and decreasing capital costs of BESS, as anticipated in the future:

- Base scenario: Considering current cost of BESS and applicable energy charges
- Future scenario: With estimated projections for cost of BESS and energy cost after 5 years

(Refer "Assumptions" below for more details on scenarios)

| Total cost of oper-ations (INR/kWh) | BAU Case | Case I | Case II |
|---|---|---|---|
| Base Scenario | 5.72 | 6.56 | 6.29 |
| Future Scenario | 6.92 | 7.34 | 6.97 |

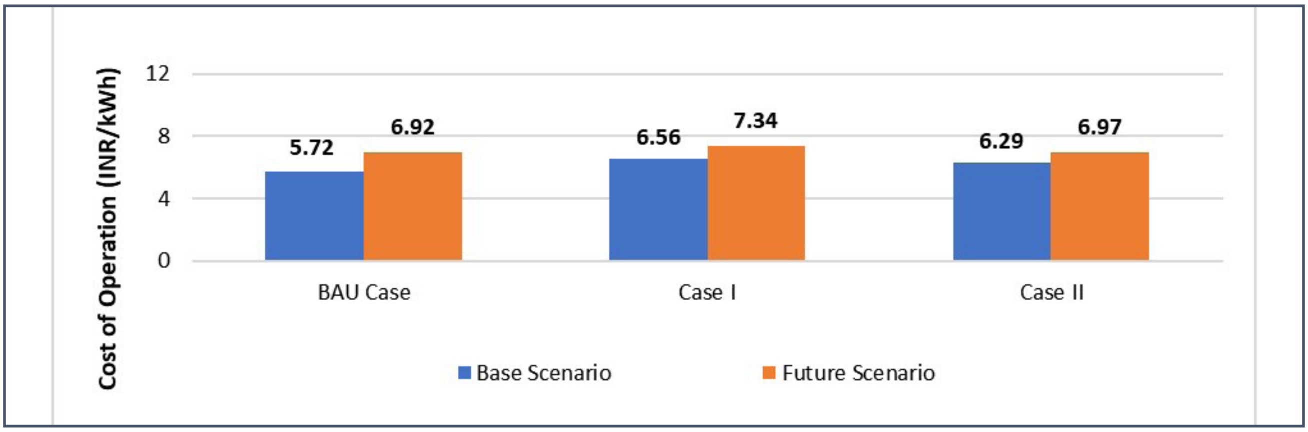



**Figure 28: Comparison of Operational Costs in Baseline against BESS Deployment Cases**

### Findings and Results of Cost Analysis

**Impact of introducing RE and BESS on total cost of operations** - For the base scenario, when BESS is deployed with net-metered RE (Case I), the TCO is higher by 14.7% as compared to that in the absence of BESS (BAU case). In the future scenario, the TCO of BESS with net-metered RE (Case I) is seen to reduce and come closer to BAU TCO costs, with a difference of 6% between the two (due to lower capital costs of BESS and increasing grid power costs). In case of BESS implemented with RE deployed with a gross-metering model, the cost of operations is comparatively lower (Case II in comparison to Case I).

**BESS Cost Estimates**

| | |
|---|---|
| Capital cost of BESS (existing scenario) | ₹131.3 Lakhs |
| Capital cost of BESS (future scenario) | ₹103.3 Lakhs |

**Feasibility for BESS**

| BESS for large hotel | For Surat and Rajkot |
|---|---|
| Savings in energy bill | • Implementation of BESS reduces the peak load of the hotel.<br>• It also offers power factor correction, which may otherwise entail additional equipment such as fixed capacitors or automatic power factor controllers to improve the power factor.<br>However, the deployment of BESS increases the cost of operations in existing and future scenarios, due to the current high cost of technology. |
| Maximizing RE utilization | • An on-site captive RE plant optimizes the operations. It provides charging to the BESS and also reduces energy requirements from the grid.<br>• The cost of implementing BESS is likely to remain on the higher end, even if it is sized primarily for the application of load shaving instead of the total RE generation, due to the high-power requirements of the hotel.<br>BESS can maximize the potential for RE systems by storing the surplus energy generation (like during the off-peak hours) and helping utilize this stored energy during the night or peak hours, thus removing barriers for RE deployment such as limitations on size, generation and compensation. |

## Key Findings

**BESS is a technically viable solution to reduce the peak demand of the hotel and deliver optimal power factor correction. It can also serve as a power-backup to run the operations during grid outages. However, the TCO incurred on the deployment of BESS is higher than that of the base case without BESS.**

**Assumptions**

| Parameters | Base scenario | Future scenario |
|---|---|---|
| Grid shaving target | 20% | 20% |
| Cost per unit energy capacity[65] (USD/ kWh) | 220 | 173 |
| RE capacity (kW) | 500 | 500 |
| Power cost[66] (INR/kWh) (excludes taxes and surcharges) | 4.3 | 5.23 (assuming escalation of 5% per year) |
| Demand charge (INR/KVA) | 475 | 578 (assuming escalation of 5% per year) |
| Excess demand charges (INR/KVA) | 555 | 675 (assuming escalation of 5% per year) |
| RE per unit generation cost (INR/kWh) | 3.5 | 3.5 |

**BESS Technical Specifications**

The specifications of the BESS module considered for the analysis are as follows:

| | |
|---|---|
| BESS technology | Li-ion LFP liquid cooled |
| Battery DoD | 100% |
| Acceptable battery degradation | 80% |
| Nominal voltage [V] | 25.6 |
| Number of cells in series | 8 |
| Number of cells in parallel | 2 |
| Unit cell voltage [V] | 3.20 |
| Nominal charge capacity [Ah] | 200 |
| Nominal energy capacity [kWh] | 5.1 |
| 1-C current [A] | 200 |
| Max continuous charge C-Rate [1/hr] | 0.65 |
| Max continuous discharge C-Rate [1/hr] | 0.65 |
| Life @ 1C, 25°C, 100% DoD and 80% residual capacity [Cycles] | 6,000 |

### 10.3.2. Use-case 2 – BESS for a Mid-size Hospital

**Site details**

This case considers a hospital with a maximum load of 1,034 kW and an average load of 709 kW respectively. A representative load profile is presented below. The average daily energy requirement of the hospital is considered to be 17,140 kWh. A 200 kW solar PV system is considered to be deployed on site, which would meet 5% of the total energy requirements.

**Site details and input parameters: Mid-size Hospital**

| | |
|---|---|
| Sanctioned load | 1100 kVA |
| Average load | 709 kW |
| Maximum load | 1034 KW |
| Daily energy requirements | 17,140 kWh |
| Power supply | 100% grid |
| On-site power backup | • DG of 750 kW<br>• Average power backup requirement of 4 hours per month |

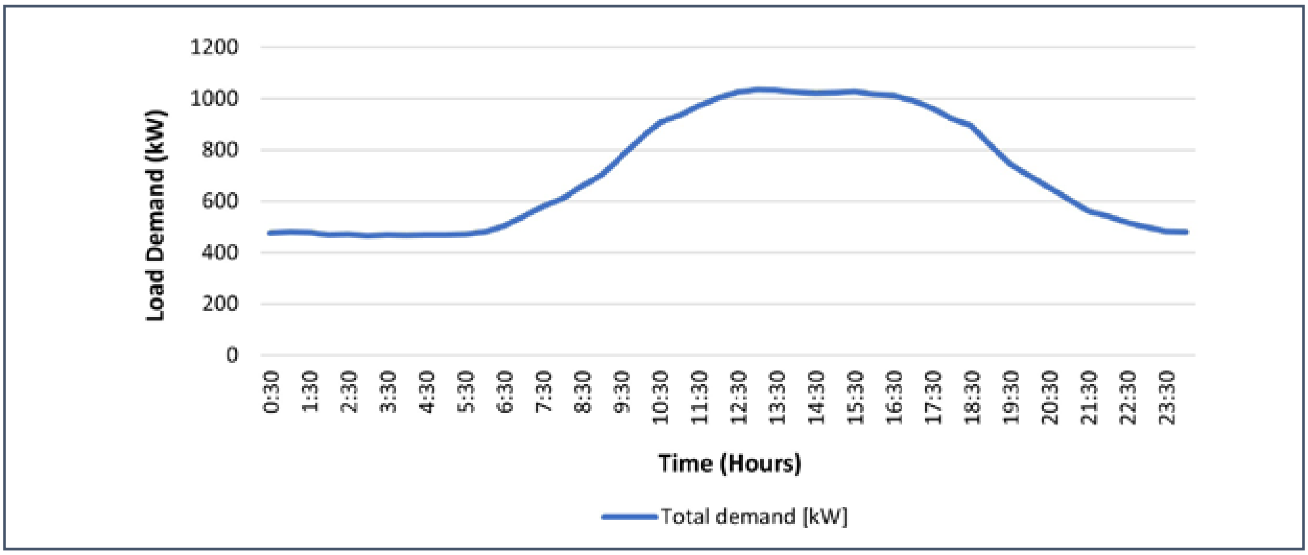



**Figure 29: Load Demand of the Hospital**

**BESS Requirement and Sizing**

**Key objective of BESS deployment:** BESS is intended to reduce the peak demand by 20%, curtailing the load from 1,034 kW to 827 kW. BESS can support power factor improvement and increase captive RE utilization. Further, BESS can provide power back-up for up to 4 hours on a monthly basis for running loads of capacity > 750 kW.

| | |
|---|---|
| Peak shaving target | 20% |
| Energy storage requirement | 3,000 kW |
| BESS charging source | Primarily through the captive RE plant and supplemented with grid power as necessary |
| BESS design capacity | 3,779 kWh/2,456 kW |

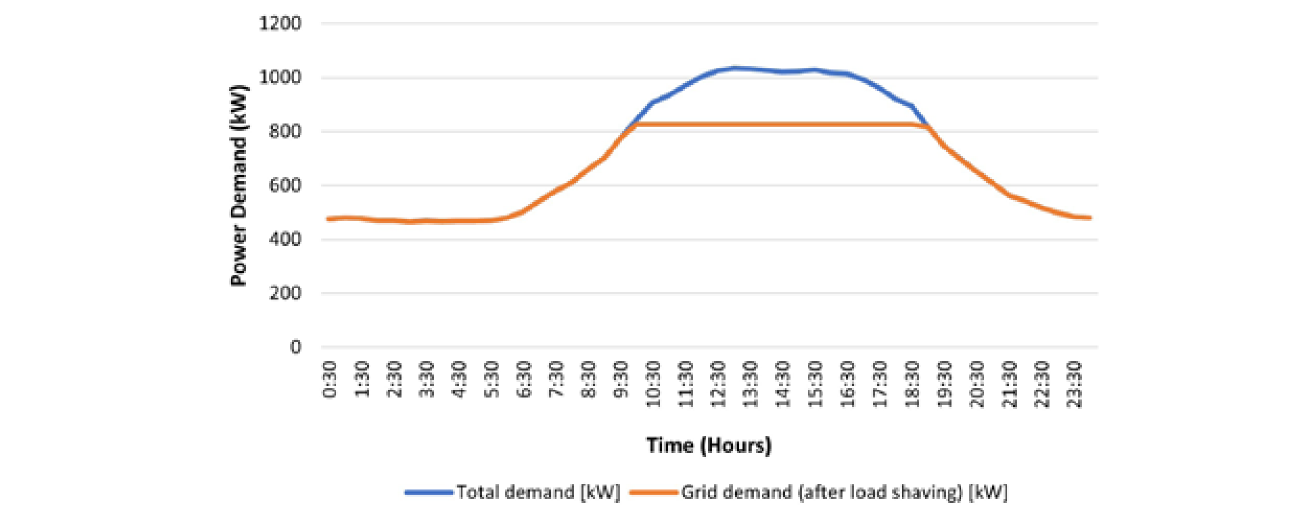



**Figure 30: Potential Load Shaving achieved with BESS Deployment**

## Cost Analysis

The purpose of the analysis is to understand and compare the estimated cost of operations (energy related) for using BESS as against the base-case without BESS. The cases are based on different combinations of an energy mix for the hospital and BESS. The analysis was undertaken for three cases, as listed below:

- BAU case: 100% grid supply
- Case I: 95% grid supply + 5% RE supply (with net-metering) + BESS
- Case II: 95% grid supply + 5% RE supply (with gross-metering) + BESS

Additionally, the three cases have been assessed for different scenarios to understand the impact of increasing energy costs and decreasing capital costs of BESS, as anticipated in the future:

- Base scenario: Considering current cost of BESS and applicable energy charges
- Future scenario: With estimated projections for cost of BESS and energy cost after 5 years

(Refer "Assumptions" below for more details on scenarios)

| Total cost of operations (INR/kWh) | BAU case | Case I | Case II |
|---|---|---|---|
| Base scenario | 6.04 | 7.40 | 7.12 |
| Future scenario | 7.27 | 8.15 | 7.77 |

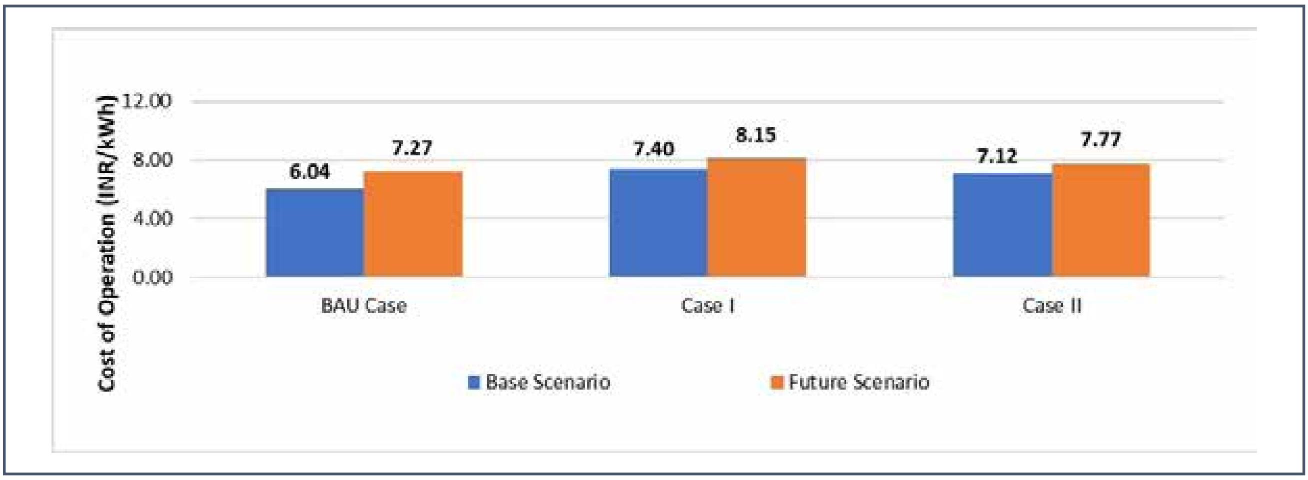



**Figure 31: Comparison of Operational Costs in Baseline against BESS Deployment Cases**

### Findings and Results of Cost Analysis

**Impact of introducing RE and BESS on total cost of operations** – For the base scenario, when BESS is deployed with net-metered RE (Case I), the TCO is higher by 22.5%, as against that in the absence of BESS (BAU Case). In the future scenario, the TCO of BESS with net-metered RE (Case I) is seen to reduce and come closer to BAU TCO costs, with a difference of 12.1% between the two. In case of BESS implemented with RE with a gross-metering model, the cost of operations is comparatively lower (Case II in comparison to Case I).

**BESS Cost Estimates**

| | |
|---|---|
| Capital Cost of BESS (existing scenario) | ₹656.7 Lakhs |
| Capital Cost of BESS (future scenario) | ₹516.4 Lakhs |

**Feasibility for BESS**

| BESS for Medium Scale Hospital | For Surat and Rajkot |
|---|---|
| Savings in energy bill | • Implementation of BESS reduces peak load of the hospital.<br>• It also offers power factor correction, which may otherwise entail additional equipment such as capacitors or automatic variable power factor controllers.<br>However, the deployment of BESS increases the cost of operations in both the existing and future scenarios, given the current high cost of technology. |
| Maximizing RE utilization | • An on-site captive RE plant optimizes the operations. It provides charging to the BESS and also reduces the energy requirements from the grid.<br>• The cost of implementation of BESS is likely to remain on the higher end even if it is sized primarily for the application of load shaving, instead of the total RE generation, due to the high-power requirements of the hospital.<br>BESS can maximize the potential for RE systems by storing the surplus energy generated (like during off-peak hours) and helping to utilize this stored energy during the night or peak hours, thus removing barriers for RE deployment such as limitations on size, generation and compensation. |

## Key Findings

**BESS is a technically viable solution to reduce the peak demand of the hospital, and maintain and improve the power factor. It also provides power-backup to run operations during grid outages. The TCO of BESS integrated systems is, however, higher than that in the BAU case.**

**Assumptions**

| Parameters | Base scenario | Future scenario |
|---|---|---|
| Grid shaving target | 20% | 20% |
| Cost per unit energy capacity (USD/ kWh) | 220 | 173 |
| RE capacity (kW) | 200 | 200 |
| Power cost[67] (INR/kWh) (excludes taxes and charges) | 4.2 | 5.11 (assuming escalation of 5% per year) |
| Demand charge (INR/KVA) | 475 | 578 (assuming escalation of 5% per year) |
| Excess demand charges (INR/KVA) | 555 | 675 (assuming escalation of 5% per year) |
| RE per unit generation cost (INR/kWh) | 3.5 | 3.5 |

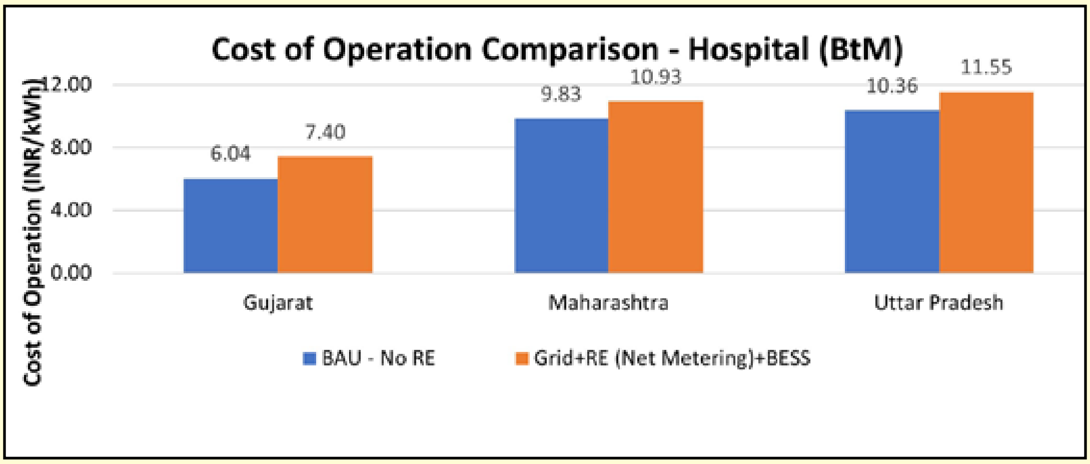
**BESS Technical Specifications**

The specifications of the BESS module considered for the analysis are as follows:

| | |
|---|---|
| BESS technology | Li-ion LFP liquid cooled |
| Battery DoD | 100% |
| Acceptable battery degradation | 80% |
| Nominal voltage [V] | 25.6 |
| Number of cells in series | 8 |
| Number of cells in parallel | 2 |
| Unit cell voltage [V] | 3.20 |
| Nominal charge capacity [Ah] | 200 |
| Nominal energy capacity [kWh] | 5.1 |
| 1-C current [A] | 200 |
| Max continuous charge C-Rate [1/hr] | 0.65 |
| Max continuous discharge C-Rate [1/hr] | 0.65 |
| Life @ 1C, 25°C, 100% DoD and 80% residual capacity [Cycles] | 6,000 |

## Prospects of BESS Implementation for End-use Consumers (Commercial, Institutional, Industrial and Residential)

- In the event of sudden increase in demand, BESS can support the power supply, reducing the peak demand, which could have a significant impact on energy costs and power supply.
- BESS can help improve frequency excursion and the settling frequency. Minimizing THD ensures the supply side of AC waveform stays very close to sinusoidal and protects converters and other equipment running on same AC supply. BESS can also help with voltage regulation.
- BESS can serve as a power-backup solution at the time of grid outages and failures, which is critical for emergency services entities such as hospitals.
- Addition of more RE capacity (possibly by sourcing through virtual net-metering, due to possible limitations of space at the site) for captive consumption in operations during the day and for charging of BESS is recommended to optimize the cost of operations.
- Electricity tariffs and peak demand charges for commercial, industrial, institutional and residential consumers in Gujarat are relatively lower as compared to other states. The viability of BESS deployed with the RE system would improve and the total cost of operations with BESS would be closer or at par with baseline costs for states in which the power and fixed charges are higher (such as Maharashtra and Uttar Pradesh) as compared to grid power charges currently applicable in Gujarat. TCO comparison for a mid-size hospital (Use-case 2) for case Grid+RE with BESS vs the BAU case (only grid) in a base scenario for Gujarat, Maharashtra and Uttar Pradesh is reflected below along with the percentage difference:



| State | Percent Difference in TCO Grid+RE with BESS case vs BAU |
|---|---|
| Gujarat | 22.5% ↑ |
| Maharashtra | 11.2% ↑ |
| Uttar Pradesh | 11.5% ↑ |

- BESS could be a viable option for minimizing energy bills of EV charging stations with the utilization of repurposed batteries for which capital cost incurred is about 25% of that of new batteries.[68] Cost analysis with re-purposed batteries and an RE system shows the cost of operations to be lower than the BAU case (100% grid). However, such a market can be established in future with the help of strong policy support to promote second life batteries.
- BESS, with a suitably advanced inverter, can also provide power factor control facilities, similar to a Static Synchronous Compensator (STATCOM).[69]
- BESS provides better integration of different sources of energy.

## 10.4. BESS for Municipal Utilities and Services

As the municipal operations are vital to meet the daily requirements of citizens, it is imperative that the energy demand of municipal utilities is met at all times. BESS is a solution available for deployment in energy-intensive infrastructure for the delivery of municipal services

The primary opportunities that can drive BESS deployment in municipal utilities are to minimize energy charges, enable captive use of RE generation, manage power quality and provide power back-up for continuous operation of the services.

In this analysis, BESS's feasibility is evaluated for an existing water pumping station in Rajkot city with a captive solar PV plant of 145 kW installed on-site. The site parameters including the power consumption profile (load profile) and power supply break-up (energy consumption from the grid and captive RE plants) were developed based on actual energy consumption patterns derived from energy bills collected for the water pumping station. Pre-feasibility of BESS is assessed, with regard to the potential benefits, including peak shaving, power factor improvement, maximizing RE utilization and provision of power backup.

### 10.4.1. Use-case 1 - BESS for a Water Pumping Station

**Site details**

An existing water pumping station in Rajkot, with an installed captive solar PV plant of 145 kW capacity, which meets 9% of the total energy requirements, was considered for the analysis. The maximum load of the pumping station is 500 kW, with an average load of 315 kW. The representative load profile developed using energy bills and operational patterns of the station is presented below. The average daily energy requirement of the station is about 7,586 kWh.

**Site details: Water Treatment Plant and Pumping Station**

| | |
|---|---|
| Sanctioned load | 700 kVA |
| Average load | 315 kW |
| Maximum load | 500 KW |
| Daily energy requirements | 7,586 kWh |
| Power supply | • Grid: 91% of total energy requirements<br>• RE: 9% (145 kW solar PV existing on-site) |
| On-site power backup | • DG of 500 kW<br>• Average power backup requirement of 2 hours per month |
| On-site capacitor bank | • 150 kVAR |

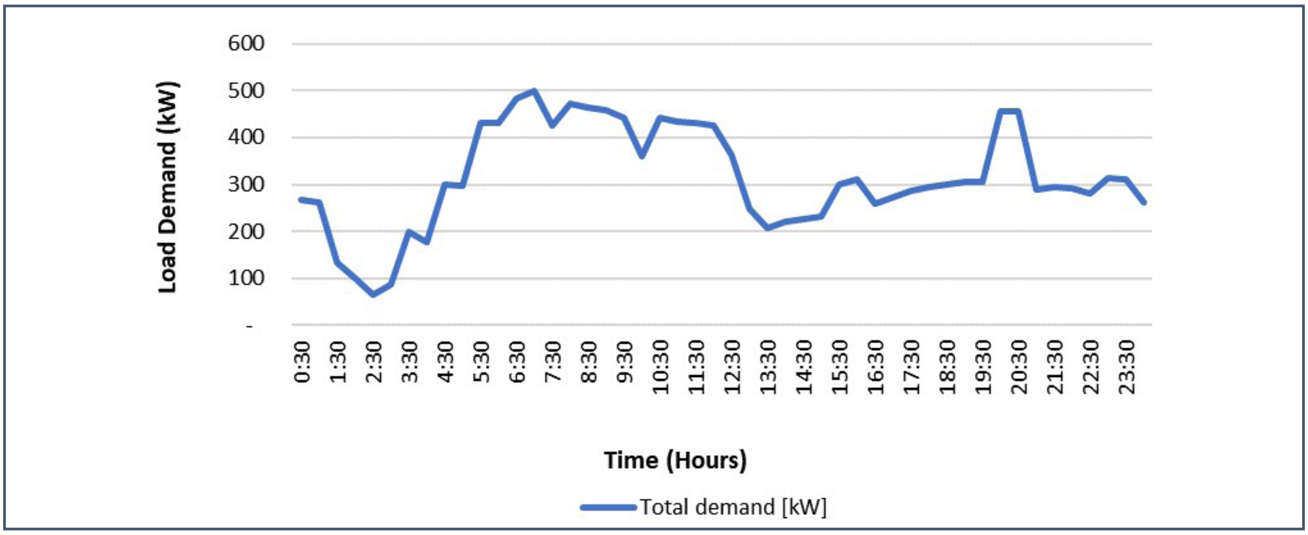



**Figure 32: Load Demand of the Water Treatment and Pumping Station**

### BESS Requirement and Sizing

**Key objective of BESS deployment:** BESS is intended to reduce the peak demand by 20%, curtail the load from 500 kW to 400 kW, improve the low power factor, and increase the captive RE utilization. It can also provide power back-up for up to two hours on a monthly basis for running loads of capacity > 500 kW.

| | |
|---|---|
| Peak shaving target | 20% |
| Energy storage requirement | 1,000 kWh |
| BESS charging source | Primarily through the captive RE plant and supplemented with grid power as necessary |
| BESS design capacity | 1,290 kWh/839 kW |

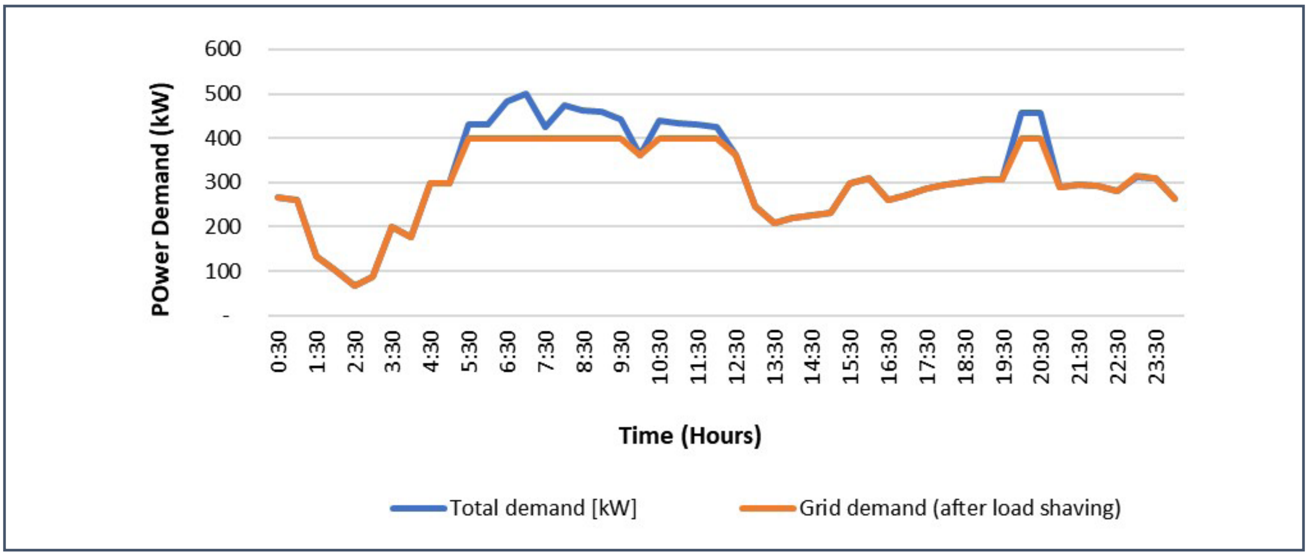



**Figure 33: Potential Load Shaving Achieved with BESS deployment**

### Cost Analysis

The purpose of the analysis is to understand and compare the estimated cost of operations (energy related) for BESS deployment as against the base-case without BESS. The cases are based on different combinations of the energy mix for the plant and BESS. The analysis was undertaken for three cases, as listed below:

- BAU case: 91% grid + 9% RE supply (existing on-site)
- Case I: 91% grid supply + 9% RE supply (with net-metering) + BESS (For base and future scenario 1)
- Case II: 91% grid supply + 9% RE supply (with gross-metering) + BESS (For base and future scenario 1)

Additionally, the three cases have been assessed for different scenarios to understand the impact of increasing energy costs and decreasing capital costs of BESS, as anticipated in the future:

- Base scenario: Considering the current cost of BESS and applicable energy charges
- Future scenario 1: With estimated projections for the cost of BESS and energy costs after five years
- Future scenario 2 (with RE supply increased to 15%, instead of 9%): 85% grid supply + 15% RE supply + BESS deployment in Case I and Case II (with estimated projections for cost of BESS and energy cost after five years)

(Refer to "Assumptions" below for more details on scenarios)

| Total cost of operations (INR/kWh) | BAU case | Case I | Case II |
|---|---|---|---|
| Base scenario | 5.41 | 6.23 | 5.73 |
| Future scenario 1 | 6.44 | 7.01 | 6.33 |
| Future scenario 2 | 6.31 | 7.23 | 6.06 |

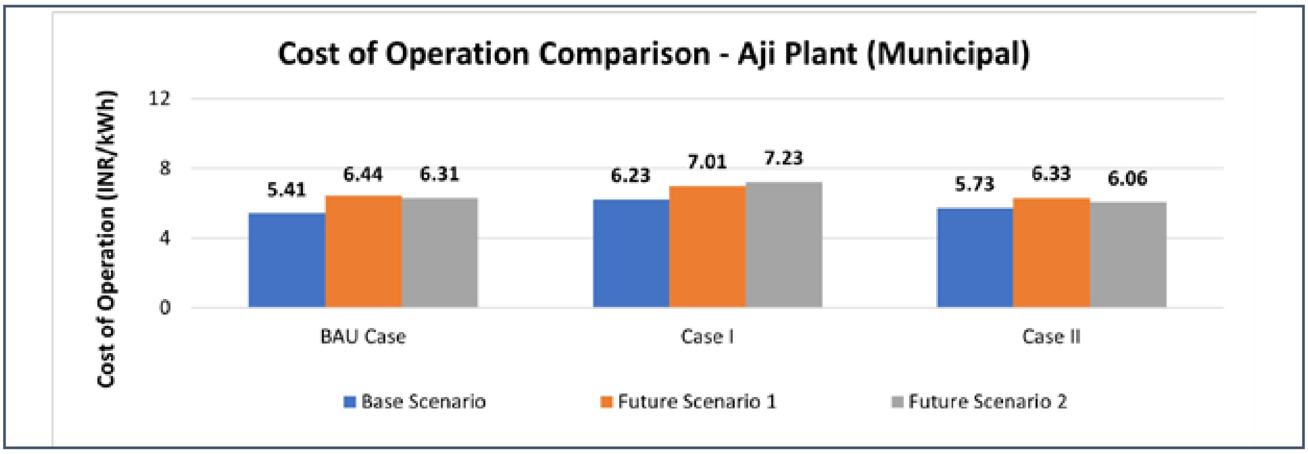



**Figure 34: Comparison of Operational Costs in baseline against BESS deployment cases**

### Findings and Results of Cost Analysis

- **Impact of introducing RE and BESS on the total cost of operations** – In the base scenario, the TCO estimated for BESS installed with RE (with net-metering) (Case I) is 15.2% higher as compared to the BAU. For Grid + BESS + RE (gross-metering), the TCO is estimated to be only 5.9% as against the existing base case without BESS deployed. For the future scenario, where BESS costs are predicted to fall and energy costs are likely to rise, the addition of BESS along with RE to the system, can bring down the TCO as compared to the BAU case.

- **Increasing the RE capacity in the energy mix (Future Scenario 2)** – Based on the future costs, when deploying BESS with a higher RE capacity, a slight decrease in operating costs can be observed for Case I (net-metered RE) while, in gross-metered RE, the TCO is observed to be nearly at par with the BAU. However, integration of a higher RE capacity, while recommended, should be evaluated on the basis of on-site parameters such as land availability and budget.

### BESS Cost Estimates

| | |
|---|---|
| Capital cost of BESS (existing scenario) | ₹224.2 Lakhs |
| Capital cost of BESS (future scenario) | ₹176.3 Lakhs |

### Feasibility for BESS

| BESS for Municipal Utilities and Services | For Surat and Rajkot |
|---|---|
| Savings in energy bill | • Implementation of BESS reduces the peak load of the water pumping station.<br>• It also offers power factor correction, thus avoiding the need for fixed capacitors or automatic variable power factor units.<br>The cost of operations in the base scenario increases with implementation of BESS, due to the current high cost of technology. But, in the future scenarios, the TCO for grid, RE & BESS converges with the TCO in BAU case. |

| BESS for Municipal Utilities and Services | For Surat and Rajkot |
|---|---|
| Maximizing RE utilization | • An on-site captive RE plant optimizes the operations. It provides charging to the BESS and reduces energy requirements from the grid.<br>• The cost of implementation of BESS is likely to remain on the higher end, even if its sizing is done with regard to load shaving requirements, instead of the total RE generation, due to the high-power requirements of the plant.<br>BESS can maximize the potential for RE systems by storing the surplus energy generation (like during the off-peak hours) and helping utilize this stored energy during the night or peak hours, thus removing barriers for RE deployment such as limitations on size, generation and compensation. |

## Key Findings

**BESS is a technically viable solution to reduce the peak demand of the water pumping station and to deliver optimal power factor correction. It can also serve as a power-backup to run the operations during grid outages. The TCO incurred on the deployment of BESS is higher when compared to the BAU case (without BESS) in the base scenario. However, the TCO in the future scenarios, for grid, RE & BESS converges with that in BAU case.**

**Assumptions**

| Parameters | Base Scenario | Future Scenario 1 | Future Scenario 2 |
|---|---|---|---|
| Grid shaving target | 20% | 20% | 20% |
| Cost per unit energy capacity (USD/ kWh) | 220 | 173 | 173 |
| RE capacity (kW) | 145 | 145 | 240 |
| Power cost[70] (INR/kWh) (excludes taxes and surcharges) | 4.55 | 5.54 (escalation of 5% assumed per year) | 5.54 (escalation of 5% assumed per year) |
| Demand charge (Up to 500 kVA) (INR/KVA) | 115 | 140 (escalation of 5% assumed per year) | 140 (escalation of 5% assumed per year) |
| Demand charge (Above 500 kVA) (INR/KVA) | 225 | 274 (escalation of 5% assumed per year) | 274 (escalation of 5% assumed per year) |
| Excess demand charges (INR/KVA) | 360 | 438 (escalation of 5% assumed per year) | 438 (escalation of 5% assumed per year) |
| RE per unit generation cost (INR/kWh) | 3.5 | 3.5 | 3.5 |

**BESS Technical Specifications**

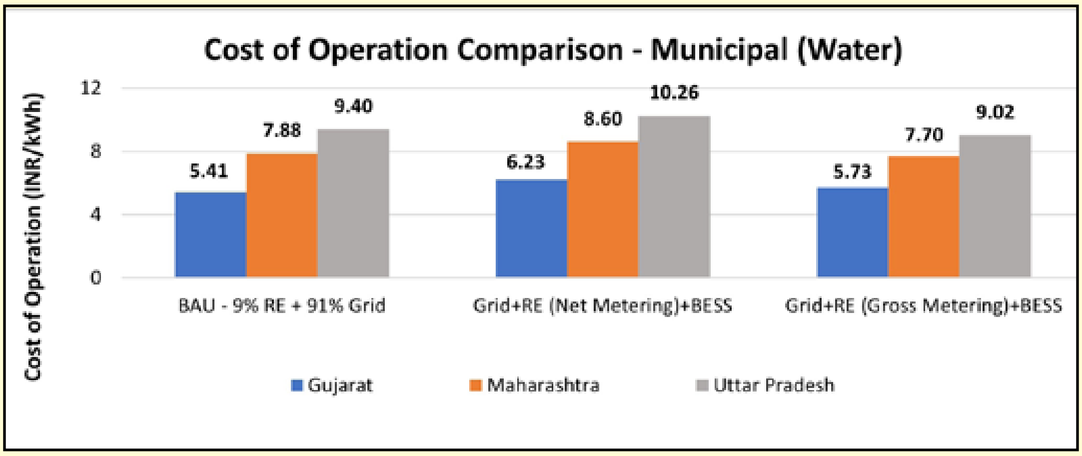
The specifications of the BESS module considered for the analysis are as follows:

| | |
|---|---|
| BESS technology | Li-ion LFP liquid cooled |
| Battery DoD | 100% |
| Acceptable Battery Degradation | 80% |
| Nominal Voltage [V] | 25.6 |
| Number of cells in series | 8 |
| Number of cells in parallel | 2 |
| Unit cell voltage [V] | 3.20 |
| Nominal Charge Capacity [Ah] | 200 |

| | |
|---|---|
| Nominal Energy Capacity [kWh] | 5.1 |
| 1-C current [A] | 200 |
| Max Continuous Charge C-Rate [1/hr] | 0.65 |
| Max Continuous Discharge C-Rate [1/hr] | 0.65 |
| Life @ 1C, 25°C, 100% DoD and 80% residual capacity [Cycles] | 6,000 |

## Prospects of BESS Implementation for Municipal Utilities and Services

- BESS can serve as a power-backup solution during grid outages and failures, which is critical for providing continuous services of municipal utilities.
- Gross metering for cost feasibility – A possible solution for increasing the cost feasibility of BESS is employing RE with gross-metering, instead of net-metering i.e., exporting the generated solar energy into the grid instead of using it for on-site operations. The TCO comparison for the water pumping station (Use-case 1) for case Grid+RE (net-metering) with BESS and Grid+RE (gross-metering) with BESS vs the BAU (only grid) in the current scenario for Gujarat, Maharashtra and Uttar Pradesh is reflected below, along with the percent difference:




| State | Percent difference in TCO Grid + RE (NetMetering) + BESS case vs. BAU | Percent difference in TCO Grid + RE (Gross-metering) with BESS case vs BAU |
|---|---|---|
| Gujarat | 15.2% ↑ | 5.9% ↑ |
| Maharashtra | 9.1% ↑ | -2.3% ↓ |
| Uttar Pradesh | 9.1% ↑ | -4.0% ↓ |

- To improve the viability of the BESS enabled system, the municipal authorities should consider and evaluate revenue from multiple value streams relevant to BESS, such as peak demand management, power factor correction, increasing captive RE utilization and power backup management.
- BESS, along with RE, reduces loading of the local DT, thus deferring the requirements for augmentation to a certain extent.

## 10.5. BESS for DISCOM Load Management

### 10.5.1. BESS for DT Load Management

**Site details**

Two illustrative load profiles for the months of May and October, representative of two different seasons, were developed for this use-case analysis, based on the load profile data provided by a DISCOM in Surat. Accounting for the worst-case scenario, the May month data has been considered for developing the base case for BESS sizing and analysis. Further iterations based on load shaving targets, load profile and the cost of the BESS system were undertaken to understand the preliminary feasibility of deploying BESS as a load management asset for the DISCOM.

**Table 6: Characteristics of Load Profile from the Month of May**

| | |
|---|---|
| DT capacity | 750 kVA (675 kW @ 0.9 PF assumed) |
| Average load | 349 kW |
| Maximum load | 610 kW |
| Average daily energy requirements | 3,982 kWh |

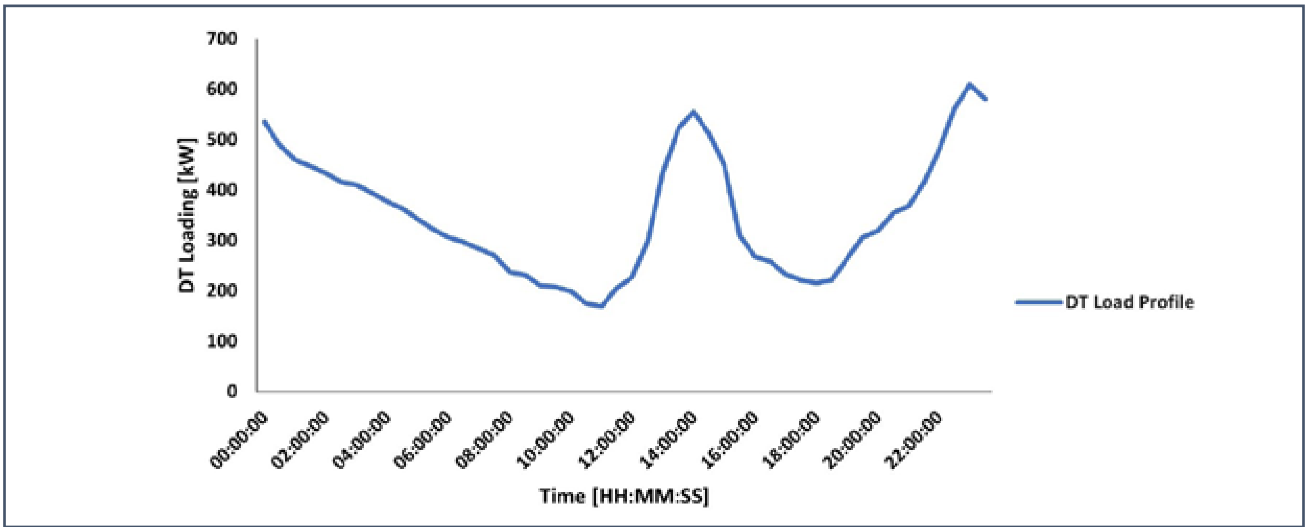



**Figure 35: Load Profile of the Distribution Transformer in May month**

The maximum load of the DT considered for this case is 610 kW for the month of May, while the average load stands at 349 kW. The average daily energy requirement is 3,982 kWh.

**BESS Requirement and Sizing**

**Key objective of BESS Deployment:** BESS is intended to reduce the load on the DT by shaving-off the peak demand when that exceeds set thresholds.

At the DT level, the deployment of BESS to manage longer durations of peak load conditions would require significant battery power capacity, making them not feasible or ideal given that the current and near future costs of the battery are bound to be high. Thus, BESS would be more suitable to deploy for DTs that see frequent peaking of loads, but for shorter periods of time, allowing the design of BESS for less energy capacity and high-power capacity. It is prudent that the battery selection for building the BESS system at the DT level should also have a similar approach.

The base case was developed while considering a 15% peak load shaving as the target based on the load profile data for the month of May. This load shaving also represents the threshold based on which the load shaving is triggered. The peak load demand of May is at 90% of the 750 kVA capacity DT, and a 15% load shaving target achieves a peak load shaving of about ~90 kW. The table below summarizes the key input parameters for the case:

**Table 7: Input Parameters for Cost Analysis**

| **Base Case** | |
|---|---|
| Data pertaining to season | Summer (May) |
| Peak shaving target | Case 1 - 15%<br>Case 2 – 18%<br>Case 3 – 20% |
| DT capacity | 750 kVA |
| BESS charging source | Grid, during off-peak hours (generally during 4:00 to 8:00 am and 7:00 to 11:00 pm) |
| BESS Charging time | 6.5 hours |
| Energy storage capacity required | 130 kWh |

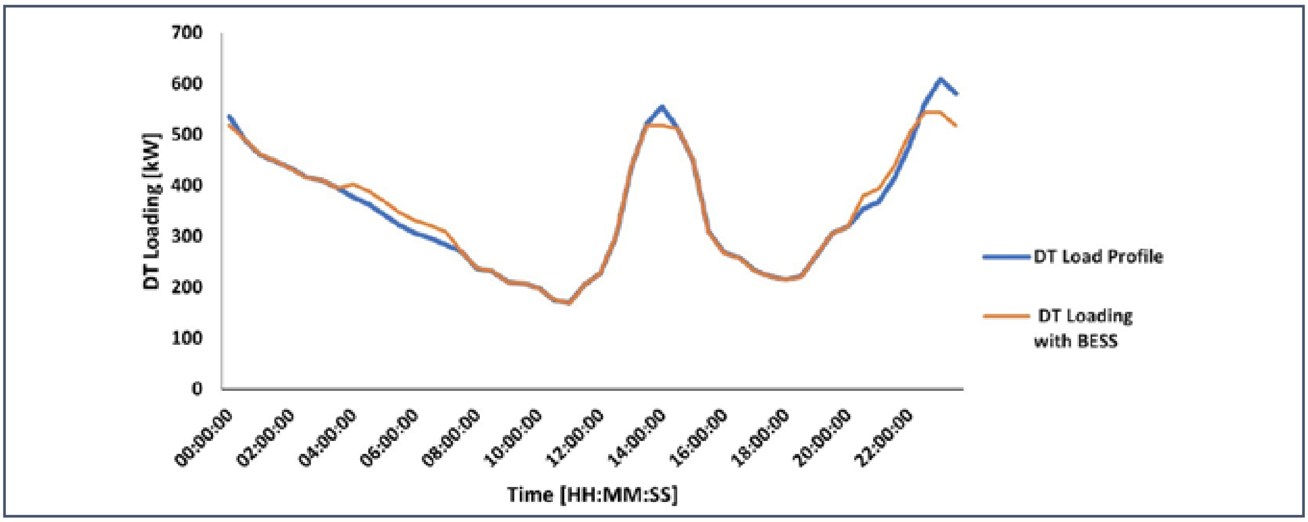



**Figure 36: Load Shaving with BESS (Base case with 15% of peak load shaving)**

## Cost Analysis

The purpose of the analysis is to understand and compare the estimated cost of operations (energy related) when using BESS, as against the base-case without BESS. Three cases have been analyzed while comparing different load shaving targets, as given below:

- BAU: No BESS, new DT deployed
- Case I: 15 % load Shaving with BESS
- Case II: 18 % load Shaving with BESS
- Case III: 20 % load Shaving with BESS

Additionally, the costs have been estimated for a future scenario to understand the impact of decreasing capital costs of BESS and the increasing cost of purchasing a new DT:

- Future scenario: 18% load shaving, with estimated projections for the cost of BESS and energy costs after five years

(Refer "Assumptions" below for more details on scenarios)

**Table 8: Cost Analysis of Deploying BESS for Peak Load Shaving of DTs in Different Cases**

| Parameter | Actual Load Shaved (In kW) | Peak load before shaving (in %) | Effective load after shaving (in %) | BESS Power Capacity (In kW) | Total Cost of BESS (Lakh INR) | Annualized cost to deploy BESS (Cases) (Lakh INR) | Annualized cost to deploy new DT (BAU) (Lakh INR) |
|---|---|---|---|---|---|---|---|
| Case I (15%) | 91.4 | 90% | 77% | 211 | ₹ 36.66 | ₹ 7.73 | ₹ 8.04 |
| Case II (18%) | 109.7 | 90% | 74% | 316 | ₹ 54.99 | ₹ 11.52 | ₹ 8.04 |
| Case III (20%) | 109.7 | 90% | 74% | 316 | ₹ 54.99 | ₹ 11.52 | ₹ 8.04 |
| Future Scenario | 109.7 | 90% | 74% | 316 | ₹ 43.24 | ₹ 9.1 | ₹ 10.26 |

**Results and Findings of Cost Analysis**

- It is observed that given the current costs of BESS, its deployment was feasible in Case I for a load shaving target of 15%. The annualized cost to deploy BESS for Case I was estimated to be around INR 7.73 lakhs, which is less than the new DT deployment cost as in the BAU case. Annualized costs of BESS were higher in Case II and Case III with higher peak shaving targets. Thus, such a system might be only partially effective for DTs that consistently face higher load peaks, which also leads to the inference that significantly higher peak demand energy would be required from BESS.

- Several iterations were undertaken for the cases with higher load shaving targets, and it was observed that the cost of BESS deployment increases significantly with increase in the shaving target (as can be seen from Cases I to III) due to higher energy requirement from BESS to manage the load characteristics of the DT. However, when a future scenario for the costs of BESS and DT deployment was considered, the load shaving of about 18% was possible at a feasible cost that is less than that of new DT deployment.

- BESS has been sized on the basis of the demand and load profile for the month of May (summer season and highest demand in the year). BESS would thereby help achieve higher load shaving in other seasons. For instance, from the analysis undertaken for the month of October (based on the corresponding load profile), it is observed that BESS would be able to realize higher load shaving in the range of 25 to 31% of the peak load, as compared to that in May.

| Case | BESS power capacity (In kW) | Load shaving achieved during October |
|---|---|---|
| Case I | 211 | 25% |
| Case II | 316 | 28% |
| Case III | 396 | 31% |

## Key Findings

**For the load profile analysed, deploying BESS for peak load shaving of DTs is a feasible solution only when the shaving target is 15% or less as per current costs, in comparison to the deployment of new distribution infrastructure.**

**Other Findings and Recommendations**

- While considering BESS deployment, DTs should not be shortlisted and prioritized on the basis merely of peak demand, frequency of peak loading, and the costs associated with these incidences. Other factors such as the criticality of the consumers served by the DT and the constraints on space available for upgrading DTs should also be considered, to justify the deployment of BESS only for load shaving, given their current costs.

- If BESS is installed as a movable system, it can be deployed within hours to a new site and can be useful in handling one-off very high peak demands across various sites, such as during special events, festivals and unscheduled demand. Over time, BESS deployed for a particular DT can be shifted to other locations that are overloaded, once upgradation of the said DT is unavoidable.

- Even with projected future costs, BESS is not a feasible option for providing load shaving services beyond a certain percentage of the peak load, as evident from the future scenario of Case I in the analysis. Thus, it is imperative that when evaluating BESS feasibility at the distribution level, the DISCOM needs to consider and evaluate revenue from multiple value streams that can result from BESS deployment. Using BESS for multiple applications will help maximize its utilization and thereby improve viability. BESS can primarily support peak demand shaving during peak consumption period (for e.g., summer) while also help in reactive power control applications during off-peak consumption period (for e.g., winter). Deploying BESS with customizable energy management systems (EMS) and advanced communication systems can help improve its utilization and the benefits accrued.
- BESS can stabilize the frequency and voltage of the power supply, providing either frequency containment, short and long-term frequency restoration or reactive energy for voltage control. It can also help the DISCOM avoid UI charges, but detailed data (discretized to seconds) on load and frequency profile is required to conduct such a detailed analysis on the cost benefits.

**Assumptions**

| Parameters | Base scenario | Future scenario |
|---|---|---|
| BESS cost per unit energy capacity (USD/kWh) | 220 | 173 |
| DT capital cost price escalation | - | 5% per year |

**BESS Technical Specifications**

The specifications of the BESS module considered for the analysis are as follows:

| | |
|---|---|
| Battery DoD | 100% |
| Acceptable battery degradation | 80% |
| Nominal voltage [V] | 51.5 |
| Number of cells in series | 14 |
| Number of cells in parallel | 1 |
| Unit cell voltage [V] | 3.68 |
| Nominal charge capacity [Ah] | 64 |
| Nominal energy capacity [kWh] | 3.3 |
| 1-C current [A] | 64 |
| Max continuous charge C-Rate [1/hr] | 1.00 |
| Max continuous discharge C-Rate [1/hr] | 1.00 |
| Life @ 1C, 25°C, 100% DoD and 80% residual capacity [Cycles] | 6,000 |

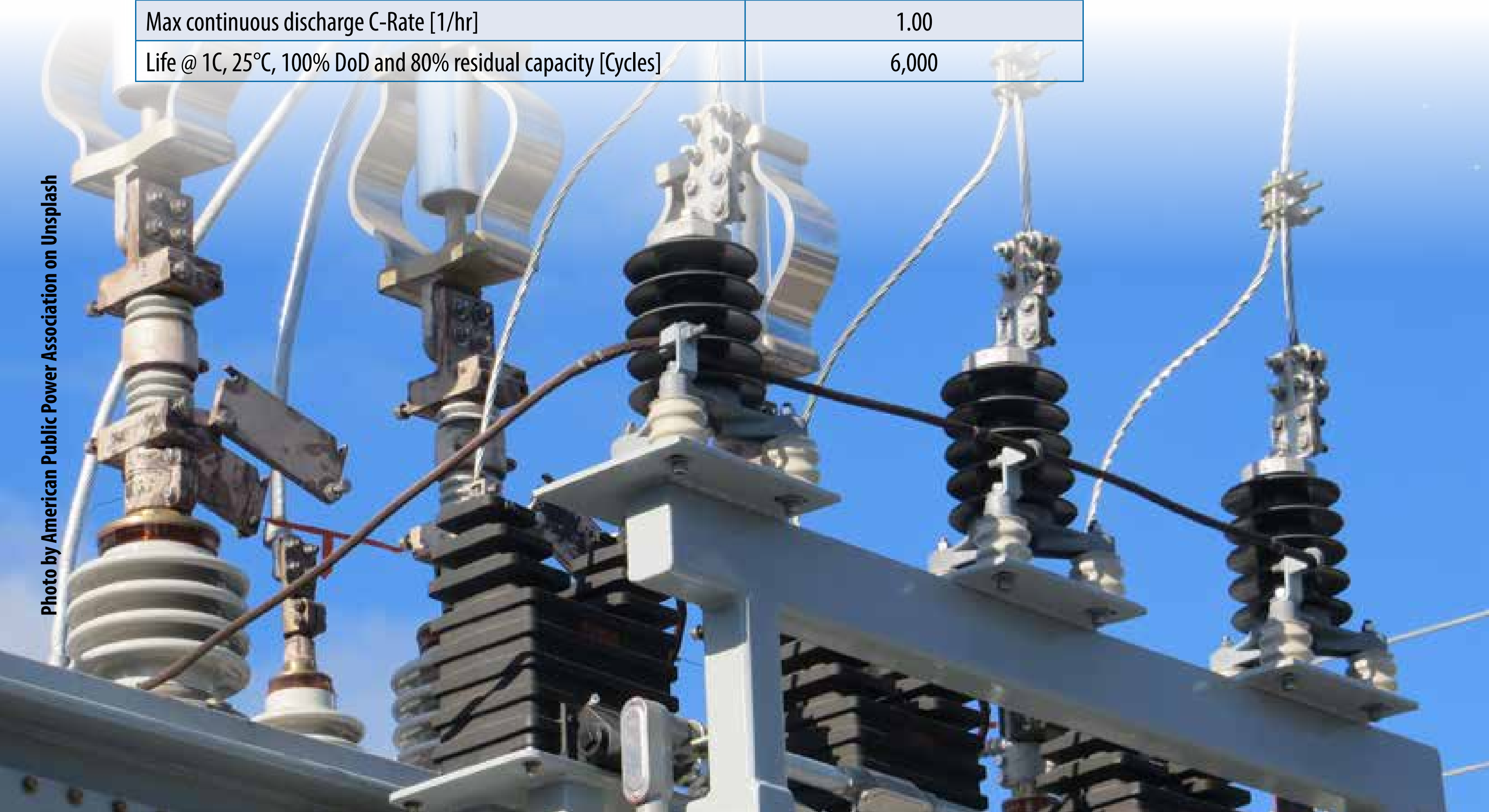


Photo by American Public Power Association on Unsplash

# 11. Business Models for BESS implementation

The clean energy transition is changing the landscape of the power sector, with RE generators impacting energy sales from traditional utilities, whereas the end-consumers have become prosumers, leading to lower demand. The current power market needs to absorb intermittent RE supplies to the grid and consider major shifts towards energy storage technology to better integrate the increasing share of RE into the system. Thus, the large scale-up of RE is driving the need for energy storage solutions across the value chain of the power sector. Energy storage can be expected to be uniquely positioned in the power sector and become a new business line in the energy space, with market players being required to build their energy service solutions and business models around it.

Conventionally, GT&D utilities have experience in balancing demand and supply. Thus, they can also successfully own and operate ESS's and provide associated services, giving them unique advantages in the new and evolving power sector landscape. However, new players in the market can enter it by offering only energy storage capacity and act as independent storage providers (ISPs), as against the independent power producers (IPPs) we see today.

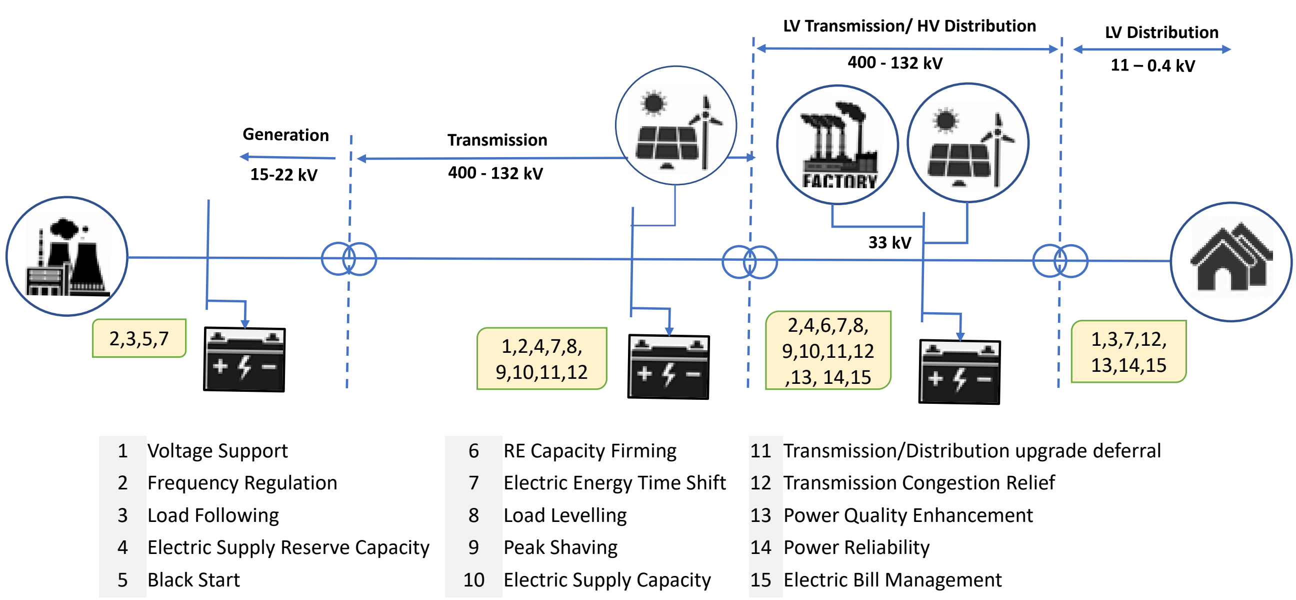
Given that the penetration of energy storage is still at a nascent stage, no single business model has been crystallized yet into an effective implementation model for deploying energy storage solutions. Several players from different value chains of the power markets across the globe are experimenting with different business models, gaining experience and building partnerships that are required to pre-empt the competition and stay ahead in the evolving power sector.[71]

The success of a business model for any new technology is determined by its interaction with, and impact on, the stakeholders. The need for stakeholders, be it investors, policy makers, public sector decision makers or players in the value chain, is to better understand a business model, its value addition, and sustainability to take informed decisions on various aspects of bringing new technologies, such as energy storage solutions to the market. Regulations and policies of the power sector should also be amended to consider ESS's as part of the value chain and define rules, regulations, compliance requirements, and goals and targets to deploy ESS's at both FtM and BtM applications.

BESS is the primary energy storage technology in today's power market, especially Li-ion based BESS, which is the most prevalent and mature technology available. BESS is being deployed as a pilot or at-scale across the globe under various business models that are tailor-made to a given power market. The following sections will discuss the commonly employed and emerging innovative business strategies that can work in favour of deploying BESS. Table 9 lists the typical implementation models identified for BESS, based on its location on the value chain and ownership, through which innovative energy storage solutions and business models are emerging.

**Table 9: Key Business Models to Deploy BESS for FtM and BtM Applications**

| Front-of-the-Meter models | Behind-the-Meter models |
|---|---|
| • BESS as generation asset | • BESS under CapEx model |
| • BESS as transmission network asset | • BESS under ESCO/RESCO model |
| • BESS as distribution network asset | |
| • BESS as merchant asset | |




*Source: BESS in the United Kingdom: A Review of Current State-of-the-Art and Future Applications*

**Figure 37: BESS Services across Power Market Value Chain**

## 11.1. Implementation Models for BESS in Front-of-the-Meter Applications

The GT&D utilities understand the value addition of utility-scale FtM BESS deployment as it can support renewable integration, provide grid services, and deliver efficiency and cost benefits directly to the consumers. However, the key challenge is in determining the right business model or in adjusting their business model to best utilize the stacked value of BESS, taking into consideration the policy and regulatory uncertainties pertaining to tariffs, ownership, and control of assets. GT&D utilities need to explore and experiment with innovative business models and build partnerships, especially with third party players in the power market who will be key to the scaling-up of energy storage deployment in the power market value chain.

In FtM applications, BESS can be broadly deployed in four different models, depending on the location and ownership of the asset. Table 10 gives an overview of the implementation models for BESS in FtM applications.

**Table 10: Overview of Implementation Models to Deploy BESS for FtM Applications**

| Details | Generation coupled asset | Transmission asset | Distribution asset | Merchant asset |
|---|---|---|---|---|
| Location of Battery | Generation | Transmission network; FtM | Distribution network; FtM | Anywhere |
| Ownership | Generators/IPPs | ISPs/regulated utilities | ISPs/Regulated Utilities | ISP |
| Dispatch | IPPs | System operators | System operators | ISP |
| Applications | Firming the intermittent RE; ramping for thermal generation | Ancillary services; deferral of transmission lines; load shifting | Ancillary services; deferral of distribution network (transformer/feeder); load shifting | Energy arbitrage |
| Value maximization | Medium | Maximum | Maximum | Low |
| Bankability | Medium | High | High | Low |

*Source: Sterlite Power: Business Models for Utility-Scale Energy Storage in India*

### 11.1.1. BESS as Generation Asset

Under this model, the traditional GENCOs or IPPs including solar PV parks, wind farms, and gas plants for peaking capacity will own the BESS asset and will use it for applications such as firming of RE capacity, ramping up generation from thermal plants, capacity reserve, and peaking plant (see Figure 38). The BESS asset can be co-located with the generator and dispatched by the generation company as needed, to meet their scheduled generation or to provide primary frequency response (as in India, primary response is the responsibility of the generator) when there is an Area Control Error (ACE)[72] in the grid.

Also, GENCOs and IPPs can utilize part of the capacity of BESS for themselves and can sell the services of BESS to transmission or distribution companies through an Energy Services Agreement (ESA). The arrangement will outline an annual/quarterly payment of fixed and variable charges based on tariffs notified by the relevant regulatory commission. In such cases, BESS can also be deployed at the transmission side and dispatched by the generation utility or IPP based on signalling from the SLDCs or RLDCs, as and when their services are needed in the grid. The BESS asset, though owned and operated by the GENCO, will be treated as an independent storage provider for the purposes of scheduling and dispatch by the system operators in such cases.

In the Indian context, GUVNL recently invited tenders for 500 MW RE generating assets with assured peak power supply along with ESS's, which may be located anywhere in Gujarat.[73] The tender notes that the project must comprise a minimum of two components - RE and energy storage, and the energy storage should be half of the RE component capacity. Further, Solar Energy Corporation of India (SECI), a GoI enterprise, in April 2022 invited requests for proposals for the setting up of interstate transmission system (ISTS)-connected pilot projects of standalone BESS, with an aggregate storage capacity of 1,000 MWh (500 MW x 2 hours).[74] This was done after several buying entities across the country showed interest in utilizing ESS's on an 'on-demand' basis, suited to their requirements during peak and off-peak hours.

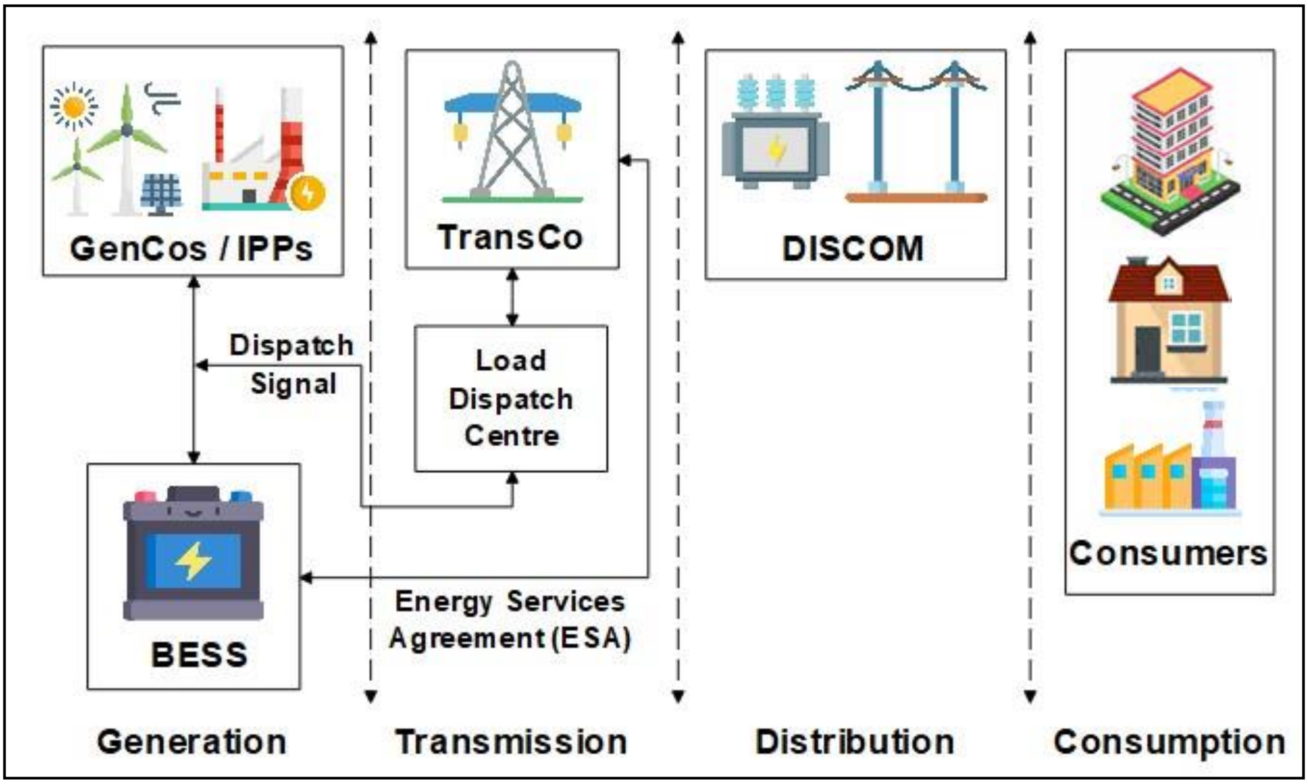



**Figure 38: BESS Deployed as a Generation Asset**

**Advantages of BESS as a Generation Asset**

- **Multiple applications for storage on generation side:** Using BESS, GENCOS can co-optimize operations of their thermal power plants and RE plants. Energy storage can be used to meet the synchronous reserve requirements, primary frequency response and peak capacity.
- **Additional income generation asset:** BESS can be used as an asset to defer or lower the requirement of new additional generation or reserve capacity and may be an additional source of income asset in the wholesale electricity market and bring in revenue for the generation company.
- **BESS as a generation asset does not require licensing for installation:** In the Indian context, classification of stand-alone BESS as a generating asset at par with a GENCO has made it a delicensed activity under the ambit of the Electricity Act 2003. Hence, its installation would not need the regular regulatory approvals for licensing, thereby expediting the entire proces.

**Disadvantages of BESS as a Generation Asset**

- **Reduced bankability of the project:** The energy storage generation per unit cost in its current context is high as compared to other sources of generation. Hence, the revenue linked to only generation and not to other applications that BESS provides may reduce its financial viability, especially when financed through non-recourse debt.
- **GENCOS may lack technical know-how:** Energy storage technologies are relatively new in the power market and are still evolving. The technical know-how on BESS and its operations may be lacking, with GENCOS needing external support.

### 11.1.2. BESS as Transmission Network Asset

In this implementation model, a transmission company will own the BESS asset and primarily be used for ancillary services, viz. voltage support and frequency regulation. The BESS will also help maintain electric supply reserve capacity, which can be used, if necessary, as spinning reserve in case of transmission interruption or for black start of the transmission system. It can further be used for congestion relief, if installed downstream of the congested section of the transmission network.

The BESS in this model will be dispatched by the load dispatch centre/grid controller and is expected to deliver maximum benefits to the health of the system (see Figure 39). Among other things, the grid controller can use BESS as a tool to limit the intermittency of the system and match the generation and load side of the electricity value chain in an efficient manner.

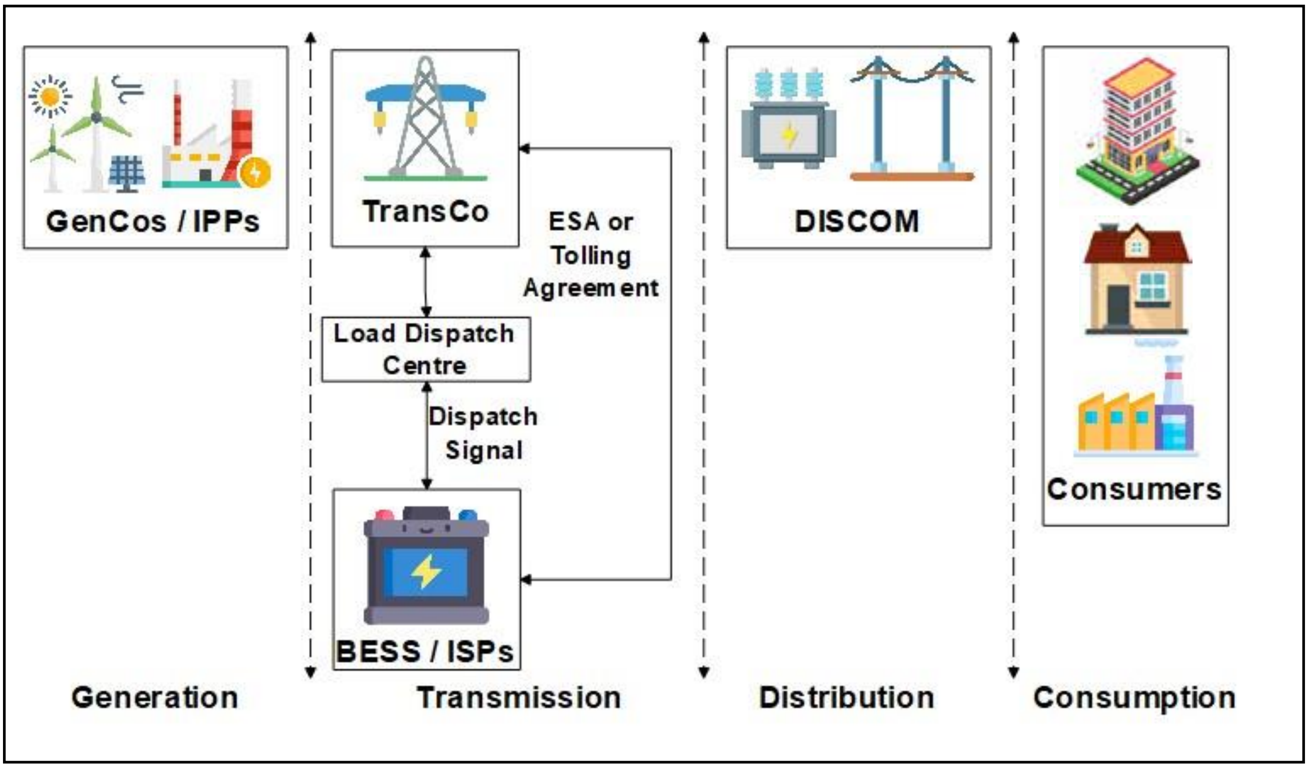



**Figure 39: BESS deployed as a Transmission Asset**

ISPs can also sell their services directly to a TRANSCO under a contractual agreement such as the ESA or under a tolling agreement (INR/kW-year), as prevalent in the United States power market, where storage providers own and operate the storage asset and the TRANSCO pays an annual premium and provides charging energy, and uses the stored energy when needed for grid services.

To examine the efficacy of BESS in India, the Power Grid Corporation of India Limited (Powergrid) launched a 1 MW pilot project with 500 kWh battery technologies and an associated battery management system, in Puducherry.[75] The storage system is being used for frequency regulation and energy time-shift applications.

**Advantages of BESS as a Transmission Asset**

- **Multiple benefits from BESS, both upstream and downstream of transmission network:** BESS as a transmission asset can provide multiple services such as voltage support, secondary and tertiary frequency regulation, spinning reserve capacity, and black start capability.
- **Ownership by transmission asset helps avoid regulatory approvals:** Unlike stand-alone BESS assets, the transmission network owning and operating BESS need not go through regulatory scrutiny for licensing and approvals. BESS can readily be deployed by TRANSCOS through CapEx or financed models.
- **Relieves transmission congestion and defers transmission system upgrade:** Deploying BESS downstream of the congested section of the network can relieve congestion and reduce transmission access and congestion charges, which will greatly benefit DISCOMs and consumers. BESS can also defer upgradation or expansion of the transmission network capacity.

**Disadvantages of BESS as a Transmission Asset**

- **Complex payment structure among beneficiaries:** When BESS is installed as a transmission asset, the direct beneficiaries of the system are both upstream and downstream, and hence it is difficult to apportion the benefit in value terms. therefore, benefits are more qualitative than quantitative, making the payment structure cross-linked and complex.
- **Complex control algorithms make load dispatch difficult for operators:** Given the multitude of services BESS can provide as a transmission asset, control algorithms to operate the BESS asset need to optimize its value and limitations and may require SLDC/RLDC to have sophisticated control algorithms to manage the portfolio of such assets.

### 11.1.3. BESS as Distribution Network Asset

Under this model of deploying BESS at the distribution network level, a DISCOM will own the BESS asset and may use it for peak load management, ancillary services, power quality enhancement, energy arbitrage, and as spinning reserve. BESS, when deployed as a distribution asset, can help the upstream transmission network to better manage congestion, especially if the DISCOM has high scheduled power and faces regular peak loading issues. The BESS asset will then be dispatched by the DISCOM based on the signalling from the load dispatch centre (see Figure 40).

Similar to the model of deploying BESS as a transmission asset, the DISCOM can also buy BESS services under a special contracting arrangement (ESA/tolling agreement) with an independent storage provider. The storage provider owns and operates the system on behalf of the DISCOM and dispatches BESS services based on signalling from the load dispatch centre and on real-time system parameters to ensure grid stability. Contracting the BESS services provides benefits upfront from day one and reduces the CapEx burden and operation and maintenance (O&M) risks involved for the DISCOMs, which is useful, given that several DISCOMs in India are generally financially stressed.

The BESS asset can also be deployed at the DT or feeder station level by the DISCOM for load management as required, based on congestion levels at the local network and infrastructure (see Figure 41). However, a contractual agreement to buy this service may not be viable for the DISCOM if it requires BESS to be deployed exclusively for load management as financial benefits are minimal. This is especially so at the DT level, where it will work as a distribution asset rather than a grid asset that can render services to the grid.

In 2019, the first grid-scale ESS project was completed by Tata Power, AES Corporation and Mitsubishi Corporation at the Rohini substation in New Delhi, with a capacity of 10MW for many applications, including peak load management, power quality enhancement and frequency regulation.

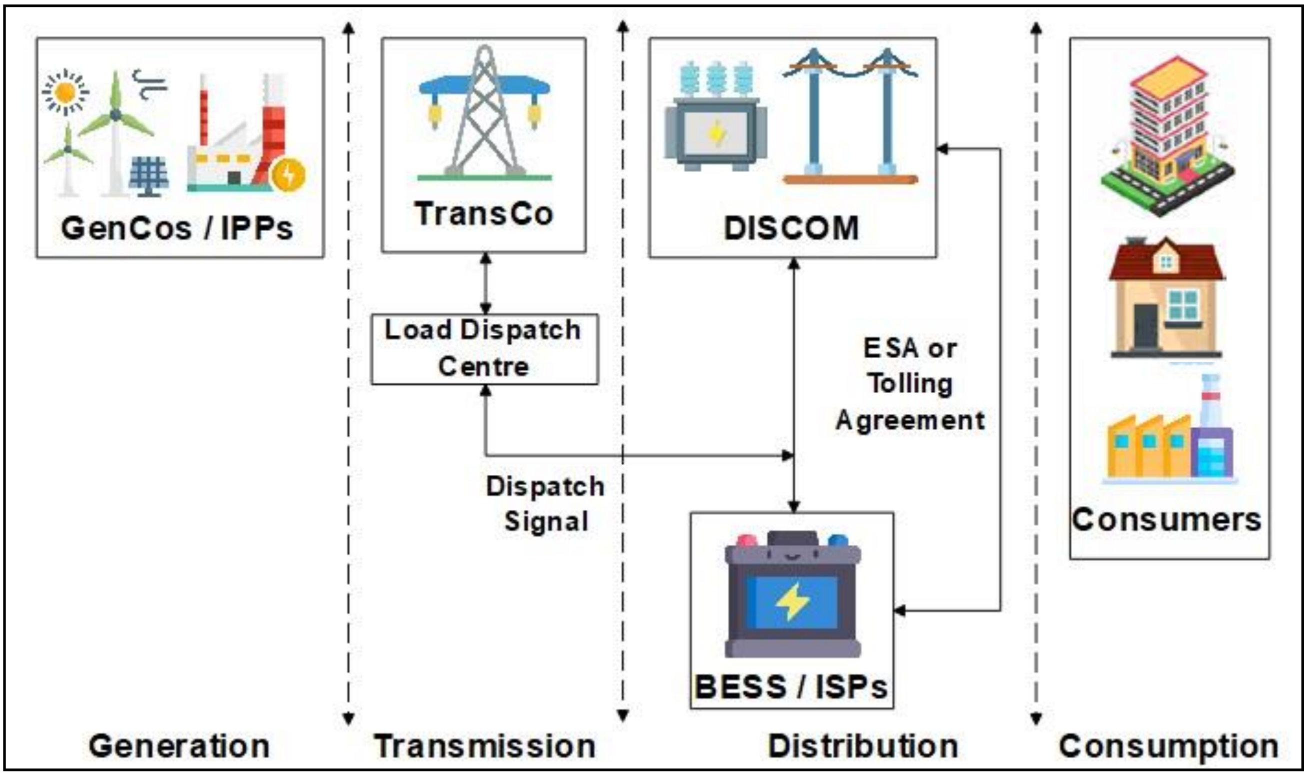



**Figure 40: BESS Deployed as a Distribution Asset to Provide Grid Services**

Since DISCOMs interact directly with large consumers and high-power demand areas such as commercial areas in cities, and large residential neighbourhoods, it is possible to implement innovative collaborative models to deploy BESS to support the local distribution network, while passing on part of the benefits to the customer through cost concessions or payments. One such example of implementation is explained as a case study in the box item below.

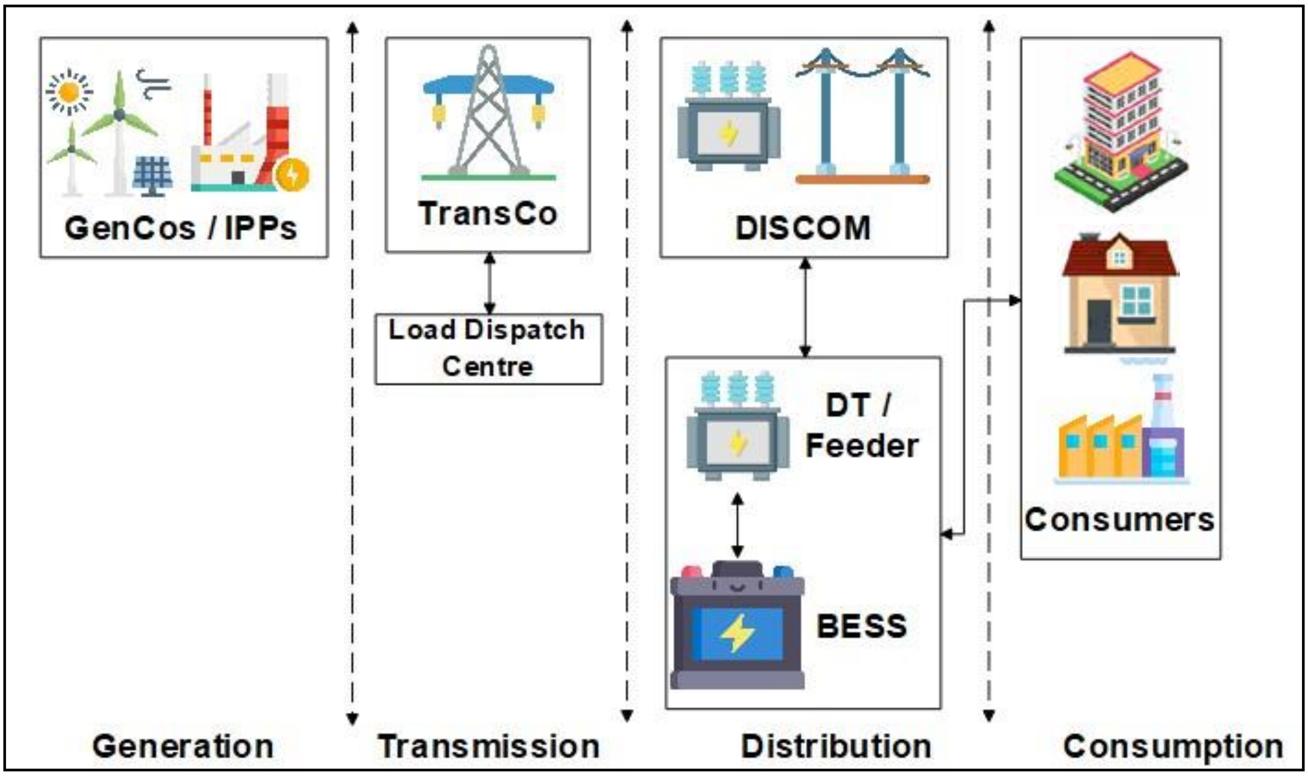



**Figure 41: BESS Deployed as a Distribution Asset to support Distribution Network Infrastructure**

## Case Study: StorageShare Model

**Background**

The Sacramento Municipal Utility District (SMUD), a community-owned electric utility, launched an innovative program in January 2020 to help achieve its net-zero carbon target by 2040.

**The Business Model**

Through SMUD's Energy StorageShareSM program, a utility-owned FTM energy storage asset can be purchased, which enables commercial customers (on tariffs with demand charges) to invest in it by purchasing "shares" that reduce their demand charges (1 share = 1 kW of demand charge reduction). This provides an alternative to BTM batteries. The demand fee reduction is applied to a customer's bill over a 10-year period by SMUD, who bases the share values on existing customer rate classes.

**Target Beneficiaries**

The program is targeted at commercial customers with a low load factor and high peak demand, customers in locations with low grid needs, and those not seeking back-up power. The program allows SMUD to optimize grid benefits of energy storage in addition to lowering customer power prices by building and managing a battery in accordance with local grid requirements.

*Source: Smart Electric Power Alliance and Energy Storage Association, 2020. Utility Business Models for Grid Connected Storage.*

**Advantages of BESS as a distribution asset**

- **Supports transmission network to manage congestion:** When BESS is deployed by a DISCOM as a grid asset, it will significantly improve the resilience of the DISCOM by providing grid services, acting as reserve capacity/power backup. It can also help the upstream transmission network to better manage congestion.
- **Defers distribution network upgrade or expansion:** Deferral of upgrade or expansion of existing distribution network can be achieved by deploying low-capacity BESS assets. This can lower costs for customers and improve utility asset utilization, especially when deployed as a system that can be moved across several sites as per load management requirements.

**Disadvantages for BESS as a distribution asset**

- **Reduced financial viability when deployed for end-distribution services:** The per unit generation cost of energy storage is comparatively high in its current context. Thus, when revenue or benefits are linked to the end distribution assets like DTs and do not account for other services, it may reduce the financial viability of the asset, especially when financed through non-recourse debt.
- **DISCOMs may lack technical know-how:** Unlike a TRANSCO, a DISCOM cannot always contract BESS services from ISPs, if it intends to deploy BESS for various services to better manage its operations across its networks for industrial, commercial and other consumers. But they may also lack the technical know-how on BESS and its operation and might require external support.

### 11.1.4. BESS as Merchant Asset (Private or Third-party Ownership)

Under this model, the ownership of the BESS asset is with private or third-party players in the power market, who act as ISPs to render services to the market. Traditionally, increased electricity prices typically lead to larger profits. However, for storage to be profitable, price volatility is crucial. Volatility of electricity prices is anticipated to rise in tandem with the increasing penetration of wind and solar energy in many global grids[76], while the same is yet to hold its sway in an evolving Indian electricity market. This requires private capital investment for energy storage in the Indian power market, which continues to be predominantly state-owned, except on the generation side.

ISPs can provide services by deploying BESS as a transmission or distribution or end-consumer level asset. The location of the ISP-owned BESS asset will be dependent on the type of service rendered and to which segment/player in the market. The ISPs can dispatch the BESS based on signalling from the load dispatch centre, when the services are directly rendered to the grid. In other cases, it will be dependent on contractual agreements, and inter-party scheduling methodology agreed upon between the parties (see Figure 42).

With the Ancillary Services Regulations notified in March 2022, BESS as a merchant asset may be an attractive option to entice electricity market proponents to participate in the market. ISPs, along with other market participants, can play a significant role in the Ancillary services market aimed at ensuring fast and reliable load generation balancing forces through market procurement, once they become operational in India.

ISPs can also engage in energy arbitrage in the global markets where they earn revenue from opportunistically buying and selling electricity at hourly or sub-hourly intervals. ISPs can provide grid services by deploying BESS both as a transmission and distribution asset and can play aggregator roles in deploying it for a group of consumers and engaging in the power markets, while passing on the benefits to the consumers.

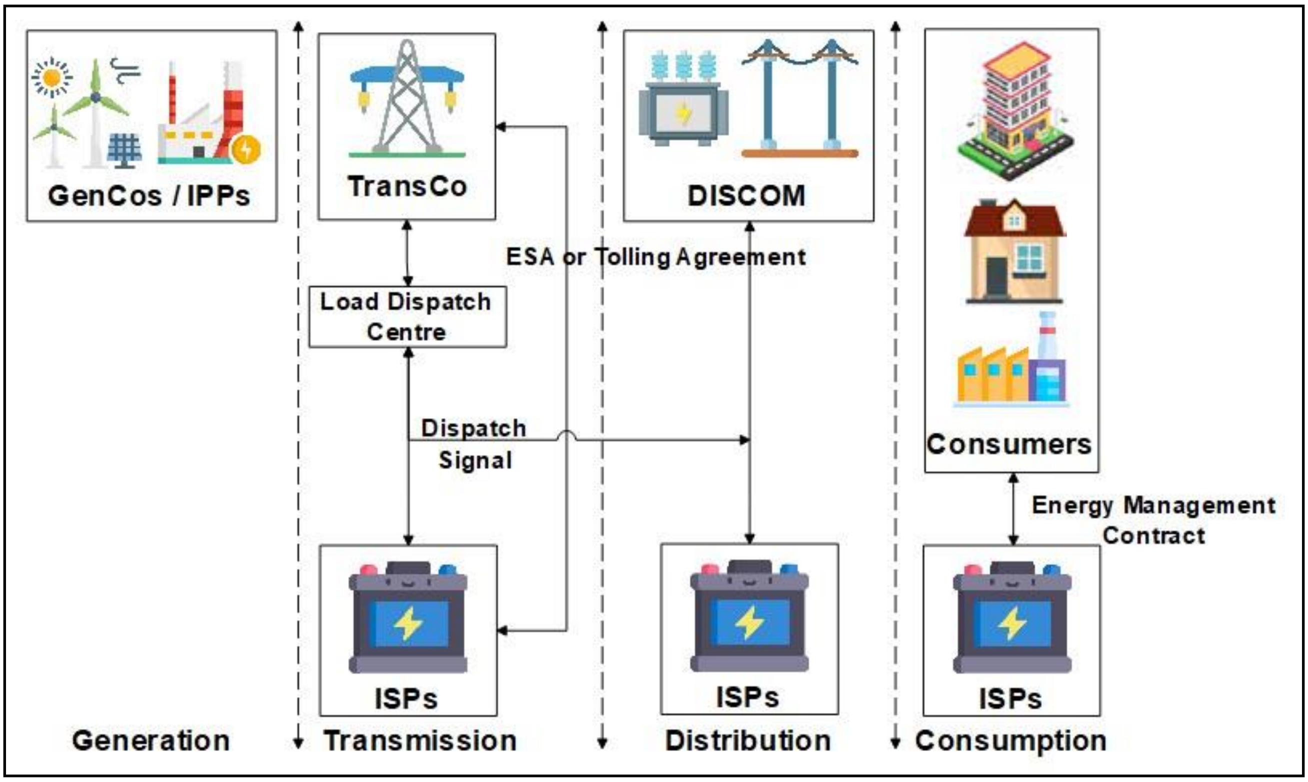



**Figure 42: BESS Deployed across Power Value Chain as Merchant-owned Asset, Providing Storage Services**

**Advantages of BESS as a Merchant Asset**

- **Strong opportunity ahead:** With the integration of additional VRE in the grid, the market is expected to be strong for ESS's that can bring stability to the grid. With decreasing costs of BESS, several opportunities exist in different segments of the power market, given the regulatory acceptance in India in the light of ancillary services market and a push for resource adequacy. This opportunity can be explored by merchant-owned BESS that can play an important role in the market by taking on the requisite CapEx and O&M risks, while providing crucial services to the power market..

**Disadvantages of BESS as a Merchant Asset**

- **Pairing with RE may not always be a value maximiser:** Since charging is only permitted during times when the RE sources are producing energy and because the net production of the renewable asset is decreased, dedicated renewable (wind and solar) charging adds expenses to projects (due to battery efficiency losses). The trade-offs should be measured, when comparing projects that couple RE with energy storage to those that use standalone storage to provide services to generators.
- **Policy to be an uncertainty for merchant storage:** Merchant storage may be subjected to changing policy interventions, subject to the nascent stage of the technology, and it may take time to find its feet in an Indian market, which is currently heavily tilted on the price points rather than resource adequacy front.

- **GHG emissions from storage and its attractiveness to climate-sensitive funders:** The pressure on lenders to invest in projects that mitigate climate change is likely to increase the scrutiny placed on the emissions associated with the manufacturing, assembly and systems operations of storage system components, which are largely ignored today..

## 11.2. Implementation Models for BESS in Behind-the-Meter Applications

BtM refers to systems that are located on the consumer side of the electricity market, such as in homes, commercial areas and industrial facilities. They are usually owned by consumers and are mainly intended for their captive use.

Consumers with high power demand and energy consumption end up paying significant energy bills. They are mostly unaware of the potential benefits that can accrue from using an ESS as an energy management asset, including reduction in electricity tariffs (both energy and demand charges), improved voltage profile, and power quality enhancement, among others.

Building this awareness and developing flexible business models that can be tailor-made to the needs and circumstances of a consumer is crucial to the deployment of BESS in BtM applications. Consumers should be encouraged by DISCOMs to explore energy storage options through pricing mechanism. They can also explore collaborative business models with end-consumers to deploy BESS for energy management on the BtM side.

In BtM applications, BESS can be typically deployed in two different models, CapEx and Energy Service Company (ESCO)/Renewable Energy Service Company (RESCO) models, depending on the ownership of the asset, investment type and operations. Table 11 gives an overview of the implementation models for BESS in BtM applications.

**Table 11: Overview of Implementation Models to Deploy BESS for BtM Applications**

| Details | CapEx Model | ESCO / RESCO Model |
|---|---|---|
| Location of battery | BtM | BtM |
| Ownership | Consumer facility | ISPs |
| Dispatch | Consumer | ISPs |
| Applications | Energy arbitrage, peak load management, power back-up, power quality enhancement | Energy arbitrage, peak load management, power back-up, power quality enhancement |
| Value maximization | Maximum | Maximum |
| Bankability | Low to medium | High |

### 11.2.1. CapEx Model (Customer/Facility Owned BESS)

In the CapEx model, all investments are made by the host facility viz. commercial establishments like hotels, hospitals, retail centres, shopping malls and industries. The host facility takes on both the CapEx and O&M risks and strives to get optimal benefits out of the BESS deployed. However, the host facility requires significant technical expertise to deploy and operate the BESS, even if it is only for captive use. Unlike RE plants, BESS requires technical expertise for regular monitoring, planned operation and maintenance (though minimal), taking into consideration the system performance characteristics.

Alternatively, large consumers that would like to own and operate BESS can contract energy storage service providers to deploy BESS, and to operate and maintain the asset on behalf of them, based on fixed annual premiums, similar to an O&M contract entered into with RE developers.

**Advantages of CapEx model**

- **Ownership with the host entity:** Since capital expenditure is from the host entity, the interest of the consumer is paramount, and the system will be optimized to enhance energy performance of the facility.

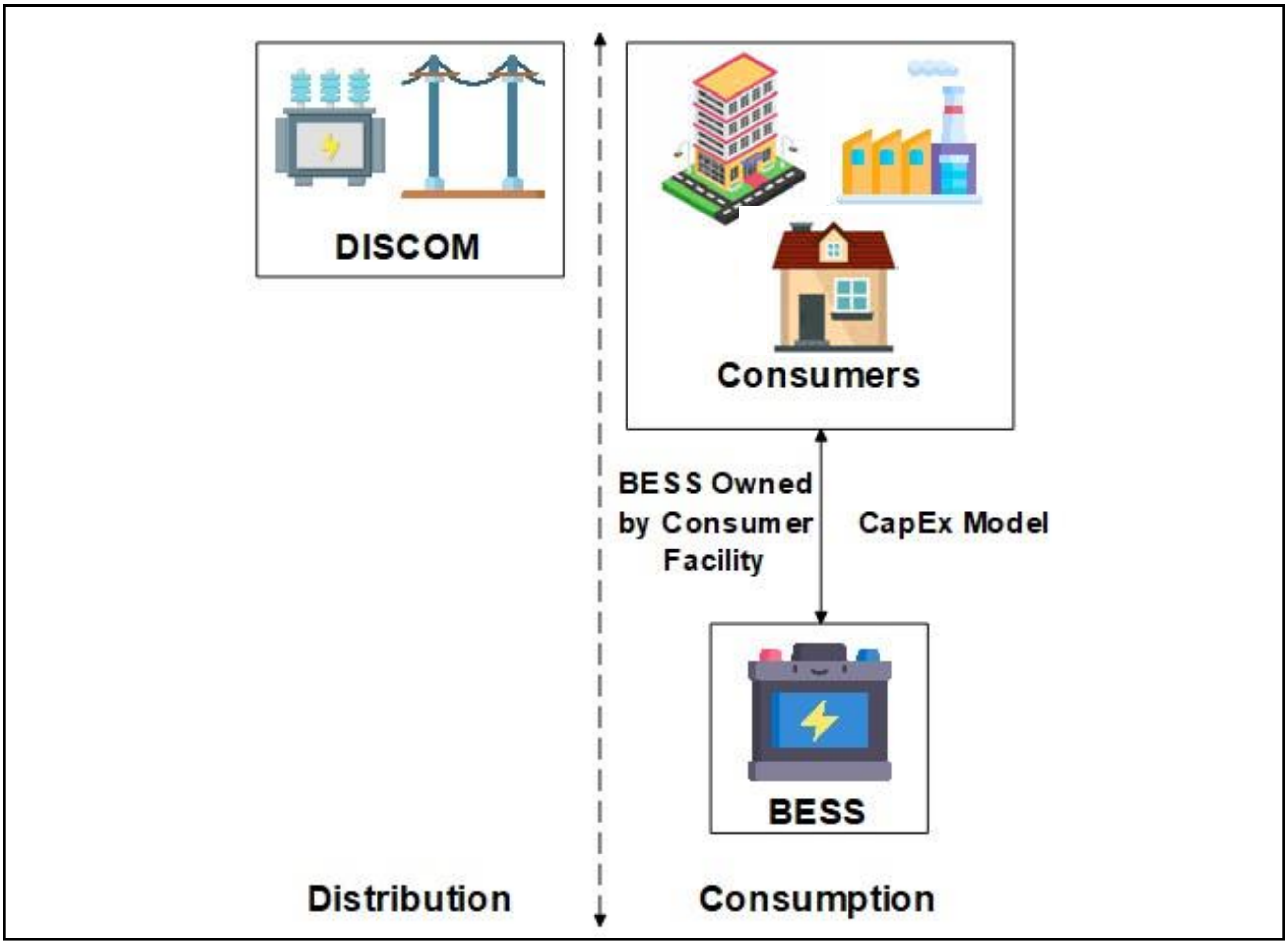



**Figure 43: BtM BESS Deployed through CapEx Model**

**Disadvantages of the CapEx model**

- **CapEx burden on host facility:** Given the current costs of battery systems, the upfront investment cost may be a restricting factor for the deployment of BESS by consumers.
- **Lack of technical know-how:** Lack of technical know-how and expertise in the operation of BESS could result in sub-optimal performance of the system and minimal benefits achieved.
- **Control may not be with system operator:** Since the deployment is BtM, the engagement of the system operator is limited, and the operation of the BESS will be focused on energy performance of the host facility and not on ensuring overall grid performance or stability during charging or discharging of BESS.

### 11.2.2. RESCO/ESCO Model (Vendor/Third-party Owned)

End-consumers that do not have the financial leverage to deploy BESS as an energy management asset can opt for an ESCO/RESCO model, wherein the expertise of an industry expert/institution is leveraged to avoid an upfront cost, while a fixed annuity payment is made on the basis of certain conditions met by the operator.

In the ESCO/RESCO model, ISPs can enter the BtM market by offering more holistic energy management services, as opposed to offering energy storage services exclusively. Many of these firms can include ESCOs/RESCOs that offer long-term energy management contracts to their customers, which can also include energy efficiency measures, and RE deployment.

In this model, the financing of the project upfront is managed by the ESCO/RESCO, which will also operate and maintain BESS as part of an energy management contract. The contract is a robust mechanism under which a minimum performance is guaranteed by the service provider to the host facility, while receiving a fixed/variable premium from the facility depending on the system performance. This model eliminates the performance anxiety of a consumer by assuring the security of performance. On a global scale, these models have allowed a growing number of commercial and industrial customers to benefit from energy storage deployment without incurring significant upfront expenses.

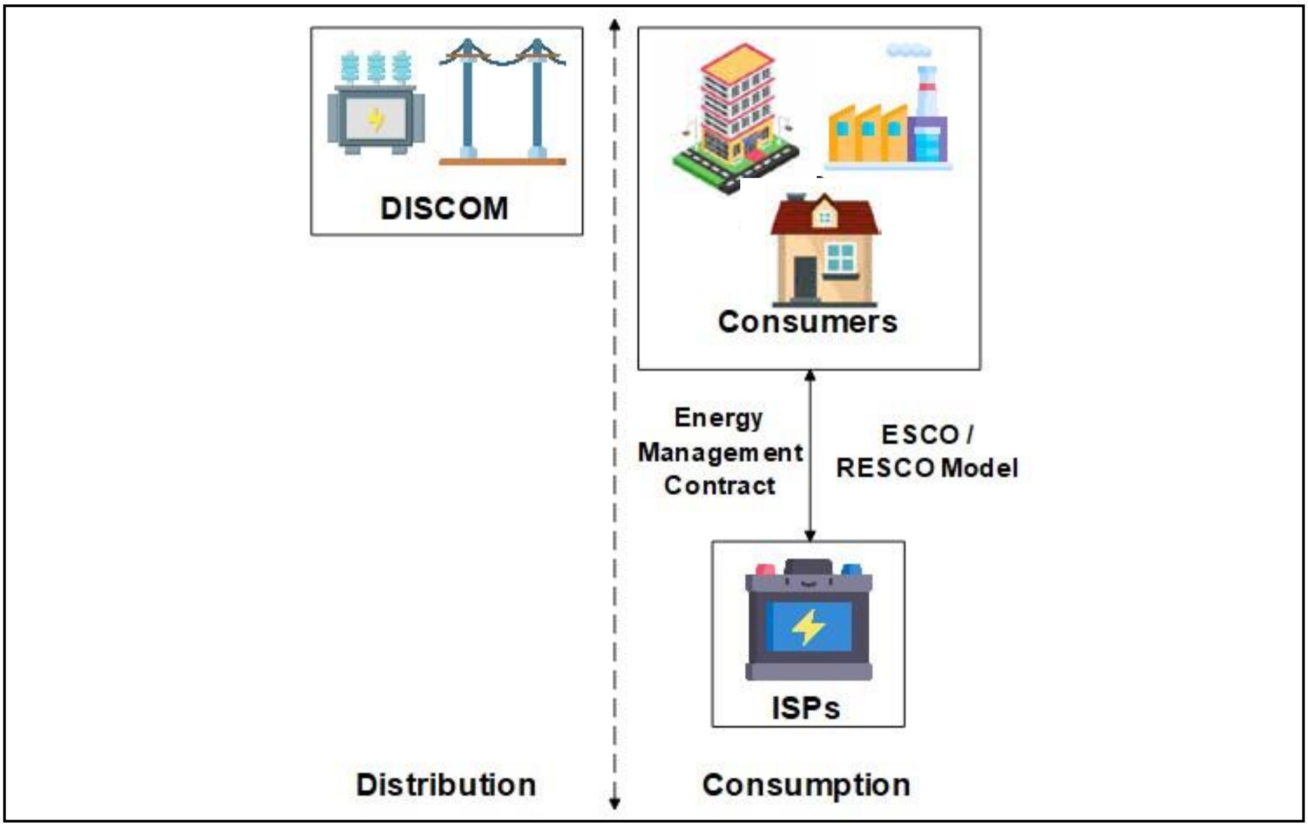



**Figure 44: BtM BESS Deployed through ESCO/ RESCO Model**

**Advantages of BtM ESCO/RESCO model**

- **No upfront investment cost for host facility:** In the ESCO/RESCO model, the total upfront investment is being made by the expert agency, which may or may not finance the project and enters into a contract with the host based on their financing and operational model.
- **Proper operation and maintenance ensured by experts from ESCO/RESCO:** The agency also ensures O&M as per standard operating procedures and the requirements of the host facility, and is paid annually on the basis of meeting system performance criteria agreed upon with the facility.
- **Involvement of Resident Welfare Associations and similar communities:** The involvement of ESCO can allow BESS uptake at the micro-level and bring in masses who benefit from it. This shall bring in BESS orders in volumes as it has done for solar rooftops in recent times.

**Disadvantages of BtM ESCO/RESCO model**

- **Control may not be with system operator:** Since the deployment is at the BtM, the engagement of the system operator is limited, and the operational algorithm for BESS used by the ESCO/RESCO will be focused on optimal energy performance for the host facility, as their revenue is dependent on it. Therefore, the grid characteristics and stability may not be a key criterion for charging or discharging of BESS.

# 12. Enabling Actions and Recommendations for BESS Adoption

This section presents key enabling actions and recommendations that have been identified from the study and assessment for Rajkot and Surat and are pertinent to the shortlisted BtM and FtM use-cases. Based on the state and local context in Rajkot and Surat, opportunities, actions and urban planning linkages have been identified using which urban and power sector stakeholders (specifically ULBs and DISCOMs) can work together to jointly promote BESS at the city-scale. Policy and regulatory measures to support BESS adoption have also been suggested.

## 12.1. Leveraging Urban Planning Linkages and Coordinated Action between Urban and Power Authorities

With their urban development trajectory and plans, Rajkot and Surat are poised for an increase in building stock, infrastructure and utilities, leading to a rise in energy demand and the need for sustainable and reliable energy supply at the city-scale. Both cities have ambitious plans for RE and EV scale-up, which needs to be integrated into their urban energy systems and electricity networks.

While city governments have a limited role in energy distribution, through their core functions of spatial and urban planning, they can influence energy use and power distribution networks. City planners and DISCOMs need to work closely together for effective integration of urban development planning and urban energy planning, specifically electricity planning.[77] Such an integration will enable sustainable energy management at the urban scale and support the integration of RE, e-mobility and efficient solutions such as BESS.

### 12.1.1. ULBs and DISCOMs Coordinate on Integrated Spatial and Energy Planning at the City-scale and Promote BESS through Urban Development Regulations

City development planning processes undertaken by the ULB in coordination with the Urban Development Authority (UDA) includes zonal and land-use planning i.e., identifying and demarcating transit-oriented zones, preparation of micro-scale town planning schemes, high-density development corridors, mixed compact land use, commercial and industrial zones, and areas for greenfield development and redevelopment. Officials from local DISCOMs and GETCO can be engaged as part of the Development Planning Committee that includes stakeholder representation to provide inputs and steer the development of the urban spatial and development plans. This will facilitate inclusion of energy planning into the overall urban planning process through the following entry points:

- DISCOMs will be aware of specific locations targeted for development and proposed spatial planning and zoning at an early stage. This will help estimate the power demand and loads against existing infrastructure capacity, plan for peak demand management by using BESS and other solutions, and electricity distribution network management in advance. DISCOMs can also suggest inclusion of appropriate provisions for energy infrastructure at select sites for effective energy planning.
- The DISCOM and GETCO may suggest suitable energy management options for grid balancing or to encourage the use of RE, supplemented by BESS, at the planning stage for several consumers, particularly HT consumers such as industries and large commercial complexes. ULBs and the UDA may consider promoting such measures through mandates or incentives included in the General Development Control Regulations (GDCR).
- The DISCOM will be informed on sites where densification and redevelopment has been proposed by the ULB and about the ensuing impacts on future electricity demand. For such sites, DISCOMs will be able to better assess future power demand against existing grid capacity and infrastructure, aiding distribution planning and identification of opportunities for integration of RE and BESS for sustainable energy management.
- DISCOMs can share information on electricity distribution characteristics and challenges in the city, including DT overloading, T&D network congestion, voltage, and frequency fluctuations, and on RE integration plans with the ULBs and urban planners. Potential measures for efficient energy planning to be included at the larger development planning or town planning scale can be identified along with DISCOMs.

The DISCOMs can provide inputs to ULBs related to zoning, development mix and building prototypes that are tailored for efficient energy use and to enable deployment of BESS.

- The DISCOM can coordinate with the ULB and relevant transport authorities for zoning and locating EV charging infrastructure, factoring in the existing electricity network capacity, implications of resulting energy demand on grid infrastructure, opportunities for RE integration, and network upgrade planning.

### 12.1.2. Urban Local Bodies and DISCOMs can Coordinate during Planning and Implementation of Electric Mobility and Sustainable Energy infrastructure to Promote BESS

The concerned departments of ULBs (such as Energy Efficiency Cell in SMC, Implementation Committee formed under Smart City SPV, or Electrical department of ULB) can coordinate with DISCOMs and power sector institutions for planning and effective implementation of city-level policies and projects on e-mobility and charging infrastructure, RE deployment and energy management. BESS adoption can be promoted through joint action targeting priority use-cases across these areas as noted below.

**Coordination for EV Charging Infrastructure and BESS**

- DISCOMs can work closely with the ULB and urban transport agencies for EV charging infrastructure planning, identification of locations and land allocation. This would help DISCOMs plan for and meet immediate power demands through existing grid network and understand the need for system augmentation. Opportunities for BESS deployment for public EV charging infrastructure (especially high power-rated fast-charging stations) or at locations where BESS can dovetail with on-site RE deployment and help in the deferral of costly network upgrades, can be identified.
- Information from the ULB on EV targets and plans for charging infrastructure deployment can feed into technical studies, needs assessment and demand forecasting by DISCOMs to plan for current and future EV loads. This will support DISCOMs in developing load management strategies and grid upgradation plans, integrating solutions such as BESS, planning for power purchases and supply as necessary, and identifying opportunities to promote RE and BESS solutions at EV charging stations.
- ULB and DISCOMs can jointly promote RE and BESS as an integrated solution to make EV charging sustainable and to align them with net-zero emission targets and sustainability goals. To this end, a program targeting public and large commercial EV charging infrastructure can be built over time. Such mid to large-scale charging stations can be targeted for BESS pilot projects to be implemented jointly with charging operators.
- DISCOMs can work with ULBs to assess locations where EV adoption is expected to grow rapidly. DISCOMs can then plan for power supply and DT upgrades to cater to the large number of EV chargers that might come up at those locations in the long-term, rather than to the few charging stations expected in the short term. Given the uncertainties around utilization of EV charging stations and their power demand at present, opportunities to supplement DT upgrades and optimize the power demand at the charging stations through on-site solar PV and BESS, can be explored.
- ULBs can coordinate with DISCOMs to identify clusters such as IT parks, knowledge parks, industrial hubs, greenfield development areas, and special economic zones where the deployment of mid to large-scale EV infrastructure (fast-chargers) in public parking integrating RE and BESS (if feasible) can be targeted.
- Public e-bus and commercial fleets are currently being deployed on a pilot-scale and will grow rapidly towards fleet-wide electrification. DISCOMs can engage with ULBs and transport operators to understand the prospects and timescale of future EV expansion, allowing them to plan for distribution network upgrades to accommodate additional power demand, considering the expansion in fleet electrification. BESS can facilitate deferral of distribution capacity upgrades where feasible, and support planning for long-term distribution network augmentation.[78]
- DISCOMs can advise operators of large fleets (ULBs for public e-buses and commercial fleet operators) and EV charging facilities to optimize charging patterns to reduce energy charges, minimize grid upgrade costs, and facilitate RE and BESS adoption for time-shift and peak management.

**Coordination for RE and BESS**

- With a substantial push on RE in the overall energy mix planned - Surat, for instance, has targeted to achieve 25% of its total energy procurement from RE sources by 2030 - balancing the intermittency of RE and its smooth integration into the power system is important. DISCOMs can advise on the spatial distribution of large-scale RE projects proposed by the ULBs, considering the implications on their power distribution network. Similarly, DISCOMs can provide suggestions on rooftop solar PV deployments and large-scale RE projects targeted across different consumer categories at the city-scale. They can provide technical support to identify and evaluate opportunities to deploy BESS with RE systems, including in municipal utilities for Rajkot and Surat wherein significant RE deployment is planned.

- For municipal facilities and infrastructure, ULBs are currently incorporating power backup through DG sets for utility services (such as water and wastewater) and emergency services (such as hospitals and fire stations). DISCOMs may provide suggestions and technical support to the ULBs for pre-feasibility assessment of BESS along with RE for maximum utilization of RE plants deployed/to be deployed for captive consumption by the ULB and for replacing DG sets with BESS.

- Anticipated urban development will lead to an increase in the electricity demand for urban utilities and services (such as water, wastewater, healthcare and emergency services), as well as in commercial and industrial areas. Through information from ULBs on the type and scale of development planned, DISCOMs can carry out load growth forecasts and identify potential opportunities for BESS at feeder/DT-level and BtM, and RE deployment for peak demand management and reliable clean power supply.

- DISCOMs and ULBs can work together to engage and advise local RE developers and large consumers to co-opt for BESS, indicating the key benefits and opportunities therein. Both can together develop a scheme for developers to promote BESS uptake, in line with existing policies and regulation.

- Significant RE deployment and anchor loads will come up in growth centres and greenfield areas such as Dream City in Surat and Rajkot's Smart City area, which are within the local government control and at the early planning stage. Implementation of battery energy storage can be targeted in such areas through funding from national and state government schemes or through PPP model or direct investments.

- ULBs and DISCOMs can jointly develop and implement a BESS pilot project, potentially attracting technical assistance and concessional financing. Such a demonstration project can boost stakeholder confidence in the technology, capture benefits realized at the end-use as well as at the distribution network, showcase the business model and prove commercial viability, and provide information and experience for broader private player adoption in the future.

### 12.1.3. Institutional Framework for Coordination between City Government, DISCOM and Stakeholders

In the medium term, the necessary integration of urban and energy planning at the city-scale and across urban infrastructure can be facilitated and formally operationalized through a 'Technical Unit' within the city government. This Technical Unit would be responsible for planning, implementation, and overall coordination with various stakeholders on sustainable urban energy management. It will advocate and promote sustainable energy systems and technologies, including BESS.

The Technical Unit can align with existing institutional structures in the ULB and need not be a standalone entity. It can be embedded in an existing nodal department, such as the Energy Efficiency Cell in SMC, Electrical and Lighting department in RMC, or a department in the Smart City SPV as appropriate. The nodal department will directly report to the Municipal Commissioner on various activities undertaken by the Technical Unit, which is envisaged to be led and managed by dedicated ULB staff. To begin with, the unit can be established on a smaller scale to include one or two full-time technical staff and be built and expanded over time. Services of external consultants or experts can be utilized on part-time basis as needed, depending on the ULB context and capacity.

A key function of the core team of the Technical Unit will be periodic coordination with local DISCOM(s). To enable this, a technical officer(s) from the concerned DISCOM is proposed to be a part-time member of the Technical Unit who would report to a higher authority or decision-maker in the DISCOM (such as Managing Director). The Managing Director of the DISCOM(s) is suggested to also be a part-time member of the Technical Unit and may report directly to the Municipal Commissioner, as needed.

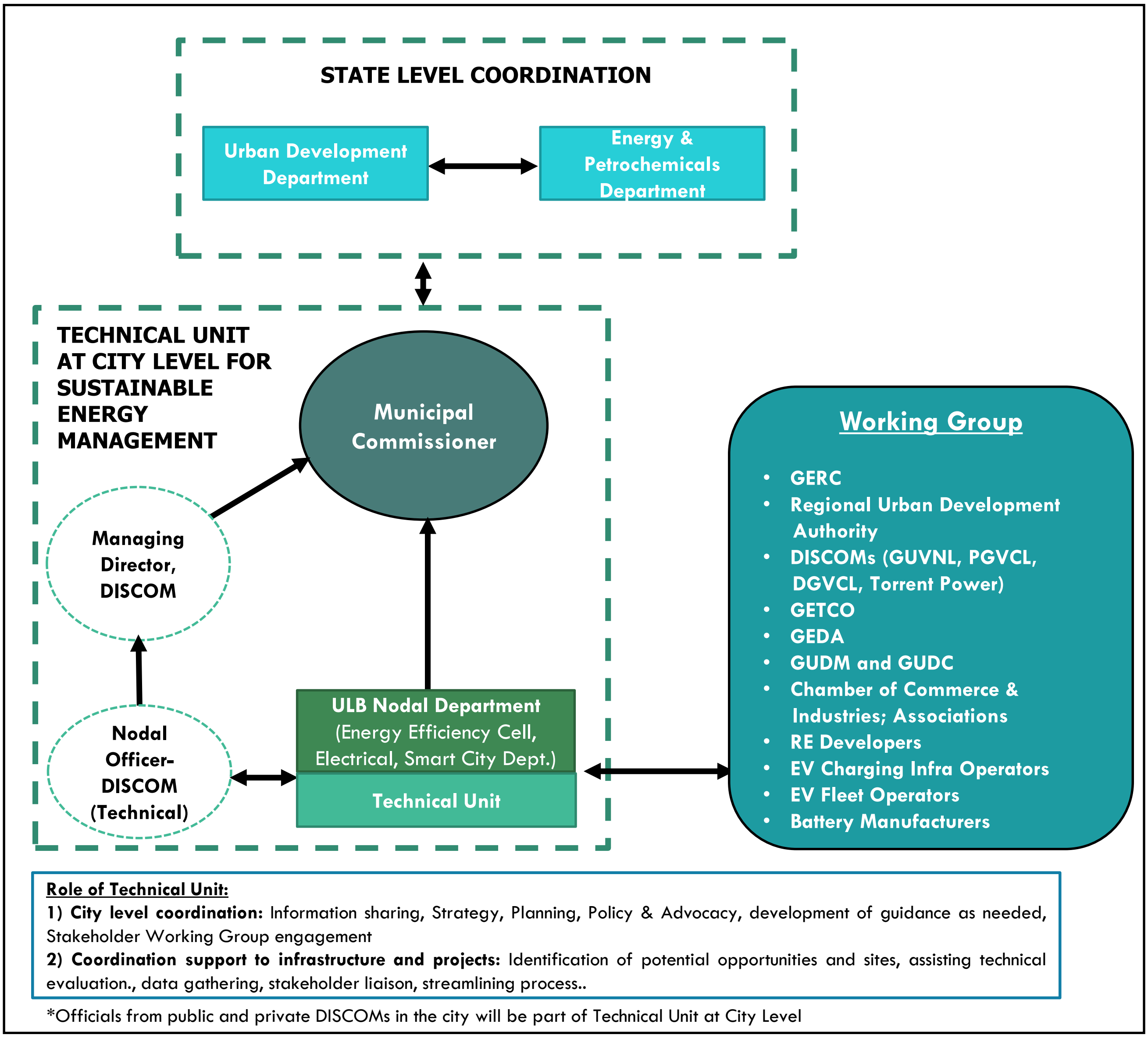



**Figure 45: Institutional framework for coordination between local implementing authorities, DISCOMs and other stakeholders**

The Unit is proposed to engage with its members from the DISCOM (bi-monthly or quarterly) to discuss urban and power planning, RE and EV planning by the ULB and other stakeholders, energy demand and power-related issues faced by the DISCOM, for data sharing and recording, and for evaluation of various options for sustainable energy management in the city (including BESS). The proposed structure can help the ULB leverage the technical expertise and knowhow of the DISCOMs for integration of BESS in areas of high potential, while DISCOMs can utilize information on urban development, plans and the existing capacity in the ULB (viz. Surat has Energy Efficiency cell, for instance, that can collaborate).

Specifically with regard to BESS, the key activities of the Technical Unit can include capacity building of local officials to increase awareness, establish data sharing and information recording protocols between various stakeholders, bridge the knowledge gaps to enable adoption of BESS with EV and RE projects, support prioritization of BESS use-cases depending on location or targeted consumers, liaise and engage with the concerned parties for BESS evaluation at potential sites, and support the identification of implementation and business models, among others.

The Technical Unit will function under the directive of state departments for energy and urban development, and report to them through the Municipal Commissioner. The Energy and Petrochemicals Department of the Gujarat Government is responsible for overall energy management in the state, while the Urban Development Department is responsible for state-wide urban development.

A key responsibility of the Technical Unit will be to periodically coordinate and engage with a wider local stakeholder **'Working Group'**, proposed to be chaired by the Municipal Commissioner. The Working Group will discuss, and provide inputs on city-wide sustainable energy management, planning and recommendations for interventions including BESS (as possible) and may meet on a quarterly or half-yearly basis. It can include stakeholders such as DISCOMs, GETCO, GERC, GEDA, Chamber of Commerce and Industries and related associations, EV fleet operators, EV charging operators, RE developers and battery manufacturers among others.

## 12.2. Policy and Regulatory Support for BESS

Existing policies and regulations in India of relevance to BESS have been discussed in Section 7. This section provides recommendations and interventions on policy and regulations in order to strengthen the role of storage in the power system.

### 12.2.1. Policy Measures to Enable BESS Adoption

A key enabler required for BESS deployment and its scale-up in the Indian power market landscape is a comprehensive National Energy Storage Policy that guides the development of the energy storage industry. A comprehensive policy is crucial for the development of the energy storage sector, as it can provide a long-term vision and road map for proliferation of storage, and support the establishment of necessary incentive structures to attract private-sector participation. The necessity of such a national policy framework should also be established through the Electricity Act 2003, as has been done for the National Electricity Policy and National Tariff Policy, both of which are amended periodically as per the needs of the Indian power market. Notably, the Draft Electricity (Amendment) Bill, 2020 proposed a National Renewable Energy Policy to be notified by the Central government. Such a policy should also include considerations and opportunities for BESS deployment to enable higher integration of VRE into the Indian power system.

At the city level, BESS deployment can be accelerated through local and sub-national policies and targets. Such local interventions are discussed below.

**Mandatory Inclusion of BESS in the RE sector policies**

With an increase in the share of RE in the energy-mix, a new set of challenges has been faced by industry players in the energy sector. Apart from the intermittency issues, recovery of network investment costs is one of the major obstacles to the grid integration of various RE sources. Provision of BESS in state RE policies shall go a long way in facilitating the integration of RE. As Gujarat is inherently resource-rich in terms of solar and wind power, facilitating abundant RE is challenging while keeping the grid safe and avoiding fines and penalties[79] to RLDC. Further, the cost recovery of network investments is achieved mostly from the consumers, which increases their financial burden. The mandate for BESS incorporation by the state governments at multiple inflection points of the electricity value chain can be a prudent investment decision in the long run.

Recommendations in this regard are:

- It is crucial to create market instruments that capitalize on the fast response time of batteries. High-capacity BESS projects for FtM applications can be implemented for intermittent capacity firming for the generators and deferral of grid network investments for both transmission and distribution companies. This can also help alleviate the resulting financial implications on consumers.

- Given that the Indian RE sector is now mature, the imposition of stiff penalties for forthcoming utility-scale grid-connected RE plants, when energy production differs greatly from forecasts, can incentivize RE owners to install BESS to reduce such deviations and supply committed RE based power.

- BtM projects with RE and BESS offer peak load shaving and energy bill reduction for consumers, while alleviating peak load stress on DISCOMs at the same time, and provide the DISCOMs a tool to regulate ancillary services. Enabling smaller participants such as BESS operators and 'prosumers' (producers–consumers) to offer ancillary services by reducing the minimum bid size (MW) and volume of available energy (MWh) shall be an important intervention to promote BESS.

**DISCOMs to plan and develop proposals for implementation of BESS projects at city level**

With the increasing VRE and EV integration in the local grid system, DISCOMs encounter several challenges such as high varying load and demand, and the management of grid infrastructure. Addressing these challenges in load management is of utmost importance for DISCOMs to ensure reliability and quality of power supplied to the end consumers. BESS can be deployed by DISCOMs for distribution load management, ancillary support and to assist in operational expenditure management. DISCOMs that perceive opportunities and requirements for BESS in their distribution infrastructure can plan for implementation of BESS and seek necessary approvals from the regulator through the following avenues:

- Submission of a detailed project report, incorporating technical and financial proposals for the projects, to the concerned SERC to seek approval
- Including BESS under CapEx as part of DISCOMs' multi-year-tariff proposal and seek SERC approvals

DISCOMs can potentially recover the expenditure for such BESS projects at distribution-scale through a marginal tariff hike spread among their consumer base, which is benefited through the BESS project, or through legacy charges in tariff increase staggered over a few years, subject to the approval of the SERC.

**Inclusion of BESS in Urban Planning, City Climate Action Plans and Sustainable Development Plans**

Cities are setting-up RE targets to boost deployment of renewables and meet climate and sustainable development goals. Surat and Rajkot have prepared Climate Action Plans that include RE and energy-efficiency strategies. They have ambitions to align with and support India's net-zero emission targets. Considering the benefits of deploying BESS along with RE and EV infrastructure, cities can implement BESS at a pilot scale as a best practice under relevant state and national government schemes, policies and programs, which can pave the way for further BESS proliferation. As noted in section 12.1, ULBs can also promote BESS at the city-scale through urban and land-use planning mechanisms.

- **From an urban system perspective**, state and city policies should include provisions to promote BESS as an energy management asset that supports the scale-up of RE and sustainable energy use in major urban services and public utilities, greenfield developments, special zone developments, and areas with mini-grids. This can help steer and advance BESS deployment. Establishing measures and targets for BESS in policies can help instil investor confidence and bring coherence in the energy-related interventions that the local governments are implementing.
- **From the mobility transition perspective**, cities can equip charging stations with RE and BESS to help achieve net-zero ambitions. Through the Surat EV policy 2021, Surat targets the installation of 500 EV charging stations to support electrification of its mobility sector. Rajkot is currently in the process of drafting an EV policy of its own and is increasing its e-bus fleet. Hence, BESS can be promoted through the policy to support the establishment of low-carbon and energy-efficient charging infrastructure. Specific targets can be outlined for EV charging stations to be equipped with BESS, where suitable.
- **From an energy perspective**, both Surat and Rajkot have set ambitions goals for RE uptake, which offers opportunities for BESS. Specific targets can be set to promote deployment of BESS in forthcoming installations of RE systems by both cities.

**Incentives for early adopters of BESS and load managing facilities**

As a solution that supports the integration of VRE, energy storage should be rewarded for its contribution to improving energy security, providing reliable power and decarbonizing the electricity grid. For instance, large industrial and commercial facilities can have varying and unpredictable electricity demand, depending on the day, time, season and other factors that make it challenging for local DISCOMs to manage the supply of power. At times, DISCOMs need to procure additional power from power exchanges at significantly higher costs to meet the demand during peak hours. Deployment of BESS in such facilities and end-consumers can help better balance loads between peak and off-peak times, ultimately also benefiting the DISCOMs in terms of energy security and efficient network operations at lower costs.

With BESS offering such services and benefits at different points of the electricity value chain, helping mitigate deviations in the electricity system and improve grid security, financial incentives, such as those listed below, can be offered to promote BESS. This will also help support the financial viability of BESS deployment, given its high capital costs at present.

- Fiscal or tax incentives, among others, can be offered to the best-performing power generation asset.
- Such incentives can be financed, at least partially, through penalties that are collected from deviating agencies
- Tax depreciation can be offered for energy storage installations, to reduce the tax obligations by a certain percentage of the income or corporate tax (for the businesses and individuals) and help reduce BESS costs.

Early adopters of RE-cum-BESS installations can be offered appropriate incentives that are proportionate with the capital cost of BESS, up to certain BESS module capacities (to be decided by the concerned authorities).

**Promotion of BESS through nodal agencies or dedicated Technical Cell at the State level**

Formation of a dedicated Technical Cell or Unit for Energy Storage at the state level can promote adoption and realization of opportunities across urban areas and beyond. Such a state-level Cell can be responsible for BESS-related promotion planning, execution, monitoring, coordination, and preparing and disseminating data at periodic intervals to stakeholders in a transparent manner. The Cell can be formed inside the existing state nodal agencies for RE. In addition, to address knowledge and capacity gaps, the nodal agency can undertake targeted capacity building and knowledge dissemination programs designed for policymakers, ULBs, urban development authorities, DISCOMs, industries and commercial entities, real estate developers, technical institutions, and financiers, among others.

The state-level Cell can coordinate with the city-level Technical Unit for sustainable energy proposed in section 12.1.3. Adoption of BESS at the city-scale can be expedited through the involvement of DISCOMs and ULBs, as these are the entities well-versed with local conditions and requirements from the urban and energy perspectives. In the case of RE, DISCOMs have facilitated the installation of solar rooftop systems under MNRE guidelines. A similar mechanism can be potentially explored for BESS. Incentives for installation of BESS to be offered by the nodal agency can be facilitated through state or central financial assistance, in cognizance of the share of battery storage systems expected in the energy mix.

**Performance Guarantees to support BESS projects by National or State Government**

One of the major barriers to adoption of BESS is the lack of financing options available for projects. The lack of clarity that exists around revenue streams and lifecycle of BESS projects hampers the confidence of the financing institutions and banks.

Performance guarantees can help reduce the risk perceived by investors in BESS projects implemented through new technologies or new manufacturers.[80] Possible actions that can be taken by the central or state governments, including MoP or state government department, can enable the creation of a performance guarantee fund that assures the success of the project if implemented through an accredited agency (like an ESCO) and covers the risk of a financial institution up to a certain extent.

- For creation of such a fund, assistance of multilateral organizations or the National Clean Energy Fund or similar funds can be looked at.
- The state-level nodal energy agency (or dedicated Cell proposed above) can support in facilitating relevant activities..

**Re-purposing decommissioned EV batteries for BESS**

The batteries that are used in a typical EV have utility for operation as a module for BESS even after their life-course with parent EV machine. Batteries used as a prime mover for an EV need to be discarded after a certain degradation of its useful capacity. Re-purposing such batteries for BESS installation can reduce the upfront procurement cost and help accelerate adoption.

- Policy impetus for rejuvenating such EV batteries can be floated under specific conditions of the safety protocol.
- Special cell created under a nodal agency can approve and facilitate higher immediate uptake of BESS.
- Reduced taxes on the usage of such batteries can be extended by appropriate finance departments of state/central government.

### 12.2.2. Regulatory Measures to Promote BESS Adoption

Regulatory recommendations have been provided considering the current regulations in place and other notified regulations that are yet to be fully implemented in the Indian power system.

**Promotion of fast-responding assets for grid services**

Increasing the ramp rate for generators in the Indian Electricity Grid Code from the current 1% per minute will also promote the use of fast-responding assets, as conventional generators often do not meet this requirement, even though the CEA technical standards require generators to have ramping capabilities in the 3-5% range. CERC should also introduce penalties for generators who fail to provide the 1% ramping. This can enable the deployment of fast-responding assets, such as energy storage plants that can also be co-located with generators to provide ramping.[81]

The Ancillary Services Regulations should also be amended to provide incentives for faster and accurate response from fast-responding assets such as energy storage sources, which when online can respond in milli-seconds to seconds. The regulations created by the CERC/SERCs are generally based on energy measurement in a 15-minute time block, and accordingly, all open access-based inter-state and intra-state transactions are settled on a 15-minute basis. Services such as the reserve response for frequency regulation need to have a different set of time block-based parameters, ideally based on time-blocks in seconds and minutes, as prevalent in developed markets such as that of the United States, a separate metering arrangement and payment mechanisms.[82]

**Establishing market-based mechanism for primary frequency response under the Ancillary Services Regulations**

The scope of the Ancillary Services Regulations 2022 includes only SRAS and TRAS, while inertial and primary response requirements are to be met by the generators through governor control, as specified in the Indian Electricity Grid Code and the CEA technical standards for connectivity to the grid. Though generators are mandated to provide these services, they are not compensated for doing so through any compensation or payment mechanism.

The actual primary response can be lower than desired at times due to technical difficulties for units, especially conventional generators, to respond in time and when generators do not retain adequate capacity on reserve.[83] Though introduction of Automatic Generation Control (AGC) for secondary reserve control signals significantly improves the time-sensitivity of response to secondary reserve ancillary requirements, it is important to also enable fast-response to primary frequency response requirements, which, as stated earlier, is currently met by the generators themselves. Thus, amending the Ancillary Services Regulations to bring PRAS under a market-based mechanism or direct payment mechanism and improving of the time-block granularity of energy measurements for forecasting and scheduling of ancillary services reserves, will enable deployment of fast and accurate response to load generation imbalances in the grid through participation of fast-responding assets like energy storage plants.

**CERC should frame regulations on the ownership of Energy Storage Assets and their market-participation**

CERC, through a staff paper on introduction of electricity storage systems in India, has outlined the potential ownership models for energy storage, and the Ministry of Power in its recent clarifications to the power sector stakeholders has defined an energy storage asset as a generation, transmission or distribution asset, and described various ownership models and rules. However, no rules and regulations have been notified by the CERC in this regard. Clearly defining the energy storage ownership rules and formalizing the roles and responsibilities of the appropriate commissions, agencies etc. under different ownership models for energy storage investments from different segments of the power sector through CERC regulations can reduce uncertainty for investors.

**Regulatory framework for grid interconnection process and operational code for energy storage in the Intra-state power system**

In 2015, CERC amended the DSM regulations 2014 to regulate the forecasting and scheduling of regional i.e., interstate RE generators and control their deviations. Further, based on the framework established by the forum of regulators led by the CERC, state regulators notified forecasting and scheduling regulations for intra-state RE entities. Along the same lines, CERC should take steps to establish a national framework for state regulators to define regulations on the interconnection of energy storage assets with the intra-state T&D networks, and the operational code for different energy storage technologies based on the Indian Electricity Grid Code.

**Establishing Safety Standards for Energy Storage Technologies**

Establishing proper safety standards and procedures for the commissioning, operation and decommissioning of energy storage assets, based on their technologies, is necessary for energy storage deployment and scale-up. As energy storage grows in India, the development of new codes, standards, and regulations and increased education, training, and technical support for the same will be critical for the safe and timely deployment of energy storage technologies in the Indian power market.

**Enabling energy storage assets to earn revenue from multiple services to the grid**

Given the multitude of services that can be provided by an energy storage asset, the Indian power market regulations, designed for conventional grid assets, and the lack of compensation mechanisms for several of the services that energy storage can provide to the grid, do not allow capturing of the operational value and limitations of energy storage technologies, while also rendering them financially unviable. Increasing access to multiple revenue streams can improve the economic viability of energy storage investments, such as including them in the ancillary services for frequency response, allowing direct payments for firming services provided to generators, especially RE sources, and for improving power quality and reducing losses in the T&D network etc.

**Provisions in the National Tariff Policy for charging of BESS**

The MoP should amend the National Tariff Policy or provide clear guidelines to the state regulators to enable a unique tariff structure for charging of BESS in line with the EV charging tariffs prevalent in some states. As BESS is still evolving in the Indian market, concessional tariffs may help early adopters in achieving financial viability that can further increase deployment of BESS and its scale-up in India's power market.

**Enabling DISCOMs to integrate BESS deployed as BtM system into their schedule for load management**

Akin to the different demand side management strategies that utilities can implement to manage their peak loads, they can collaborate with large consumers on BESS under a price/incentive-based contract or agreement for their load management or ancillary services to the grid. However, clearly defined rules and regulations and smart metering systems are paramount to the implementation of such strategies. The roles and responsibilities of the regulators, utilities and agencies like the SLDCs also need to be clearly defined

# Annexure 1: Case Studies of Utility-scale BESS

## 1. Tata Power 10 MW Grid-Scale ESS - India's First Grid-Scale Battery-Based ESS

**Location:** Rohini, New Delhi, India

**Project Started:** 2019

**Project Brief**

Tata Power Delhi Distribution Ltd. (TPDDL) distributes electricity to some 7 million consumers in north and northwest Delhi. Tata Power, the AES Corporation (NYSE: AES) and Mitsubishi Corporation partnered together on the 10 MW system to accelerate the adoption of battery-based energy storage technology in India.

The 10 MW project located at TPDDL's sub-station in Rohini, Delhi, provides grid stabilization and better peak load management, adds system flexibility, enhances reliability and protect critical facilities for 2 million consumers served by the company.

The project is situated in a 66-/11-kV substation operated by TPDDL. The 10 MW size of the project is divided into four transforms of 2.5 MVA rating each. There are a total of 8 cores of BESS, divided into 31 racks for battery nodes. The capacity of one battery module is 6.5 kWh with a voltage rating of 51.7 V. There are a total of 14 modules connected in one node. The inverters are connected at 415 V (L-L) to the switchgear with individual switch breaker.

This historic project showcases the valuable role energy storage plays in enabling India to achieve its sustainable energy goals.

**Key Issues**

*Peak Load Management, System Flexibility and Reliability to More Than 2 million Consumers*

India is no stranger to power outages. The challenge for the power distribution utility is to maintain the power drawal schedule within ±150 MW or 12% of the schedule, as per the Deviation Settlement Mechanism (DSM) regulation. Despite accurate forecasting, there are various external factors contributing to the deviation in schedule due to sudden change in temperature, humidity and rain, among others. DSM regulations have engendered revenue risks for utilities in states with higher DSM charges. Utilities are struggling to balance their demand and supply on a real-time basis, with DSM regulations reducing the operating frequency band.

TPDDL has set its deviation limit at ±38MW. However, the utility struggled to balance its drawal schedule and has paid a heavy penalty as DSM charges in recent years. In FY 2018-19, TPDDL paid approximately INR 63 million as Additional Deviation Charges (ADSM), while in FY 2019-20 the utility was charged approximately INR 67 million as ADSM penalty.

TPDDL, of late, has also experienced issues related to frequency regulations, peak load management and reactive power management.

**The Solution – Battery Energy Storage System**

TPDDL implemented a 10 MW battery grid-scale ESS as a pilot project to address the issues pertaining to frequency regulation, energy arbitrage, DSM, peak shaving, reactive power control, and several others.

The project employs Fluence's (a Siemens and AES company offering energy storage technology solutions globally) Advancion Energy Storage Platform. The installation is made up of 31 Advancion nodes, with a total capacity of 10 MW-10 MWh. Battery-based energy storage enables electricity to be stored and subsequently delivered within milliseconds, reducing the instability of the electric grid and enabling more energy to be


Image Credits: (Tata Power Delhi Distribution LTD.)

captured and delivered on demand.

**Key Outcomes**

The following outcomes were observed from the pilot assessment of the TPDDL's 10 MW BESS system

*Peak Load Management*

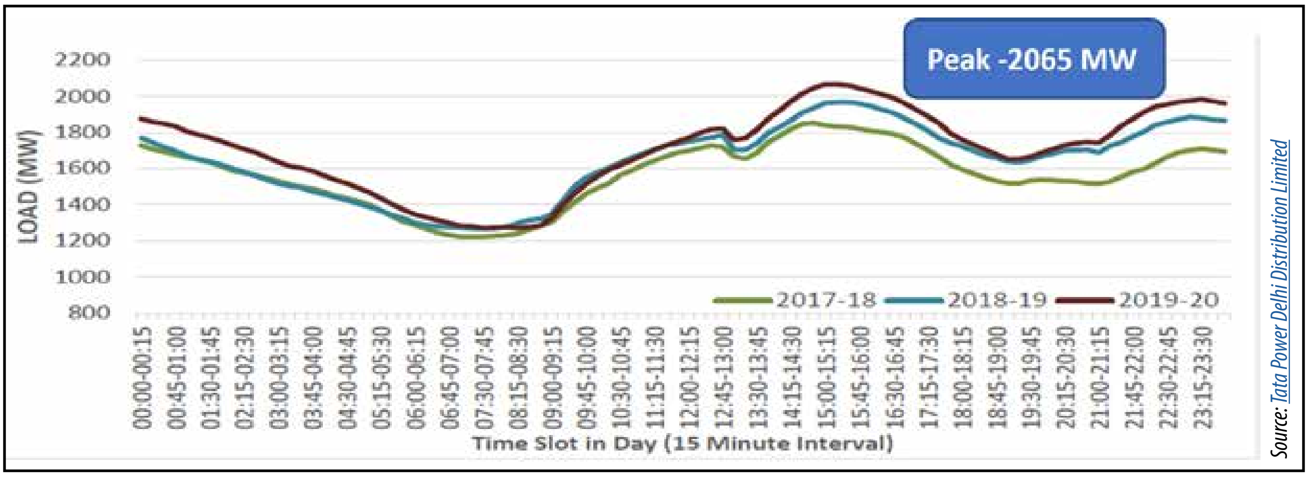



**Figure 46: Peak Load Curve – TPDDL**

As peak load periods occur only for shorter durations in a day, they can be managed locally through BESS without dependence on costlier generation plants.

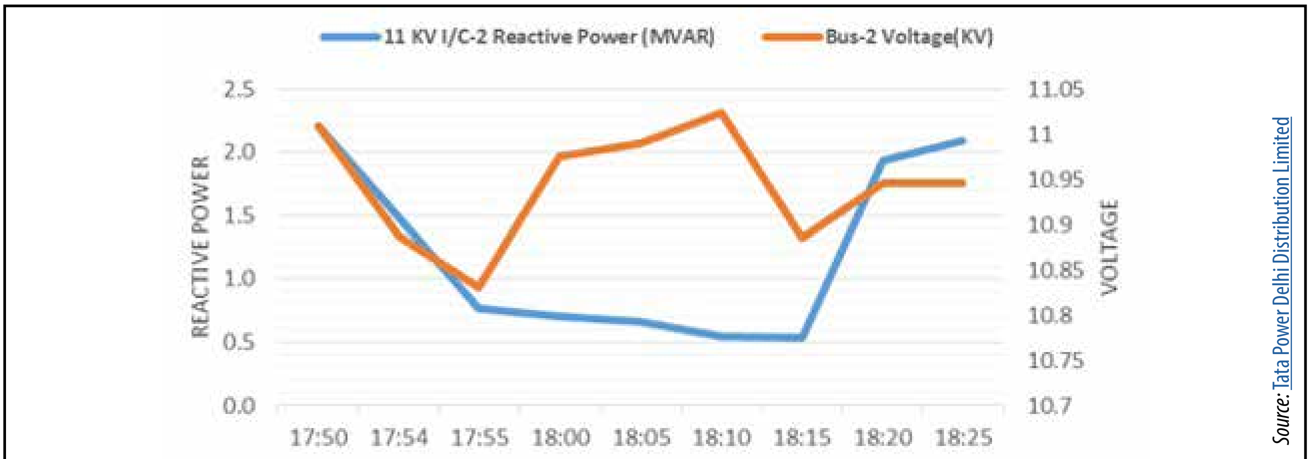



**Figure 47: Voltage vs Reactive Power Profile - 10 MW BESS TPDDL**

*Reactive Power Management*

The deployed BESS provides active power output as well as reactive power at the same time and has the four-quadrant operation ability. Reactive power application has been used for 13 instances and as a result, the voltage was observed to have improved by 2.51%.

*Frequency Regulations*

BESS plays a key role in enhancing the flexibility and reliability of the power grid. Frequency regulations are mainly provided by ramping (up and/or down) of generation assets. BESS can achieve ramp up within seconds in comparison to normal generation, which takes time in minutes to ramp up.

*Deviation Settlement Mechanisms (DSM)*

DSM means the sum of charges for deviations for all time blocks in a day payable or receivable, excluding the additional charges. Time block DSM indicates the charge for deviation for the specific time block in a day payable or receivable, excluding the additional charges. DSM charges paid for the violation in six time blocks are INR 6.85 lakhs. BESS considerably reduces the DSM penalty amounts due to fast ramp-up within minutes of deviation.

**Operational Challenges**

*Fire safety: SoC of the 10MW BESS system is limited to 75%*

The state of charge (SoC) is the level of charge of an electric battery relative to its capacity. The SoC of the 10 MW DELHI BESS system has been kept limited to only 75% as a precautionary measure, in view of the fire incident of April 2019 at a battery storage plant of the Arizona Public Service site at Phoenix. The ideal SoC of a fully charged battery is approximated as 100%.

*Replacement of Batteries' Modules by LG Chemical at Delhi BESS*

Thirty-seven modules of the 10 MW DELHI BESS system were replaced as a precautionary measure, following a fire incident at an ESS site in Korea, since both battery systems were from the same manufacturing batch (LG Chemical).

**Project Details***

| | |
|---|---|
| **Project size** | 10 MW, 10 MWh |
| **Technology** | Fluence's Advancion Energy Storage Technology Platform |
| **No. of cores** | 4 (2.5 MWh/MVA per core) |
| **No. of racks in each core** | 31 racks |
| **Capacity of each battery** | 6.5 kWh |
| **Total energy capacity of each rack** | 85 kwh |

**References:**


1. Project Spotlight_Delhi_Fluence_PS-001-01-EN.pdf (fluenceenergy.com)
2. Distributed Energy Resource (DER) Integration (tatapower-ddl.com)
3. Future Scenario and Challenges of Indian Power Sector – Subrata Dey (nptidurgapu r.com)


* Energy Storage at the Distribution Level – Technologies, Costs and Applications, Shakti Sustainable Energy Foundation and TERI.

## 2. BESS Pilot Project – USAID's Greening the Grid (GTG) RISE Initiative in Collaboration with Powergrid, Puducherry

**Location:** Puducherry, India

**Project Started:** 2017

### Project Brief

USAID's GTG RISE initiative, together with Powergrid in Puducherry, has built a pilot facility to test the technical and economic effectiveness of grid-connected BESS. The project's objectives include enhancement of the existing BESS facility and assessment of the economic value of the storage system, technical design and demonstration of the array of BESS applications viz. dynamic frequency regulation, RE time shift, capacity firming etc., in providing grid support and detailed modelling study on the need, quantity and location of storage systems in India in the sub-15-minute time scale.

### About the Pilot Facility

With a capacity of 1 MW with 500 kWh battery technologies and an associated battery management system, the pilot facility was built to examine the efficacy of BESS in India. This pilot facility tests the technical and economic effectiveness of grid-connected BESS in providing dynamic frequency regulation and other ancillary services; capacity firming and energy time shift of VRE generators, peak shaving and load following; and dynamic reactive compensation and voltage support.

As part of the pilot project, a techno-feasibility assessment of BESS in providing ancillary services (frequency reserves) was conducted for the southern grid. The study aimed at managing large-scale RE integration into the Indian power grid and understanding the required frequency reserves and the role of BESS for these reserves. The study has been conducted for Energy Time Shift and Frequency Regulation applications.

Under the initiative, three different technologies, namely Li-ion, Advanced Lead and Flow Batteries of 1.25 MW capacity, have been installed together to the 22 KV distribution grid on a pilot basis.


*Image Credits: (Battery Energy Storage System (BESS) | Greening the grid (gtg-india.com))*

### Key Outcomes

The pilot proved to be crucial in providing inputs to CEA and the Bureau of Indian Standards (BIS) to finalize standards for BESS grid interconnection, which will feed into policies and regulations to support BESS deployment.

The study highlights that with increased RE penetration, we need to ensure a reliable, flexible and adaptive grid. The economics of battery storage changes with a higher penetration of RE. BESS provide critical ancillary service support.

*Energy Time Shift*

As the duration and power to be discharged/charged from the battery systems can be programmed, considering the load flow history of the feeder, the load burden can be reduced using BESS during peak hours, while the voltage profile and power factor of the system can be improved.

*Frequency Regulation*

BESS can help arrest the nadir frequency with its fast-response characteristics, from conventional units, and help achieve the target value for the quasi-steady state frequency, thus reducing the burden on conventional units due to high RE additions to the grid.

*Commercial implications and Regulatory requirements*

BESS can support the grid for frequency regulation effectively and be used to ensure the required sign changes.

The price of BESS installation is much lower than the DSM penalty for a whole year. An analysis of the applications of BESS in the electrical grid shows that it can maintain grid stability, reduce losses and lead to economic benefits.

**Battery Technical Specifications**

| **Parameters** | **Li-ion Battery** | **Advanced lead Acid Battery** | **Flow Battery** |
|---|---|---|---|
| Capacity | 250 kWh | 250 kWh | 1000 kWh |
| Power | 500 kW for half hour | 500 kW for half hour | 500 kW for four hours |
| Charging rate | 3 hours from rated DoD to full capacity | 3 hours from rated DoD to full capacity | 5 hrs. from rated DoD to Full Capacity |
| DC-DC round-trip efficiency | >90% | >80% | >75% |
| Service life | 10 years | 10 years | 10 years |
| Life cycle | 4,000 cycles | 3,000 cycles | 3000 cycles |

**References**


1. Battery Energy Storage System (BESS) | Greening the grid (gtg-india.com)
2. Greening the Grid: USAID GTG-RISE Initiative in India and Ancillary Services from Battery Energy Storage Systems
3. Powering India's transition to renewable energy: Battery energy storage system (BESS) pilot goes live at Puducherry plant | Greening the grid (gtg-india.com)

## 3. Powell Sewage Treatment Plant - Energy Efficiency Enhancing System with Energy Storage and Energy Management System

**Location:** The Republic of Korea

**Project Started:** 2017

**Project Brief**

A sewage treatment and water reuse facility always remains operational and continues to consume electricity from the grid and peak load can occur anytime. This was the biggest challenge faced by the Powell sewage treatment plant in Korea. Since there was no integrated monitoring system for the power load situation, it was difficult to effectively control the peak load. To effectively use electricity and manage consumption, Powell decided to implement Factory Energy Management System (FEMS) with ESS.

**Key Issues**

*(High Costs Due to Peak Electricity Demand Charges + Managing Energy Demand)*

The Powell sewage treatment plant was facing issues of high electricity costs due to peak demand charges and a lack of infrastructure to manage the plant's energy demand. Powell faced challenges in monitoring and optimizing the facility's electricity usage in real-time.

**The Solution**

*Factory Energy Management System (FEMS) + Energy Storage System (ESS)*

Gridwiz (a clean energy company in Korea) offered an energy efficiency enhancing system, which combines FEMS and ESS. This system was implemented in Powell in October 2017. The system, which consists of FEMS, controls the energy management of the factory and ESS plays the main role of peak reduction and reduction of electricity costs.

Considering the power load pattern, efficiency and economic feasibility, the system was constructed with 1,644 kWh and PCS 250 kW batteries. By managing energy demand through FEMS and using stored energy when required, the facility can modulate its electricity demand, while still providing adequate sewage treatment, therefore reducing peak demand. This approach also allowed the facility to participate in a demand resource trading market, reducing its net energy costs*.

In a period of 11 months, the system reduced peak load of 514 kW (approx. 10%) from 5,380 kW to 4,866 kW through FEMS, and reduced electricity costs by about 200 million South Korean Won within 10 months through ESS.

**Key Benefits**

Powell's energy efficiency enhancing system with ESS and FEMS is expected to reduce peak demand by approx. 100 kW annually, and the electricity costs by about 160 million South Korean Won in the 15 years from October 2017.

**References**


1. ISGAN-Casebook-Energy-Storage-Systems-March-2019.pdf (nsgm.gov.in)
2. Creating Livable Asian Cities (adb.org)


* ISGAN-Casebook-Energy-Storage-Systems-March-2019.pdf (nsgm.gov.in)

## 4. Sterling Municipal Light Department – Solar PV + Battery Storage System Project

**Location:** Chocksett Road Substation, Sterling, Massachusetts, US

**Year Commissioned:** 2016

**Project Brief**

Sterling Municipal Light Department (SMLD) is a municipal utility serving the small England town of Sterling, Massachusetts, which has around 3,700 customers, including residential, commercial, municipal and industrial ones.

The project is the first utility-scale energy storage facility in Massachusetts and the largest battery installation of its kind in New England, in terms of megawatt hours, and 2 MW of batteries for energy storage have been installed at the substation.

The Sterling energy storage project was supported by the Massachusetts Department of Energy Resources, U.S. Department of Energy's Office of Electricity (DOE-OE), Sandia National Laboratories, Clean Energy States Alliance, Clean Energy Group, and the Barr Foundation.

**Key Issues**

*Resilient Power + Variable Solar Generation + Rising Cost of Capacity and Transmission Services*

In 2013, SMLD became the number one utility in Massachusetts for solar watts per customer, with a total installation of 3.2 MW of solar PV. Solar accounted for approx. 30% of SMLD's peak load. At this high level of penetration, the variable nature of solar generation began to cause problems.

Additionally, the costs of capacity and transmission services, based on SMLD's peak demand for power purchased from the grid operator, were rising dramatically. These costs increased from $500,000 in 2010 to $1.2 million in 2017. To control rising costs linked to the utility's share of regional demand peaks and to firm the output of its solar generation, SMLD needed a new strategy.

**The Solution**

*Solar PV + Battery Storage System Project*

SMLD deployed a 2 MW/3.9 MWh battery storage system at Sterling's Chocksett Road Substation that is able to isolate from the main grid in the event of a power outage and, with an existing PV array, provide up to 12 days of emergency backup power to the Sterling police station and dispatch centre, a community facility providing first responder services.


*Image Credits: Clean Energy Group (Sterling's Solar + Energy Storage System - Clean Energy Group (cleanegroup.org))*

**Key Benefits**

By discharging the batteries during hours of peak electricity demand, the Sterling energy storage project is expected to save the town's ratepayers at least $400,000 per year by decreasing costs associated with capacity and transmission charges from the regional power services supplier, ISO New England. Sterling will be able to lower its demand for grid services from the ISO by discharging the battery system during times of regional peak demand.

- The 3.9 MW/hour ESS supports critical emergency response functions by providing up to 12 days of backup power to the Sterling police station and dispatch centre during grid outages.
- The battery storage system supports the utility's distribution system on a daily basis, resulting in approximately $400,000/year in savings to the utility and ratepayers*.
- Projected revenues from utilizing the batteries for grid services are expected to result in a payback of installed costs in 2.5 years. Without grant funding, the system would still achieve a payback period of fewer than seven years.

According to a paper by Sandia National Laboratory, the biggest energy cost savings potential from the batteries comes from reducing Sterling's electricity demand during a single annual peak demand hour for the New England region. This regional peak demand hour generally occurs in July or August, and each utility in New England is charged an annual fee for capacity services based on its individual demand during that one hour**.

**Project Details**

| | |
|---|---|
| Project Capacity | 2.2 MW/3.9 MWh lithium-ion battery, installed on feeder with existing 2 MW solar PV system |
| Installed cost | $2.52 million |
| Payback | 6.3 years (2.5 years with grant funds) |
| Loads supported | Full operation of police station and emergency dispatch |
| Configuration | Ground-mounted |
| Estimated annual generation | 1,526,000 kWh |
| Ownership structure | PPA |
| Battery technology | Lithium-ion battery installed in 40 racks within a metal container that includes all controls and other associated hardware, plus cooling and fire suppression systems |

**Break-down of Year-One Savings**

| | |
|---|---|
| Capacity savings | $ 240,660 |
| Transmission savings | $ 145,671 |
| Energy arbitrage | $ 12, 567 |
| **Total year-one savings** | **$ 398,898** |

**References**


1. Resilient Power Project Case Study, Clean Energy Group - Sterling-case-study.pdf (cesa.org)
2. Sterling's Solar + Energy Storage System - Clean Energy Group (cleanegroup.org)
3. Sterling, Massachusetts Changes the Business of Electricity in New England — Forever | Renewable Energy World
4. The Value Proposition for Energy Storage at the Sterling Municipal Light Department - Clean Energy Group (cleanegroup.org)


* Project Fact Sheet - Sterling-Overview.pdf (cleanegroup.org)

** Report - Small Community Saves Big with Energy Storage - Clean Energy States Alliance (cesa.org)

## 5. SunSmart Emergency Shelters Program - Solar with Battery Back-Up on Schools

**Location:** Multiple locations, Florida, United States of America

**Project Started:** 2010

**Project Brief**

The SunSmart E-Shelter Schools Program was the first mass deployment of solar with battery back-up on schools that double as emergency shelters in the United States. More than 115, 10-kW PV solar systems are installed on the emergency shelter schools throughout Florida.

Schools make excellent resilient shelters, as they are centrally located, can accommodate many people, and typically have large, flat roofs and open spaces where PV panels can be installed. This ambitious program brought together school administrators, code officials, teachers and students, solar industry professionals, researchers, and emergency management and utility personnel to create a community of solar advocates throughout the state. The SunSmart E-Shelter Program has added more than 1 MW of combined PV generating capacity to Florida using American-made components*.

**Key Issues**

*Power Outages During Storms*

Florida is especially vulnerable to hurricanes because it is surrounded by water on three sides. Its proximity to the Gulf of Mexico also creates a hostile environment, because the Gulf is usually warmer than the Atlantic Ocean. Many residents and shelters make use of fossil fuel-powered generators to provide power when the electrical grid has been compromised. However, obtaining fuel following a storm can be a challenge.

**The Solution**

*Solar PV + Battery Storage System Project*

With the Florida Department of Agriculture and Consumer Services' Office of Energy and the Energy Department's assistance, leaders of the SunSmart Schools and Emergency Shelters Program installed more than 1 MW of solar power at schools designated as emergency shelters throughout the Sunshine State.

During normal operations, the schools' solar PV systems keep the battery full and sell power to the grid. During power outages, the solar PV systems provide power to pre-determined critical loads like lighting, outlets for charging, and communications.

The Program has not only created emergency shelters, but also a solar legacy in Florida that will impact students and the communities.

Through this program, more than 350 teachers have received professional development in incorporating the science of solar PV in their classrooms**.

* Article - SunSmart E-Shelter Schools - FSEC Energy Research Center (ucf.edu)

** Article- SunSmart Emergency Shelters Program - Clean Energy Group (cleanegroup.org)

*Image Credits: Florida Solar Energy Center*

**Key Benefits**

- These schools now serve as self-powered places of refuge for communities across the state, providing emergency shelter for 100-500 people per site.
- The program proved its worth when Hurricane Irma hit Florida on October 24, 2017. During the widespread outages resulting from the storm, 41 of the 112 schools were open as shelters using their solar storage systems.
- The program helped schools reduce their energy costs by transferring excess energy to the grid.
- With the efforts of the Program, more than 50,000 students were introduced to RE technologies.

**Project Details**

| | |
|---|---|
| Project capacity | 10 kW solar PV array, with a 40 kWh battery |
| Installed cost | $ 9.8 million grant, installed costs range from $74,000 to $90,000 per school |
| No. of schools equipped | > 106 |
| Energy savings per school | $1,500-$1,600 per year |

# Annexure 2: Stakeholder Mapping

| Institution Type | National/ State/Local Level | Name of Agency | Roles and responsibilities |
|---|---|---|---|
| Policy | National Level | Ministry of Power (MoP) | MoP is an apex ministry responsible for implementing national laws and develop-ing appropriate policies and regulations for the development of electrical energy in India. |
| | | CEA | Statutory body responsible for technical coordination and supervision of power-related programs. It is responsible for preparing a National Electricity Plan in accordance with the National Electricity Policy once every five years. CEA assists MoP in all technical and economic matters. |
| | State Level | Energy and Petrochemical Department, Government of Gujarat | The Department is responsible for providing quality power and piped natural gas at sustainable rates, including regulation, GT&D. It is also responsible for policy-level decisions, ensuring private sector participation, energy conservation, pow-er sector reforms and the use of alternative sources of non-conventional ener-gy. It is also a nodal department responsible for EV charging stations and related financial assistance. |
| | | Ports and Transport De-partment, Government of Gujarat | The Department's prepares state-level transport policies and provides and facili-tates transportation-related services. It prepared the Gujarat State Electrical Vehicle Policy and is the nodal department responsible for its planning, imple-mentation and review. The Gujarat State Road Transport Corporation (GSRTC), under this department, is responsible for providing intra-city transport in Gujarat. The department has proposed increasing the share of e-buses in the GSRTC fleet. |
| | | Climate Change Depart-ment, Government of Guja-rat | The Department prepares state-level policies and action plan related to climate change, including preparation of wind power policy and solar power policy. |
| | | Gujarat Energy Develop-ment Agency (GEDA) | GEDA prepares state-level EE and RE policies, promotes EE and RE in the state and carries out related implementation. It is also responsible for effective im-plementation of rooftop solar PV in Gujarat. |
| Regulation | National Level | Central Electricity Regula-tory Commission (CERC) | It is a national-level regulatory body for inter-state transmission, rationalization of electricity prices, transparent subsidy policies, promotion of efficient and environmentally friendly policies. |
| | State Level | Gujarat Electricity Regula-tion Commission (GERC) | It is a state-level regulatory body for Gujarat, responsible for regulating the elec-tricity sector in a transparent, effective and efficient manner. Its work includes the setting up of charges for bulk and retail consumers and regulating the opera-tion of domestic transmission, including the SLDC. |
| | | Office of the Chief Electrical Inspector | This office is responsible for the administration of electricity laws, inspection of electrical installations for ensuring electrical safety, energy audit and administra-tion of lift laws. It conducts electrical safety-related inspections in accordance with approved electrical drawings and will be responsible for safety-related in-spections for solutions such as BESS. |

| Institution Type | National/ State/Local Level | Name of Agency | Roles and responsibilities |
|---|---|---|---|
| Electricity Generation | State Level | • Gujarat State Electricity Corporation Limited (GSECL)<br>• Gujarat Power Corporation Limited (GPCL)<br>• GIPCL<br>• Torrent Power | They are responsible for power generation through thermal, gas and RE (wind, solar and hydro) projects. |
| Electricity Transmission | State Level | Gujarat Energy Transmis-sion Corporation Limited (GETCO) | GETCO is responsible for operating and maintaining an efficient power transmis-sion system. |
| | | Gujarat State Load Dispatch Centre | It is responsible for carrying out real-time operations for grid control and dis-patch of electricity within the state through secure and economic operation of the state grid, in accordance with the Grid Standards and the State Grid Code. |
| Electricity Distribution | State Level | Gujarat Urja Vikas Nigam Limited (GUVNL) | The GUVNL is engaged in the business of bulk purchase and sale of electricity, and supervision, co-ordination and facilitation of the activities of its six subsidi-ary companies (GSECL, GETCO, UGVCL, DGVCL, MGVCL and PGVCL). |
| | Regional/Local Level | • Dakshin Gujarat Vij Company Limited (DGVCL)<br>• Torrent Power (Surat)<br>• Paschim Gujarat Vij Company Limited (PGVCL) | They are responsible for distribution of electricity to end-consumers and planning of electrical infrastructure to strengthen the electricity distribution network towards reducing electricity downtime and enhancing reliability. Further, they collect energy consumption charges from end-users as per the tariff stipulated by GERC, work to promote energy conservation through demand side management, and support implementation of the solar roof-top net metering program through facilitation of infrastructure for net-metering.<br><br>DGVCL and PGVCL are government-owned entities, responsible for electricity distribution in Surat and Rajkot, respectively. Torrent Power (Surat) is a private entity, responsible for electricity distribution in Surat. |
| Urban Development | State Level | Urban Development and Urban Housing Department (UD&UHD), Government of Gujarat | The Department supports and manages overall urban development in the state through preparation of policy and strategy for urban development infrastructure provisions, planning, design, and implementation. It advocates and promotes planning activities in the state, including preparing town planning and development planning guidelines and the Comprehensive General Development Control Regulations; and reviews suggestions and approves development plans prepared by the city. |

| Institution Type | National/ State/Local Level | Name of Agency | Roles and responsibilities |
|---|---|---|---|
| | | Gujarat Urban Development Mission (GUDM) | GUDM supports ULBs in planning, building, operating, managing and maintaining basic physical urban infrastructure; provides financial, technical and technological support for creating modern urban infrastructure and bridging knowledge and information gaps; supports private enterprises and the public at large for implementation and maintenance of different projects on PPP basis for all urban issues; and strengthens the urban transport system by adopting an integrated transportation system, traffic management and promoting private sector participation. The nodal agency under the UD&UHD, GUDM is responsible for increasing the share of e-buses in the city's public bus transport system under the FAME scheme. |
| | | Gujarat Urban Development Company Limited (GUDC) | GUDC assists the state government in preparing policy and strategy for urban development infrastructure provisions; in preparing guidelines for private sector participation in urban development; assessing the need and form of Government Guarantee to ULBs required for raising funds from the market; formulating, appraisal, implementing and monitoring urban projects funded from multilateral sources; and implementing urban reforms as the government's agent. |
| | Regional/ Local Level | **Surat**<br>● Surat Urban Development Authority (SUDA)<br>● SMC<br>**Rajkot**<br>● Rajkot Urban Development Authority (RUDA)<br>● RMC | **SMC and RMC:** The main planning authority for the city of Surat and Rajkot, they are responsible for providing basic infrastructure services including water supply, drainage, roads, streetlights, waste management, development planning, regulation, control and coordination of urban growth within the city. Zoning and mandating the type of land use over the entire jurisdiction is one of their key functions. They are also responsible for providing basic services and civic amenities to citizens, along with preparing and executing infrastructural development projects. SMC and RMC play the roles of planner, controller and implementer within their jurisdictions.<br><br>Further, their responsibilities include: 1) increasing the share of RE in various municipal services; 2) increasing the share of e-buses in the municipal public transportation fleets and related charging infrastructure; 3) arranging alternative sources of energy for various essential municipal services during power cuts; and 4) preparing and implementing city-level e-vehicle policies, including charging infrastructure etc.<br><br>**SUDA and RUDA:** They oversee the planning and development of larger urban agglomeration areas in their respective city including long-term planning and related development control regulations, promotion of new growth centres, implementation of strategic projects and financing infrastructure development for the urban agglomeration area. They are responsible for preparing a physical plan for the development of the urban agglomeration; preparing and implementing town planning schemes; and monitoring and controlling development activities in accordance with the Development Plan. |

| Institution Type | National/ State/Local Level | Name of Agency | Roles and responsibilities |
|---|---|---|---|
| Other Stakeholders | State/Regional Level | EV Infrastructure Provider (Public Charging Stations) | Designing and implementing public EV charging infrastructure in the city in close coordination with the city and the Energy and Petrochemical Department, Government of Gujarat. |
| | | EV fleet operators<br>● PMI Electro Mobility Solutions (Rajkot)<br>● Olectra Greentech Limited (Surat) | E-buses in the municipal public transport are being operated on the basis of the gross cost model by private EV operators. The EV fleet operators are responsible for the procurement of e-buses, providing related charging infrastructure and operating buses in the city. They are also responsible for paying electricity bills. |
| | Regional/Local Level | ● Commercial, industrial, institutional and residential consumers/ Prosumers<br>● GCCI<br>● CREDAI<br>● CII | Considering the increase in the demand for EVs, GCCI and CREDAI along with builders' associations, and CII may play major roles in scaling up EV charging infrastructure at the building level. These stakeholders may support mandating policy adoption or enabling voluntary adoption of standards to establish charging stations at the workplaces.<br><br>Further, as the majority of buildings use DG sets as power backups, CREDAI along with the respective municipal corporations may intervene to promote BESS to replace DG sets.<br><br>As commercial and industrial units are affected the most by demand charges and ToU charges, BESS along with RE would support them to manage the peak time demand. |

# Annexure 3: List of Stakeholder Meeting

| Sl. No. | Stakeholder | Date of Meeting | Mode of Meeting | Stakeholder's Representation |
|---|---|---|---|---|
| 1 | Gujarat Energy Transmis-sion Corporation Limited (GETCO), Rajkot | 20-Sep-21 | Regular | Mr. P.K. Varasada (Executive Engineer);<br>Ms. Foram Thakar (Deputy Engineer) |
| 2 | Rajkot Municipal Corpora-tion (RMC) | 21-Sep-21;<br>16-Feb-22 | Regular | Mr. K. P. Dethariya (Deputy Executive Engineer) |
| 3 | Paschim Gujarat Vij Com-pany Limited (PGVCL) | 21-Sep-21 | Regular | Mr. Jasmin J. Gandhi (Superintending Engineer) |
| 4 | Gujarat Energy Develop-ment Agency (GEDA) | 22-Sep-21 | Regular | Mr. D J Vatsrai, Sr. Project Executive, Solar PV and Bio Energy;<br>Mr. Sudhir Prajapati |
| 5 | Gujarat Power Corporation Limited (GPCL) | 22-Sep-21 | Regular | Mr. Rajendra M. Mistry |
| 6 | Gujarat Electricity Regula-tory Commission (GERC) | 22-Sep-21 | Regular | Mr. Dharmendra R. Parmar |
| 7 | Surat Municipal Corpora-tion (SMC) | 7-Oct-21;<br>20-Apr-22;<br>21-Apr-22 | Telephonic | Mr. Banchhanidhi Pani (Municipal Commissioner);<br>Mr. Jinesh Patel |
| 8 | Gujarat Urja Vidyut Nigam Limited (GUVNL) | 9-Mar-22 | Online | Ms. Sailaja Vachhrajani (GM-IPP)<br>Mr. Kandarp Mistry |
| 9 | Torrent Power, Surat | 3-Feb-22;<br>19-Apr-22 ;<br>21-Apr-22;<br>2-Jun-22 | Online and Regular | Mr. Anand Singh<br>Mr. Nimish Dantwala<br>Mr. Bhupat Makati<br>Mr. Kapil Kanudawala<br>Mr. Mukesh Patel |
| 10 | Dakshin Gujarat Vij Compa-ny Limited (DGVCL) | 4-Jun-22 | Online | Mr. J H Borisagar<br>Mr. J V Patel |
| 11 | BSES Rajdhani | 27-Jun-22 | Regular | Mr. Naveen Nagpal;<br>Ms. Sugandhita Wadhera |
| 12 | BSES Yamuna;<br>BSES Rajdhani | 11-Jul-22 | Online and Regular | Mr. Jitender Nalwaya<br>Mr. Naveen Nagpal |

# Annexure 4: Assumptions for the Technical Cost Analysis for BESS Use-cases

**Assumptions E-Car Charging station**

| Parameters | Base scenario | Future scenario with base system configuration |
|---|---|---|
| Load Profile | Developed on the basis of understanding of the time interval, contract load and operational cycle of public charging stations | |
| No. of BESS cycle in a day | 0.41 | 0.41 |
| BESS Life Estimate (months) | 120 | 120 |
| Cost of Repurposed Battery (INR/kWh) | 55 | 43.25 |
| Peak Continuous Output Current of Charger (A) | 98 | 98 |
| Peak Continuous Output Power of Charger (kW) | 17.9 | 17.9 |
| Cost of Charger (INR/kW) | 4,000 | 4,000 |
| Total Cost of Charger (INR) | 71,600 | 71,600 |
| Cabling and commissioning charges (INR) | 5,000 | 5,000 |
| Transformer Cost (INR) | 1,00,000 | 1,00,000 |
| Cost of Inverter (INR) | 176,600 | 176,600 |
| Power Back – Diesel Genset Power (kW) | NA | NA |
| Capacitor Output (kVAR) | NA | NA |
| System Efficiency | 90% | 90% |

**Assumptions E-Bus Charging Station**

| Parameters | Base scenario | Future scenario with base system configuration | Future scenario with system optimization |
|---|---|---|---|
| Load Profile | Assumed and developed on the basis of understanding of the time interval, contract load and operational cycle of the E-Bus charging station in Rajkot | | |
| No. of BESS cycle in a day | 0.46 | 0.46 | 0.46 |
| BESS Life Estimate (months) | 120 | 120 | 120 |
| Cost of Repurposed Battery (INR/kWh) | 55 | 43.25 | 43.25 |
| Peak Continuous Output Current of Charger (A) | 943 | 943 | 943 |
| Peak Continuous Output Power of Charger (kW) | 214.7 | 214.7 | 2.2 |
| Cost of Charger (INR/kW) | 4,000 | 4,000 | 4,000 |
| Total Cost of Charger (INR) | 8,58,800 | 8,58,800 | 8,800 |
| Cabling and commissioning charges (INR) | 5,000 | 5,000 | 5,000 |
| Transformer Cost (INR) | 3,00,000 | 3,00,000 | 1,00,000 |
| Cost of Inverter (INR) | 1,163,800 | 1,163,800 | 113,800 |
| Power Back – Diesel Genset Power (kW) | NA | NA | NA |
| Capacitor Output (kVAR) | NA | NA | NA |
| System Efficiency | 90% | 90% | 90% |

**Assumptions BtM Application - Hotel**

| Parameters | Base scenario | Future scenario with base system configuration |
|---|---|---|
| Load Profile | Assumed on basis of available load profiles for hotels located in similar conditions to Rajkot and Surat | |
| No. of BESS cycle in a day | 0.80 | 0.80 |
| BESS Life Estimate (months) | 120 | 120 |
| Cost of Repurposed Battery (INR/kWh) | 55 | 43.25 |
| Peak Continuous Output Current of Charger (A) | 1,333 | 1,333 |
| Peak Continuous Output Power of Charger (kW) | 273.8 | 273.8 |
| Cost of Charger (INR/kW) | 4,000 | 4,000 |
| Total Cost of Charger (INR) | 1,095,200 | 1,095200 |
| Cabling and commissioning charges (INR) | 5,000 | 5,000 |
| Transformer Cost (INR) | 3,00,000 | 3,00,000 |
| Cost of Inverter (INR) | 1,400,200 | 1,400,200 |
| Power Back – Diesel Genset Power (kW) | 750 | 750 |
| Duration of backup operation (hours/month) | 4 | 4 |
| Life of DG (months) | 120 | 120 |
| DG Cost (INR/kVA) | 8,000 | 8,000 |
| Total Cost of DG (INR) | 60,00,000 | 60,00,000 |
| Capacitor Output (kVAR) | NA | NA |
| System Efficiency | 90% | 90% |

**Assumptions BtM Application - Hospital**

| Parameters | Base scenario | Future scenario with base system configuration |
|---|---|---|
| Load Profile | Assumed on basis of available load profiles for hospitals located in similar conditions to Rajkot and Surat | |
| No. of BESS cycle in a day | 0.80 | 0.80 |
| BESS Life Estimate (months) | 120 | 120 |
| Cost of Repurposed Battery (INR/kWh) | 55 | 43.25 |
| Peak Continuous Output Current of Charger (A) | 666 | 666 |
| Peak Continuous Output Power of Charger (kW) | 168.2 | 168.2 |
| Cost of Charger (INR/kW) | 4,000 | 4,000 |
| Total Cost of Charger (INR) | 672,600 | 672,600 |
| Cabling and commissioning charges (INR) | 5,000 | 5,000 |
| Transformer Cost (INR) | 2,00,000 | 2,00,000 |
| Cost of Inverter (INR) | 8,77,600 | 8,77,600 |
| Power Back – Diesel Genset Power (kW) | 750 | 750 |
| Duration of backup operation (hours/month) | 4 | 4 |
| Life of DG (months) | 120 | 120 |
| DG Cost (INR/kVA) | 8,000 | 8,000 |
| Total Cost of DG (INR) | 60,00,000 | 60,00,000 |

| Parameters | Base scenario | Future scenario with base system configuration |
|---|---|---|
| Capacitor Output (kVAR) | NA | NA |
| System Efficiency | 90% | 90% |

**Assumptions – Municipal Utilities and Services**

| Parameters | Base scenario | Future scenario with base system configuration | Future scenario with system optimization |
|---|---|---|---|
| Load Profile | Developed on the basis of understanding of the time interval, contract load and operational cycle of Rajkot Aji Water Treatment Plant | | |
| No. of BESS cycle in a day | 0.78 | 0.78 | 0.78 |
| BESS Life Estimate (months) | 120 | 120 | 120 |
| Cost of Repurposed Battery (INR/kWh) | 55 | 43.25 | 43.25 |
| Peak Continuous Output Current of Charger (A) | 228 | 228 | 276 |
| Peak Continuous Output Power of Charger (kW) | 12.6 | 12.6 | 0 |
| Cost of Charger (INR/kW) | 4,000 | 4,000 | 4,000 |
| Cabling and commissioning charges (INR) | 5,000 | 5,000 | 5,000 |
| Transformer Cost (INR) | 1,00,000 | 1,00,000 | 0 |
| Cost of Inverter (INR) | 155,400 | 155,400 | 5,000 |
| Power Back – Diesel Genset Power (kW) | 500 | 500 | 500 |
| Duration of backup operation (hours/month) | 2 | 2 | 2 |
| Life of DG (months) | 180 | 180 | 180 |
| DG Cost (INR/kVA) | 8,000 | 8,000 | 8,000 |
| Total Cost of DG (INR) | 40,00,000 | 40,00,000 | 40,00,000 |
| Capacitor Output (kVAR) | 150 | 150 | 150 |
| Cost of Capacitor (INR) | 5,55,000 | 5,55,000 | 5,55,000 |
| Cost of Capacitor Maintenance (INR) | 12,500 | 12,500 | 12,500 |
| Total Cost of Capacitor (INR/kVAR) | 8,376 | 8,376 | 8,376 |
| Solar Power (kVA) | 161 | 161 | 267 |
| System Efficiency | 90% | 90% | 90% |

# Annexure 5: Proceedings of the Final Project Workshop

**Enabling Adoption of Battery Energy Storage Systems in Indian Cities - Introduction to BESS and use-cases for urban applications**

August 26, 2022 | Fortune Landmark Hotel, Ahmedabad, Gujarat & virtual participation on Zoom platform

## Agenda

| Time | Description |
|---|---|
| 09.30 to 10:00 | **Registration** |
| 10.00 to 10.10 | **Opening Remarks**<br>• Mr. Emani Kumar, Deputy Secretary General, ICLEI Global & Executive Director, ICLEI South Asia<br>• Mr. Siddharth Arora, Associate Director (Clean Power), Shakti Sustainable Energy Foundation |
| 10.10 to 10.20 | **Welcome Remarks**<br>• Mr. Shwetal Shah, Technical Advisor, Climate Change Department, Government of Gujarat |
| 10.20 to 10.30 | **Keynote address**<br>• Mr. Bipin Talati, IAS, Joint Secretary, Climate Change Department, Government of Gujarat |
| **Technical Session** | |
| 10.30 to 10.40 | **Battery Energy Storage Systems and Applications**<br>• Mr. Senthil Arumugam, Project Officer - Energy & Climate, ICLEI South Asia |
| 10.40 to 11.10 | **Opportunities and prospects for identified BESS use-cases in Rajkot and Surat**<br>• Mr. Nikhil Kolsepatil, Senior Manager- Energy & Climate and<br>• Mr. Harpreet Singh, Assistant Manager – Energy & Climate, ICLEI South Asia |
| 11.10 to 11.20 | **Intervention by Rajkot and Surat city on their ambitions and potential interest areas for BESS**<br>• Mr. Rohit Patel, Executive Engineer, Energy Efficiency Cell, Surat Municipal Corporation<br>• Mr. Amit Shah, Deputy Executive Engineer, Roshni Department, Rajkot Municipal Corporation |
| 11.20 to 11.30 | **Coffee Break** |
| 11.30 to 11.45 | **Experiences from BESS deployment in power distribution at Delhi**<br>• Mr. Naveen Nagpal, Asst. Vice President, BSES Rajdhani Power Limited |
| 11.45 to 12.10 | **Benefits and cost evaluation of BESS for priority use-cases**<br>• Mr. Kunjan Bagdia, Senior Consultant (E-mobility and Utilities), pManifold Business Solutions Pvt. Ltd. |
| 12.10 to 12.20 | **Overview of Business Models for BESS**<br>• Mr. Senthil Arumugam, Project Officer - Energy & Climate, ICLEI South Asia |
| 12.20 to 12.55 | **Open discussion on enabling strategies and interventions to scale-up BESS deployment in cities** |
| 12.55 to 13.00 | **Closing Remarks**<br>• Mr. Emani Kumar, Deputy Secretary General, ICLEI Global & Executive Director, ICLEI South Asia |

## Highlights & Key Outcomes

The project "Strategies for Enabling Energy Storage in Indian Cities" was implemented in the cities of Rajkot and Surat in Gujarat state to explore and identify specific use-cases and applications for BESS, particularly to support the RE and EV transition in the two cities. A final project workshop was conducted on August 26, 2022 to share the analysis and findings of the assessment. The workshop was attended in in-person and virtual mode by 76 participants (34 in-person, 42 virtual), among them representatives from state and city level governments of Surat, Rajkot, Ahmedabad, and Vadodara and DISCOMs; urban and energy sector practitioners; and other key stakeholders.

In his inaugural address, Mr. Emani Kumar, Deputy Secretary General, ICLEI Global & Executive Director, ICLEI South Asia shed light on the significance of BESS to address new challenges such as peak load management and demand-supply gaps with the increasing contribution of RE on the generation side and large uptake for EVs in cities. Mr. Kumar further emphasized on the projected growth of RE in India, in-line with the Hon'ble Prime Minister's commitments during the COP26 Glasgow Summit to achieve net-zero emissions' target by 2070.

Mr. Siddharth Arora, Associate Director (Clean Power) from Shakti Sustainable Energy Foundation highlighted the three areas identified in the International Energy Agency (IEA) report where Gujarat needs to focus for better integration of RE in its electricity system - demand side management, flexibility of thermal plants, and storage components including BESS.

Mr. Bipin Talati, IAS, Joint Secretary, Climate Change Department, Government of Gujarat apprised about the prominent mark that Gujarat has made in RE generation by covering around 3.5 lakhs households with solar PV systems. Gujarat ranked number one among states in the implementation of rooftop solar plants and will soon implement a 30,000 MW mega solar plant in Kutch. He emphasized the importance of BESS for grid balancing, with respect to increasing RE share in the energy mix and the state government's strong focus on EV uptake expected to increase load management challenges for DISCOMS.

Mr. Shwetal Shah, Technical Advisor, Climate Change Department, Government of Gujarat, highlighted India's ambitious NDC commitments to achieve net-zero emissions by 2070, among other ambitious targets, and that BESS is an indispensable component on this path. He noted that local capacity building is important to facilitate the adoption of BESS.

Mr. Rohit Patel, Executive Engineer, Energy Efficiency Cell, SMC and Mr. Amit Shah, Deputy Executive Engineer, Roshni Department encapsulated for the audience the achievements of Surat and Rajkot cities in the field of RE and EVs. The Energy Efficiency Cell within SMC monitors and regulates the power consumption for facilities with load demand above 30 KW. SMC has implemented 6.9 MW capacity of solar and 35.7 MW of wind power plants to power around 87 HT connections of municipal facilities. From the e-mobility point of view, Surat is the first city to prepare an exclusive EV Policy 'Surat City Electrical Vehicle Policy 2021' with a targeted installation of 100 public charging stations by the end of this year. RMC plans to deploy decentralized solar power plants at the water pumping stations and scale-up EVs.

Mr. Naveen Nagpal, Asst. Vice President, BSES Rajdhani Power Limited (BRPL), shared insights from BESS deployment in BRPL's power distribution network in Delhi. He apprised participants about the practical use-cases of BESS and benefits being realized through pilots in six locations, with BESS being used for peak load management, energy arbitrage and reactive power management. He emphasized that energy storage is a must for flexibility in high VRE scenarios and called for the need to conduct a probabilistic study to assess the impact of RE addition on power portfolio reliability and quantification of need for their power balancing, to identify requirements for solutions such as BESS.

The team of experts from ICLEI South Asia – comprised of Mr. Nikhil Kolsepatil, Mr. Senthil Arumugam and Mr. Harpreet Singh – presented on BESS technology and its applications. They highlighted key opportunities and prospects for BESS in the context of the existing scenario, targets for RE & EV in Surat and Rajkot, five BESS use-cases identified in the two cities, an assessment framework to help with the preliminary scoping of BESS in each of the five use-cases, and a few innovative business models to support the implementation of BESS.

Experts from pManifold – Mr. Kunjan Bagdia, Senior Consultant and Mr. Vikrant Vaidya, Senior Partner – presented the outcomes of the pre-feasibility analysis of BESS for BtM and FtM use-cases undertaken as part of the study. Mr. Bagdia explained the methodology followed for the use-case analysis and highlighted the results of comparison of TCO for the baseline (without BESS) against TCO with implementation of BESS in each use-case.

The workshop provided various insights on the implications, challenges, benefits, and a way forward in enabling strategies and interventions to scale up BESS deployment in cities.

## Key Outcomes

- Introduced applications of BESS at the city level - Detailed city-specific assessments for BESS adoption highlighting the existing scenario and targets for RE and EV, and specific opportunities for BESS in FtM & BtM applications for Surat and Rajkot, were presented in the context of promotion of ESS's.
- Presented Assessment Framework for BESS use-cases and applications, developed to guide and underpin preliminary scoping of BESS deployment at the city-level. The framework is a tool to help assess and understand the challenges, opportunities and feasibility of BESS adoption for specific applications at the urban scale.
- Established understanding on the financial bankability of BESS projects - Pre-feasibility level analysis undertaken across four of the shortlisted BESS use-cases (3 BtM and 1 FtM) was presented and discussed. DISCOM load management and municipal services were identified as the use-cases with relatively higher potential for BESS implementation.
- Aroused stakeholders' interest through innovative business models - Applicable business models for BESS deployment at the city scale, identified for both BtM and FtM battery storage systems based on global case studies, were presented to the stakeholders.
- Discussed enabling actions for BESS adoption - Enabling strategies and interventions to scale-up battery energy storage including coordination mechanisms between ULBs, DISCOMs and power sector actors, necessary policy and regulatory measures were shared and discussed with the participants.
- The workshop enlightened the participants on the key requirements and opportunities for the city and DISCOM to work together for BESS towards effective implementation of distributed RE and EV transition at the city scale.
- A typical BESS system needs value stacking in terms of multiple uses instead of a single use. Further, it is important to monetize multiple value streams for the economic viability of BESS.
- Pilot scale projects are needed on priority for more successful demonstration on-ground. The Climate Change Department of the Gujarat Government is willing to support such initiatives with knowledge and technical partners.

## Key Points from the Speakers

**Emani Kumar, Deputy Secretary General, ICLEI Global & Executive Director, ICLEI South Asia**

- For India's long-term goal of reaching net-zero emissions by 2070, separate targets need to be identified as a trajectory for each decade till 2070.
- Cities are witnessing the highest peak demands and there is a significant positive correlation with the temperature increase from climate change.
- Increasing contribution of RE in the generation side and large uptake of EVs in the cities, brings new challenges such as electricity demand and supply gaps. BESS will help manage such gaps and shave peak loads efficiently.

**Siddharth Arora, Associate Director (Clean Power), Shakti Sustainable Energy Foundation**

- Lack of predictability in the output of RE plants aggravates the problem of consistently matching supply with energy demand.
- Alongside BESS, Shakti Foundation is exploring the potential for other storage solutions as well. Pumped storage has a potential of around 100 GW in India.
- Besides being faster to deploy at scale, battery storage systems offer many benefits over traditional grid storage solutions. BESS supports in demand side management, avoiding/minimizing DSM charges and offers flexibility to the power generators.

**Bipin Talati, IAS, Joint Secretary, Climate Change Department, Government of Gujarat**

- Gujarat Government established the first subnational department dedicated to climate change in Asia in 2009.
- Gujarat is the leading state in RE generation with 3.5 lakh households covered with rooftop solar PV system. The target is to achieve solar rooftops on 30 lakh households. The state is also going ahead with the implementation of a 30,000 MW mega solar plant in the Kutch region.
- The Climate Change Department has created a budgetary provision of INR 1 crore for research work under the 'Energy Transition Roadmap'.
- Highlighted the importance of BESS for grid balancing with rising contribution from RE. He noted that battery storage is especially important for smaller capacity balancing.

> **"With large capacities of renewable energy, especially solar and wind, coming in the electricity grid in Gujarat, deploying energy storage systems is imperative for the grid balancing - matching the supply of energy to demand."**

**– Mr. Bipin Talati, IAS**
Joint Secretary, Climate Change Department, Government of Gujarat (paraphrased)

**Shwetal Shah, Technical Advisor, Climate Change Department, Government of Gujarat**

- India has ambitious NDC commitments. The Cabinet approved a revised NDC to achieve net-zero emissions with more ambitious targets in a scientific way.
- As per the MNRE notification in July 2022, around 4% of energy storage obligations are to be included in RPOs
- Local capacity building is required to facilitate the adoption of BESS. The start-up ecosystem in this area will enable the procurement of raw materials.
- Climate Change Department will facilitate engagement with knowledge partners and support pilot scale projects in Gujarat.
- Disposal and recycling of batteries is an important issue that needs to be properly provisioned through policies/regulations.

**Mr. Senthil Arumugam, Project Officer - Energy & Climate, ICLEI South Asia**

- As per India's updated NDC target 2022 and its energy transition, India aims for 50 percent of cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030. It aims to achieve 30% share of EVs in new vehicle sales by 2030, with projections estimating total EV sales to reach 14.8 million by 2030 under the e-mobility transition.
- Increasing VRE integration into the grid, EV deployments and development of EV charging infrastructure, net-zero ambitions of cities encouraging distributed energy resources (DERs) necessitates energy storage deployment to ensure grid flexibility. T&D network congestion relief is another important service that BESS can provide.
- BESS applications in FtM operations viz. peak demand management, ancillary services (frequency and voltage regulation, black start operations), capacity enhancement deferral, reduction of deviation penalties and UI charges, and grid integration of VRE were highlighted. BtM applications of BESS including peak load management to save electricity charges, support EV charging infrastructure, maximize RE potential for self-consumption, improve power quality and clean back-up power/uninterruptible power were also discussed.
- Gujarat's target of installing more than 64 GW of solar and wind power by 2030 would lead to ~7% of curtailment unless energy storage is deployed. IEA suggests at least a four-hour duration battery storage addition of 4 GW in Gujarat to avoid curtailment.

**Mr. Rohit Patel, Executive Engineer, Energy Efficiency Cell, Surat Municipal Corporation**

- SMC's annual electricity consumption is around 320 GWh in which RE contributes 30% with total capacity of around 51.05 MW. The estimated monetary saving due to RE is INR 66 crores.
- In-house and external energy audits have been conducted as a part of energy efficiency measures by the SMC, resulting in energy savings of 34 GWh per annum and monetary benefits of around INR 17 crores per annum.
- Surat is the first city to have a city-wide EV policy in India and has the highest no. of EVs among all cities in Gujarat.
- SMC has planned to install 100 public charging stations by end of 2022, of which 50 shall be installed in the PPP model.

> **"Surat Municipal Corporation's strong focus on deploying RE at various facilities with envisaged monetary & environment benefits acts as an opportunity for deploying BESS alongside RE, which will reduce the peak demand of the facilities, & also serves as a power-backup to run the operations during grid outages"**

**– Mr. Rohit Patel**
Energy Efficiency Cell, Surat Municipal Corporation (paraphrased)

**Mr. Amit Shah, Deputy Executive Engineer, Roshni Department, Rajkot Municipal Corporation**

- Deployment of 150 public e-buses is targeted by 2022. 23 E-buses were procured to serve Rajkot city and commenced operations in August 2022.
- The city has planned to deploy a few pilot projects with BESS and solar for EV charging stations.
- RMC has implemented decentralized solar projects at 40 to 50 locations within the RMC premises and has targeted commissioning of 4 MW RE for wastewater and water pumping stations.

> **"Rajkot is planning to install decentralized solar power plants & has installed such plants at around 40 locations. We are also going ahead with RE implementation at water pumping stations & launching EV charging stations."**

**– Mr. Amit Shah**
Deputy Executive Engineer, Rajkot Municipal Corporation (paraphrased)

**Nikhil Kolsepatil, Senior Manager & Harpreet Singh, Assistant Manager – Energy & Climate ICLEI South Asia**

- Surat and Rajkot have significant RE deployment. More than 35% of the total electricity requirement of municipal facilities in Surat is being fulfilled by RE. The RE generation accounts for 3.6 % of total city-wide electricity requirements for Rajkot.
- Surat aims to accommodate around 40,000 new EVs and develop 500 EV charging stations in the city by June 2025. Surat also plans to procure 300 e-buses for its public fleet. Similarly, Rajkot plans to procure 150 public e-buses by 2023.
- One e-bus is estimated to consume around 250 kWh of electricity per day, amounting to 112 MWh electricity consumption for 450 e-buses across the two cities (300 and 150 e-buses for Surat and Rajkot respectively).
- HT consumers in both cities have to pay an additional ToU charge for power consumption during peak hours (7am to 11am and from 6pm to 10pm). This creates an opportunity to assess feasibility for BESS deployment.
- The Gujarat Solar Policy 2021 requires that HT/EHV consumers shall consume solar energy generated for captive use between 7am and 6pm of the same day, with surplus energy is to be sold to the DISCOM through gross-metering mechanism at INR 2.15 per kWh. BESS can be helpful in this case, to store excess RE generation (during off-peak hours) for utilization in a cost- effective manner.
- BESS can be deployed across various applications and use-cases in cities, either as a FtM or BtM solution. The use-cases shortlisted for the selected cities are 1) EV charging infrastructure, 2) end-use consumers (commercial, industrial and residential) 3) municipal utilities and services as BtM applications 4) generation and transmission management and 5) DISCOM load management at power distribution side as FtM applications.
- The Assessment Framework developed for BESS use-cases and applications, under the project will guide and underpin preliminary scoping of BESS deployment for specific use-cases identified at the city level, before going into technical pre-feasibility studies.
- Assessment frameworks for BESS use-cases including municipal utilities and services, EV charging infrastructure and DISCOM load management were presented in the workshop.

**Mr. Naveen Nagpal, Asst. Vice President, BSES Rajdhani Power Limited**

- BRPL's peak load demand has increased by approximately 20% in the last 4 years and it witnesses substantial diurnal deviation of around 1200-1300 MW in peak (July) as well as lean (January) months.
- With the increasing power demand, new load entrants into the system viz. EV charging and high quantum of RE integration, BRPL is facing a few challenges in its power distribution network such as asset overloading during specific months/durations, reduced load factor on distribution assets, compliance with DSM regulations, and RPOs and Energy Storage Obligation (ESO) notified in July 2022.
- Six BESS pilot projects were implemented at selected DT sites. Major benefits emanating from the installed pilots included:
    - → shaving the transformer peak load and filling the valley during lean load,
    - → energy arbitrage (batteries are charged when the Real Time Market (RTM) rate is low and it is discharged when the rate is high), and
    - → improving the local reactive power profile
- Another urban microgrid project was implemented by BRPL in a 33 kV grid station where solar PV + BESS is being used for energy arbitrage, peak shaving, and back up supply (replacing a DG set).
- Three BESS projects are under commissioning at present and are expected to offer benefits on investment deferral, savings in peak power purchase, reliability improvement, diesel savings, emissions curtailment and energy time shift applications (viz. accommodate EV charging/ discharging behaviour).
- Immediate requirement for probabilistic study to assess the impact of RE addition on power portfolio reliability and quantification of need for their power balancing.
- BESS deployment needs financial support through concessional loan arrangement, Viability Gap Funding and similar mechanisms.

**Mr. Kunjan Bagdia, Senior Consultant, and Mr. Vikrant Vaidya, Senior Partner, pManifold Business Solutions Pvt. Ltd.**

They presented the outcomes of the pre-feasibility analysis of BESS for BtM and FtM use-cases as part of the assessment:

- For the BtM applications: BESS is a technically viable solution to reduce the peak demand of the facilities and for power factor correction. It helps maximize self-consumption from RE generation and provides reliable power-backup during grid outages. BESS deployed with RE in BtM applications such as EV charging, commercial and industrial facilities, and municipal utilities reduces the loading of the local DT, thus, deferring the requirements for augmentation to a certain extent and providing co-benefits to DISCOMs.
- From the FtM use-case analysis, it was evident that deploying BESS as primarily load shaving application was viable only when the peak loading occurs for shorter intervals and involves low load-shaving requirements or demand.
- Based on the preliminary feasibility analysis for BESS deployment for BtM & FtM applications, BESS for municipal utilities & services and BESS for the DISCOM load management are the two cases that demonstrate greater feasibility for BESS deployment.
- RE plays an important role in improving the viability of BESS in end-uses with large demand. As the cost of BESS is expected to decline significantly in future while energy costs from the grid will increase, the feasibility of BESS coupled with RE systems will improve.

**Mr. Senthil Arumugam, Project Officer - Energy & Climate, ICLEI South Asia**

He presented the key business models to deploy BESS for FtM and BtM applications:

- Typical implementation models identified for BESS, based on its location on the value chain and ownership, through which innovative energy storage solutions and business models are emerging in case of FtM applications are, BESS as generation asset, transmission network asset, distribution network asset and merchant asset. For the BtM applications, BESS under the CapEx model and under ESCO/RESCO model are two key possibilities.
- Energy from BESS can be dispatched by the GENCO for meeting scheduled generation/providing primary frequency response and can be sold to TRANSCO or DISCOM through ESA. Subsequently, BESS services can be dispatched based on SLDC/RLDC signal.
- He highlighted an example for innovative collaborative models to deploy BESS to support the local distribution network, while passing on part of the benefits to the customer through cost concessions or payments. This was implemented by 'The Sacramento Municipal Utility District (SMUD)', a community-owned electric utility, in January 2020 to help achieve its net-zero carbon target by 2040.

## Q&A Session

**Questions to BRPL**

**1. Mr. Rahul Bagdia, pManifold:**

a. **Question:** What were the space requirements implemented for BESS? Since the increase in load has made it difficult to install DT for space requirements; in this context, what innovations does BRPL think are required to accommodate BESS near the DT site?

**Answer:** Multiple sites were selected for BESS installation where space for installing a new DT was inadequate. Different BESS components were placed across adjacent locations/spaces instead of putting the whole system in a container. This helped utilize the space more efficiently.

b. **Question:** Are the BESS pilots implemented by BRPL ground-mounted or mounted on an elevated frame?

**Answer:** Being the first pilot of sorts, in order to avoid any structural complications and accommodate heavy batteries, the system is ground mounted.

c. **Question:** In a practical scenario, which site according to BRPL is prominent for stacking-up of BESS - DT location or sub-station transformer location?

**Answer:** When the benefit that is to be derived out of BESS needs a solution of MW scale viz. frequency regulation or savings on DSM penalties, the installation of BESS (of higher capacity) can be done at sub-station level transformers i.e., around 11 kV levels. Apart from this, the BESS installations are recommended at lower voltage levels as it is expected to benefit all the upstream networks.

**Suggestion:** It is important to also explore used EV batteries for usage in BESS. It may alleviate the high capital cost situation for the project

2. **Gujarat Energy Training & Research Institute (GETRI)**

a. **Question:** Since BRPL is of the opinion that Li-ion batteries are not economical in current cost dynamics, has it explored any other battery technology available in the market?

**Answer:** While cost dynamics is an important factor, it is important that value creation from the system be focused upon, as BESS can be used for various purposes and has diverse applications. BRPL floated the tender for pilots as technology-agnostic but the bids that it received from vendors were only for Li-ion phosphate battery (LFP) battery technology as it was thought to be more reliable for their requirements.

b. **Question:** Is BRPL working on other battery technologies post-first pilot?

**Answer:** BRPL is working on a MW scale BESS detailed project report (DPR). Considering the limited space available at the installation site, BRPL has taken-up to the solution provider to suggest batteries that will fulfil the requirement.

c. **Question:** Since BRPL is using its BESS pilots for high variations viz. peak shaving and valley filling, has there been any original equipment manufacturer (OEM)-specific performance-related issues with its system?

**Answer:** For use-case identified, there were only two primary performance conditions to be maintained by BRPL during the usage. These were (a) maintaining the temperature of the room storing battery between 25-300C which BRPL is doing through industrial air conditioners, and (b) maintaining DoD above 20%. The charging and discharging of batteries do not take place randomly and the batteries do not require much maintenance during operation.

d. **Question:** Is there any ongoing cycle operation with the implemented BESS system viz. if the BESS is getting charged or discharged for a specific number of cycles post which performance of the BESS system is degraded?

**Answer:** BRPL while allotting tenders emphasized the energy content to be derived from the BESS and hence whether the battery is discharged (till its acceptable DoD) in one discharge or multiple discharges, it would be considered one cycle of discharge if a specified energy content is derived at the end of it.

e. **Question:** What are the use cases for BtM storage with solar photovoltaic (SPV) since BRPL has implemented it?

**Answer:** BRPL is promoting BtM solar use-cases with BESS in Delhi but has not implemented one. A BtM user can charge BESS during day time and utilize it during peak hours, while also helping BRPL in meeting its night peak. A limited number of consumers have the capability to do so in the current context. These consumers are ToD tariff consumers and get benefits in terms of reduction of peak charges. A residential consumer in Delhi having a load of 10 kW and above can opt for the ToD tariff.

**Questions to pManifold**

a. **Question:** What are the challenges of charging EVs through RE instead of grid and DGs without interrupting overall services?

**Answer:** In an ideal situation, it would be beneficial to charge the vehicles overnight at a slower rate by operating multiple chargers at low power throughout the night.

b. **Question:** BESS is expected to generate a lot of e-waste in the time to come. Has it been considered in your analysis?

**Answer:** While the cost of recycling the e-waste has not been considered in the study, the analysis does consider the repurposed battery to do the total cost analysis. EV batteries that can't be used further may become a source for BESS projects and be very cost-effective for investors.

c. **Question:** In one of the use-cases, it has been shown that 100 kW of contract demand can be reduced if solar is installed with BESS. How can a solar system with an inbuilt CapEx cost be beneficial if BESS cost is added to the overall cost?

**Answer:** Nine percent of RE generated in the said case, if used for charging the BESS instead of getting fed into the grid as net-metering, will save the overall cost of charging the BESS. Generally, in current scenarios, RE cost is lower than the grid charging cost. One can also do away with the cost otherwise required for power factor management or backup strategy cost. Other intangible benefits viz. power quality improvement which leads to enhanced equipment life are often not considered and hence RE with BESS may be a better alternative altogether.

d. **Question:** When there is an overlap between the peak load demand and RE generation, how will the peak curtailment through the RE system with BESS take place?

**Answer:** When there is an overlap, say 9 to 11 am, the 'smart energy management system' does what is technically called 'net charging' which means that instead of completely passing through the BESS, an RE source will predominantly work to shave the peak while only a portion will charge the BESS. This will be efficient as it will not incur any charging/discharging losses in such cases.

**Questions to GETRI**

a. **Question:** Since GETRI is working on a long-term roadmap of decarbonization in Gujarat, how will BESS fit into this roadmap?

**Answer:** GETRI has recently formed a decarbonization cell to make a 'Roadmap for Decarbonizing Energy Sector in Gujarat". RE with and without storage is a strong area of focus for the cell. The introduction of smart grids, microgrids, and facilitating prosumers through solar rooftops are being looked upon with special interest. BESS is expected to balance the bankable energy. Another use case is the 'Group Net Metering' and 'Virtual Net Metering' which is expected to benefit both the urban as well as rural consumers and eventually DISCOMs. Green Hydrogen is another technological advancement that can help in the decarbonization of the sector.

**Questions to the Project Team**

a. **Question:** How are the safety concerns addressed or being covered while deploying BESS, say, in hospitals?

**Answer:** It's important to bring regulations around BESS and its subsequent stringent operational implementation. Just like the automotive industry, stationary energy like BESS will be benefitted by strong compliance. The assessment framework developed as part of the study considers the safety aspect.

## Feedback response summary

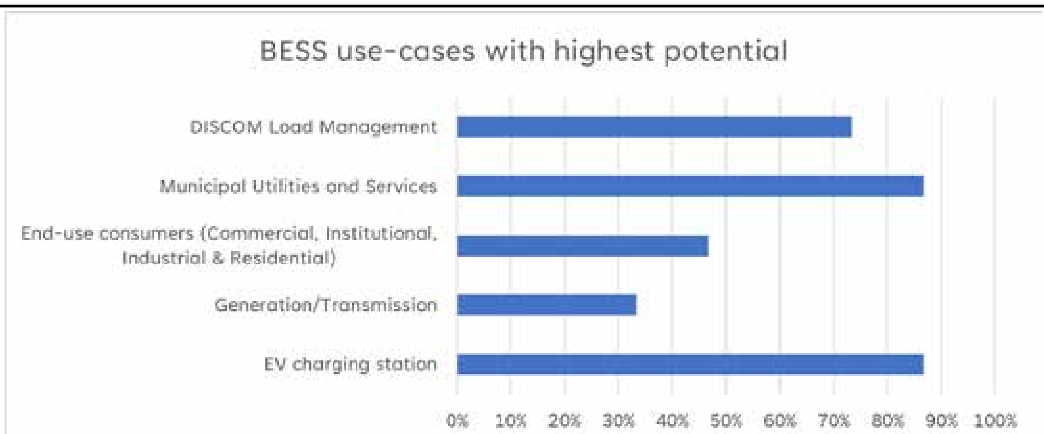
A feedback questionnaire was shared with participants during the workshop. The questionnaire was designed to capture the perspectives of participating city officials and other concerned stakeholders working in this domain on the barriers (in terms of policy, technology, finance etc.) for the deployment of battery energy storage technologies and the areas where the focus should be drawn. The questionnaire also tries to identify the use-cases that cities contemplate of having the maximum harnessing potential for BESS. A total of 15 responses were received and assessed.

The feedback questionnaire sought audience perspective on the following points:

**Use-case which has the highest applicability**

- EV charging infrastructure and municipal services have been identified as the use-cases with the highest potential for BESS implementation by 87% of the respondents.

- DISCOM load management has been identified as the category with the next highest potential for BESS deployment with 73% of respondents assenting to it..



**Any other use case that can be implemented in your views (Energy/Urban/Mobility)**

The following use-cases have been suggested -

- Agriculture sector – implementation of RE+BESS in rural areas
- BESS for emergency services

**Current gaps and challenges that are inhibiting the uptake of BESS in your city**

Absence of a robust policy on BESS at the national and sub-national levels has been identified as the biggest challenge to the deployment of the technology, by 80% of respondents.

**Suggestions to overcome policy challenges**

- Inclusion of BESS in RE policy
- Advocating overall energy efficiency at the system level
- Business model for the promotion of BESS for end-consumers
- BtM/FtM specified BESS guidelines

60% of the respondents have identified technical challenges to be the major barrier to the deployment.

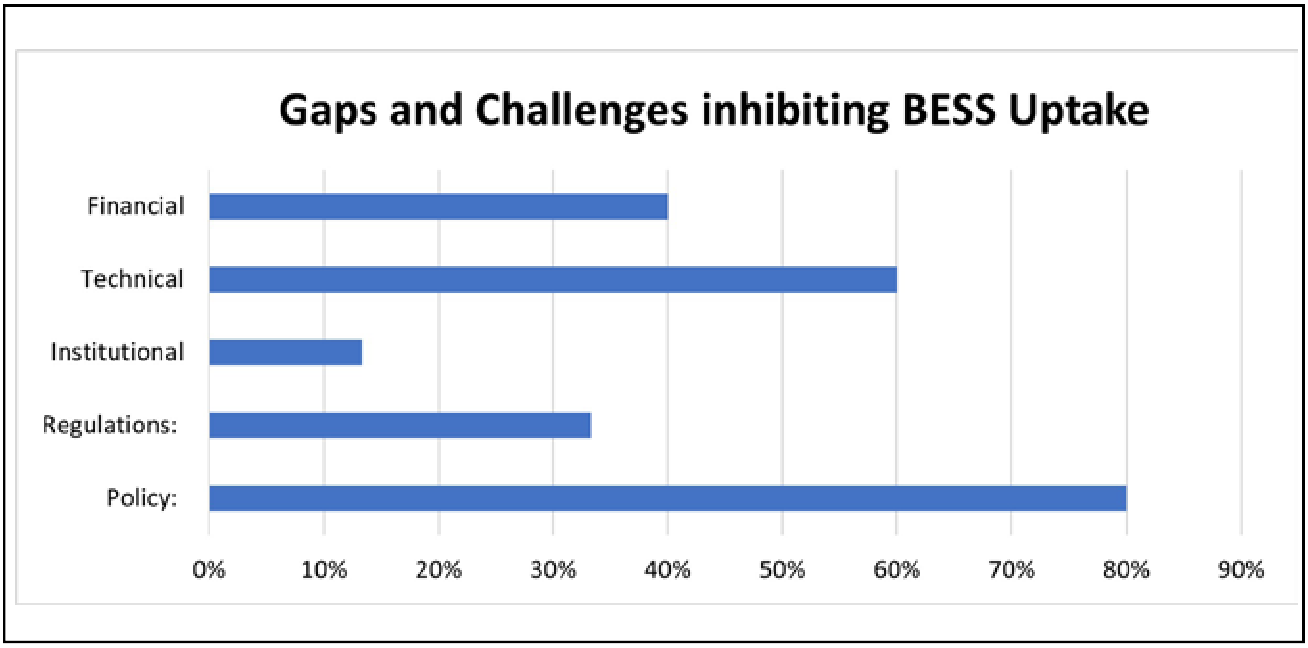
**Suggestions to overcome technical challenges**

- Tools/Framework for sizing for BESS

40% of the respondents have identified financial challenges to be the major barrier to the deployment.

**Suggestions to overcome financial challenges**

- Subsidies/financial incentives



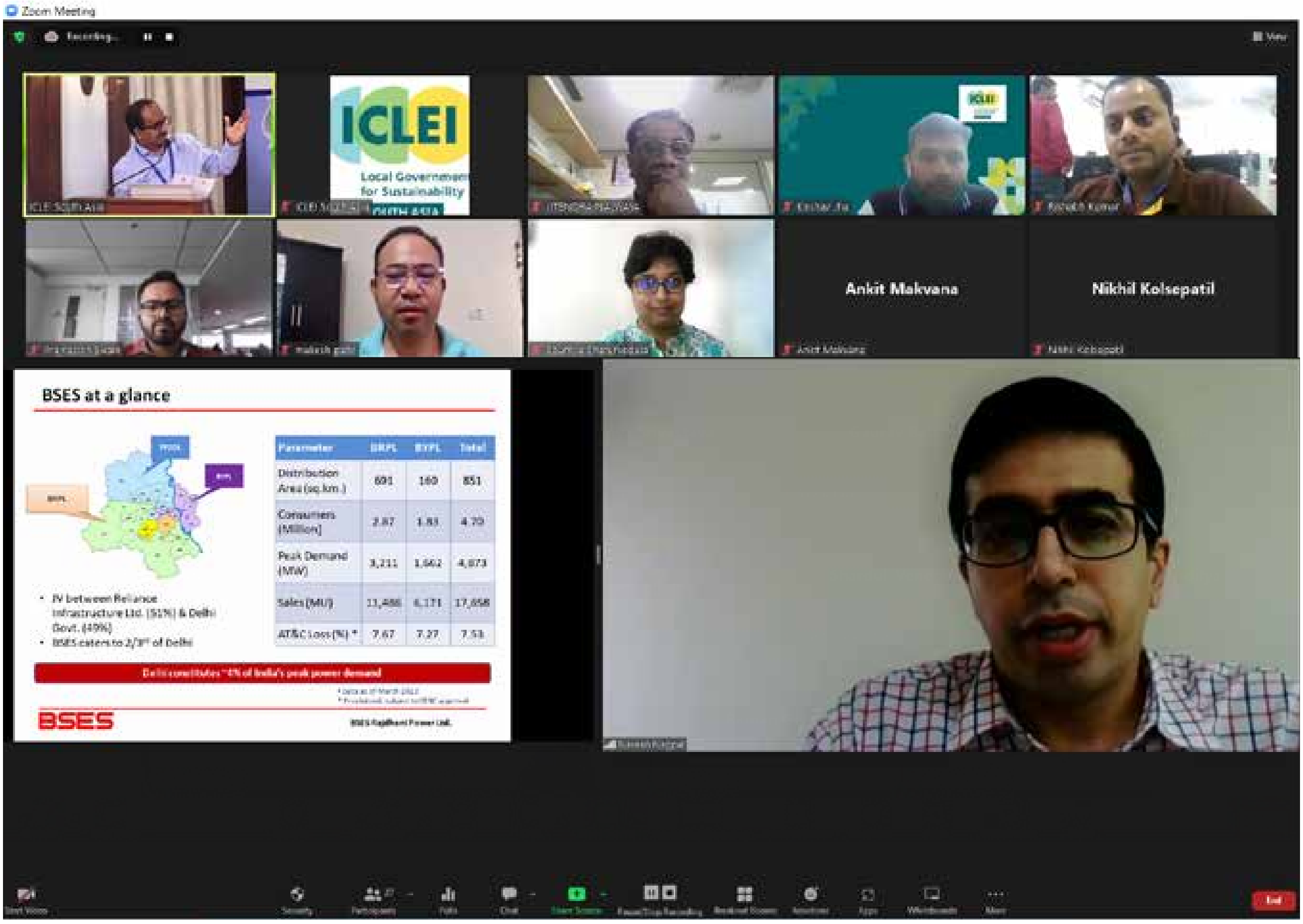
- Funds for R&D and pilot activities

**Other recommendations to overcome BESS challenges**

- Demand aggregation of batteries across industries to get the advantage of economy of scale which will otherwise be a very low volume and hence a costly preposition for stationary energy storage
- Implementation of pilot projects on ESCO/RESCO model
- Robust policy for the scrapping of batteries
- Exploration of different battery chemistries to reduce battery costs
- Setting benchmark BESS cost; incentive/VGF to be provided for pilot project during initial period

## Glimpses of the Workshop


CLEAR


Zoom Meeting
ICLEI
Local Governments for Sustainability
Ankit Makvana
Nikhil Kolsepatil
BSES at a glance
Parameter | BRPL | BYPL | Total
Distribution Area (sq.km.) | 691 | 160 | 851
Consumers (Million) | 2.87 | 1.83 | 4.70
Peak Demand (MW) | 3,211 | 1,662 | 4,873
Sales (MU) | 11,486 | 6,171 | 17,658
AT&C Loss (%) * | 7.67 | 7.27 | 7.53
JV between Reliance Infrastructure Ltd. (51%) & Delhi Govt. (49%)
BSES caters to 2/3rd of Delhi
BSES


Enabling Adoption
Storage


ICLEI
Workshop on


RAJKOT MUNICIPAL CORPORATION


y Energy
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Rohit Patel
Amit Shah

# In-person Participants

ICLEI
Local Governments for Sustainability
SOUTH ASIA

Workshop on

## Enabling Adoption of Battery Energy Storage Systems in Indian Cities

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# Endnotes


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41 It is important to understand the charging patterns in order to understand the load requirements across the day and how EV charging load correlates and whether it coincides with periods of peak electricity demand. Certain EVs such as public transport will require charging 2 to 3 times a day which will further increase the power demand.

42 Peak demand interval - Electricity Demand Intervals (15 min) in which the demand has been maximum

43 Transformers wherein capacity utilization/load exceeds 70% of the transformer capacity, are generally considered to have high load and indicates requirements for distribution system and transformer upgrade

44 1 liter of diesel consumed, emits on average 2.7 kg of $CO_2$

45 Estimated capital cost of DG set of 500 kVA capacity is around INR 40,00,000

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57 Cost considered in Base scenario is based on recent publications and cost estimation by experts and for the future scenario, the cost declination trend was analysed and the cost of BESS was arrived by considering 4.9% annual depreciation y-o-y from the base scenario, after 5 years.

58 As per GERC Tariff Schedule for FY 2022-23

59 Cost considered in Base scenario is based on recent publications and cost estimation by experts and for the future scenario, the cost declination trend was analysed and the cost of BESS was arrived by considering 4.9% annual depreciation y-o-y from the base scenario, after 5 years.

60 As per GERC Tariff Schedule for FY 2022-23

61 Decommissioned batteries from the Electric vehicles, at the end of their first life in the cars, still have a residual capacity of around 80%. This makes these "second-life batteries" ideally suited for use in energy storage systems.

62 In future scenario, the TCO of Grid + RE + BESS with repurposed batteries is likely to be lower as compared to BAU TCO by 4.96% in the case of e-car commercial charging station and 6.06% in the case of e-bus charging station.

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64 Available at: Data | Open Energy Information (openei.org)

65 Cost considered in Base scenario is based on recent publications and cost estimation by experts and for the future scenario, the cost declination trend was analysed and the cost of BESS was arrived by considering 4.9% annual depreciation y-o-y from the base scenario, after 5 years.

66 As per GERC Tariff Schedule for FY 2022-23

67 As per GERC Tariff Schedule for FY 2022-23

68 In future scenario, the TCO of Grid + RE + BESS with repurposed batteries is likely to be lower as compared to BAU TCO by 2.88% in the case of hospitals and 5.74% in the case of large hotel.

69 Static Synchronous Compensators (STATCOM) are fast-acting device capable of providing or absorbing reactive current and thereby regulating the voltage at the point of connection to a power grid.

70 As per GERC Tariff Schedule for FY 2022-23

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80 RE is must run and can only be subject to curtailment if proven reason of grid instability is shown

81 Policy and Regulatory Environment for Utility-Scale Energy Storage: India

82 Energy Storage Market Landscape Report – Supporting Structural Reforms in Indian Power Sector

83 Energy Storage Market Landscape Report – Supporting Structural Reforms in Indian Power Sector

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