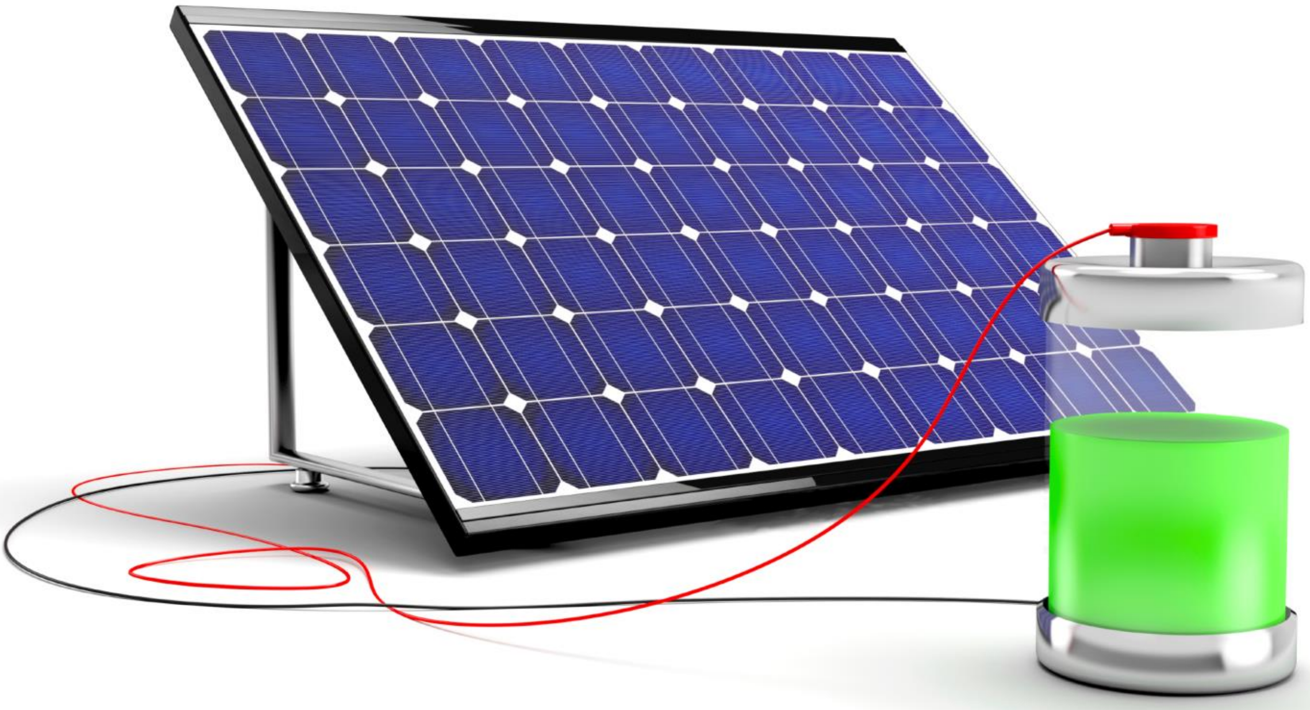
GOVERNMENT OF INDIA
MINISTRY OF NEW AND RENEWABLE ENERGY

Partnership to Advance Clean Enegy - Deployment Technical Assistance Program

PATHWAY TOWARDS **SCALING UP ENERGY STORAGE** THROUGH PILOTS AND POLICY DEVELOPMENT



2017

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PARTNERSHIP TO ADVANCE CLEAN ENERGY DEPLOYMENT (PACE-D)

Technical Assistance Program

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1. Introduction

1.1. Renewable Energy Deployment in India

The Indian power sector faces several challenges due to rapid changes in technology, market, regulation, and rapid growth of the economy. The sector must address legacy issues such as high-power losses, supply shortages, limited energy access in rural and areas, poor power quality, erratic supply, and issues affective reliability and safety. These challenges are especially severe in rural and semi-urban areas. In addition, India faces long-term challenges in reducing dependence on fossil energy and achieve energy security, arrest environmental damage resulting from fossil fuel use in line with domestic policy goals and international climate commitments. The power sector must also gear up to address new challenges arising from integration of higher quantum of Renewable Energy (RE), climate change, and a move towards decentralized energy generation. India has an estimated RE potential[1] of about 900 GW including 102 GW from wind, 750 GW from solar, and 25 GW from bioenergy[2]. The country aims to develop 175 GW of RE by 2022 and ensure that 40 percent of power comes from non-fossil sources by 2030.

The Government of India (GOI) through Ministry of New and Renewable Energy (MNRE) has been encouraging the uptake of RE at a fast pace to address challenges around the demand-supply gap as well as climate change and energy security.

1.2. Importance of Energy Storage Systems for RE Integration

RE deployment faces a series of obstacles as it scales up. RE energy is intermittent by nature, making scheduling and forecasting difficult. The direction and speed of wind or intensity of solar irradiation varies rapidly with time of day, season and local climatic conditions. Unlike fossil fuels, RE generation cannot be controlled as required, increasing challenges associated with matching of energy demand and supply. Large integration of RE generation can therefore make the grid unstable.

The issue of intermittency can be addressed by conventional technologies which can vary generation to match the supply with demand; with demand control strategies which vary demand to match supply[3]; or Energy Storage Systems (ESS), which provide the buffer to act as either demand or supply, depending on the requirements. At present, the Indian grid operates with limited storage and the output of gas, diesel or coal-based plants is varied to match demand and supply. This is inefficient and generates higher emissions. This penalty of inefficiency and emissions increases as larger RE capacities come into the grid. The use of efficient and cost-effective energy storage technologies can help make the grid more efficient and reliable, permitting greater integration of RE technologies which are rapidly declining in cost. The importance of ESS increases manifold when RE is used as standalone energy source in isolated micro grids, unconnected to the main grid. Here, the use of ESS becomes indispensable.

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[1] As of December 18, 2016, India has 15 percent of its share of power from renewable sources, with about 46 GW installed renewable capacity.

[2] http://pib.nic.in/newsite/PrintRelease.aspx?relid=155612

[3] Changing demand to match supply is difficult, although many demand management strategies are being evolved globally.

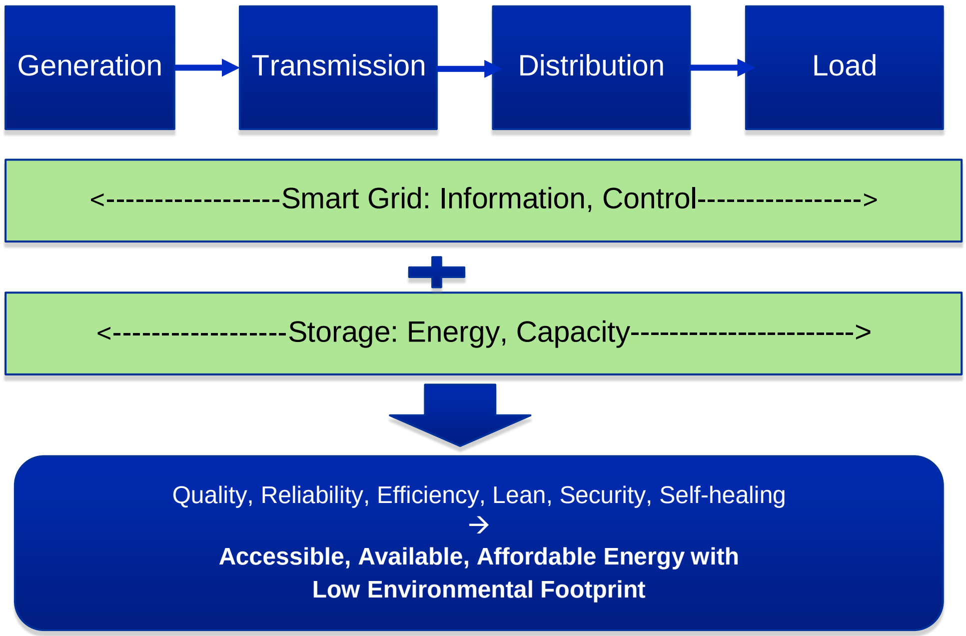

Figure 1: Modern Energy Systems Need Storage

ESS can provide significant benefits across a wide variety of RE systems, which include:

- 'Time shift' for generated energy
- Peak load shaving
- Grid stabilization
- Reduction of diesel consumption
- Improved power quality and availability
- Improved cost of delivered power
- Improved scheduling accuracy
- Output smoothing
- Fault ride through capability

1.3. Potential of Energy Storage Systems in India

Apart from the ambitious RE deployment program, India is also planning for a large electric vehicles program along with the National Smart Grid Mission and a wide-ranging deployment of microgrids coupled with distributed solar. All these developments will require large scale ESS in the country. India Energy Storage Alliance (IESA) released a market assessment report on energy storage in 2013 indicating the anticipated market potential for energy storage for different segments[4]. Based on the report, India is estimated to have a market potential for 15,000 MW of energy storage demand by 2020 driven by its RE programs, which is quite significant[5]. Sectors such as wind integration, solar integration, rural microgrids, industry backup systems, grid

[4] www.renewindians.com/2013/06/IESA-estimates-the-Indian-market-potential-of-energy-storage-to-be-15GW-by-2020.html

[5] Based on India Energy Storage Market Assessment (IESA) for 2013-20, April 2013.

ancillary services, transportation (electric vehicles), and agricultural solar pumps have 1,000 MW energy storage development potential each. However, realizing this potential remains challenging.

2. About PACE-D Technical Assistance Program

The Partnership to Advance Clean Energy - Deployment Technical Assistance (PACE-D TA) Program is a flagship bilateral program under the U.S.-India Energy Cooperation. The six year initiative is led by USAID and the U.S. Department of State and implemented in partnership with Ministry of Power and Ministry of New and Renewable Energy. The Program is focused on three key components: energy efficiency (EE), renewable energy (RE) and cleaner fossil technologies, with the overall aim of accelerating the deployment of clean energy.

One of the key focus areas of the PACE-D TA Program has been facilitation and creation of a strong market ecosystem for adoption of renewable energy technologies through the design of scalable and replicable pilot projects to spur demand in the market and attract new stakeholders to enter the market. In its initial phase, the Program undertook a detailed study to identify specific technologies, market segments and market players who could benefit from deploying RE technologies. The findings were compiled in a strategy report, which guided the design and deployment of pilot projects.

The study found that decentralized energy options such as renewable energy systems with integrated storage had significant applications for India and could serve as a long-term solution to energy access issues in the country. Realizing the importance of energy storage technologies for the future development of renewable energy technologies, USAID and Ministry of New and Renewable Energy, started working in partnership through the PACE-D TA program, and began an assessment of energy storage applications and technology uptake for India in 2013. At that stage, energy storage deployment was at a very nascent stage. Lead acid batteries had a well-established market presence in the country, while other energy storage technologies were not in deployment on a wide scale in India due to the high costs associated with these storage technologies.

Setting the Vision

The Program consulted with MNRE, industry players like India Energy Storage Alliance (IESA) and research organizations like Advanced Research Projects Agency-Energy (ARPA-E) and National Renewable Energy Laboratory (NREL). The Program also participated in field trips and stakeholder consultations organized by IESA in 2013. The first task was to understand the key drivers, technologies, application areas and business models for wide adoption of energy storage in India. Over the course of time, the Program engaged with MNRE and PSUs in development of three energy storage demonstration projects for supporting renewable energy integration. The Program also facilitated MNRE in developing outlines of National Energy Storage Mission and National Energy Storage Roadmap. A summary timeline of key engagements between MNRE and the Program are summarized below.

2013-2015 Concept and Promotion	2015-2016 Pilots and Technical Frameworks	2016-2017 Feasibility and Implementation

2013-2015 **Concept and Promotion**	2015-2016 **Pilots and Technical Frameworks**	2016-2017 **Feasibility and Implementation**

- Published report: Assessment of role of energy storage technologies in deployment of renewable energy
- Webinars and conferences on energy storage, involving international experts, industry players, policy makers, researchers
- Preparation of draft Energy Storage Vision and Roadmap for Energy Storage India for MNRE
- Discussions with MNRE and other stakeholders
	- Preparation of Expression of Interest draft for pilot projects on behalf of MNRE
	- Evaluation of bids and selection of proponents selected for energy storage demo projects
	- Preparation of framework documents for M&V and technical specifications
	- Consultations with experts
		- Support for MNRE in selection of REIL, BHEL and IOCL in response to EOI for ESS applications:
		  - Island: Microgrids for islands in Andaman
		  - C&I: Bottling plant for industrial entity
		  - Shaving of peak demand and load following
		- Feasibility Reports, Bid Documents development

Figure 2: Timeline of Key Program Activities on Energy Storage

3. Analytical Support to MNRE Energy Storage Program

Realizing the importance of energy storage for future development of renewable energy, PACE-D TA program has worked in a number of areas supporting deployment. The Program conducted detailed studies to identify the present status, applications, and technologies of energy storage around the globe and in India. Throughout the engagement with MNRE, findings were shared and discussed with key stakeholders to understand the way forward for India. The Program developed a roadmap, highlighting different milestones for accelerating the energy storage market. Key aspects of the Program's analytical engagement with MNRE are highlighted below.

3.1. Assessment on Role of Storage in Deployment of Renewable Energy

With MNRE's guidance, the Program undertook a detailed study on key energy storage technologies across the globe. The focus of the mapping and analysis was to identify emerging technologies, assess their costs, performance and maturity levels and determine their application potential for India. The study mapped and analyzed various energy storage technologies such as lithium-ion batteries, capacitor supported ultra batteries, vanadium redox batteries, sodium-sulfur batteries, reversible hydrogen fuel cells, underground thermal storage and the potential of combining onsite solar photovoltaic or solar thermal capacities with air-conditioning systems of buildings. The study also looked at concentrated solar power (CSP) systems using steam as the storage medium.

Analysis and Recommendations of Energy Storage Assessment Report

1. Detailed market assessment, including drivers, potential demand, and economic value of storage for key applications
2. Modeling of scenarios ranging from 20 percent to 50 percent renewable energy use, and assessment of related impact on the grid and the requirement of energy storage to facilitate preparation of a strategic roadmap for energy storage in India
3. Proposed approach creating a research and development program for energy storage, using MNRE's internal capability as well as joint research
4. Recommendation for setup of demonstration projects to showcase feasibility of storage for important applications in India
5. New market rules and policies needed to integrate energy storage solutions and independent storage solution service providers
6. A roadmap for advancing the deployment of energy storage solutions in India

The report titled *Assessment of Role of Energy Storage Technologies in Deployment of Renewable Energy* was released in November 2013. This first of its kind report identified the importance of energy storage, its criticality and capability to integrate large-scale RE, its variety of applications and presented estimates of economic value of energy storage for applications. The report analyzed various energy storage benefits such as time shift, grid stabilization, peak shaving of demand, improved generation efficiency, reduction in carbon emissions and improved transmission capacity utilization. The report also covered thermal energy and electrical energy storage and profiled global experience in ESS.

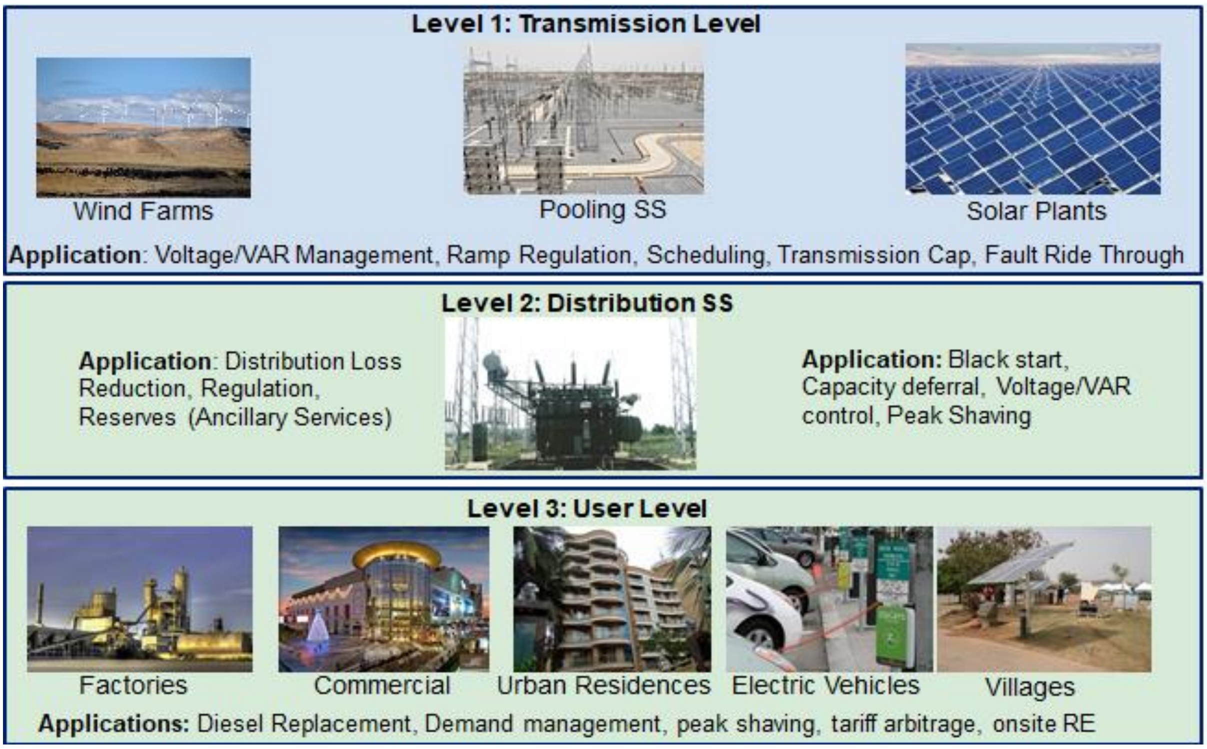

Figure 3: Storage System: Location and Application Based Architecture

Key Findings

The report identified available technologies in different stages of development. While few technologies were market ready, many required further research development and demonstration (RD&D) to assess their suitability. The report highlighted the importance of setting up demonstration projects to profile and share techno-commercial performance and the benefits of energy storage technologies in Indian context and developing a roadmap for deployment.

To understand the economic value of energy storage technologies, the report proposed three scenarios with detailed analysis with preliminary financial modeling. Scenarios included application of energy storage technologies for overcoming transmission constraint for wind generators, rural micro grids and commercial and industrial (C&I) users facing power shortage. Preliminary financial modeling showed that energy storage technologies are feasible for rural micro grids and offsetting diesel power for C&I users at current costs.

It was observed that storage technologies at cost levels of less than US$ 100/kW and less than US$ 0.01 per kWh per discharge cycle (electrical storage), will have a large potential for application in India. Batteries are approaching these cost-performance barriers rapidly and are likely to breach it within the next decade.

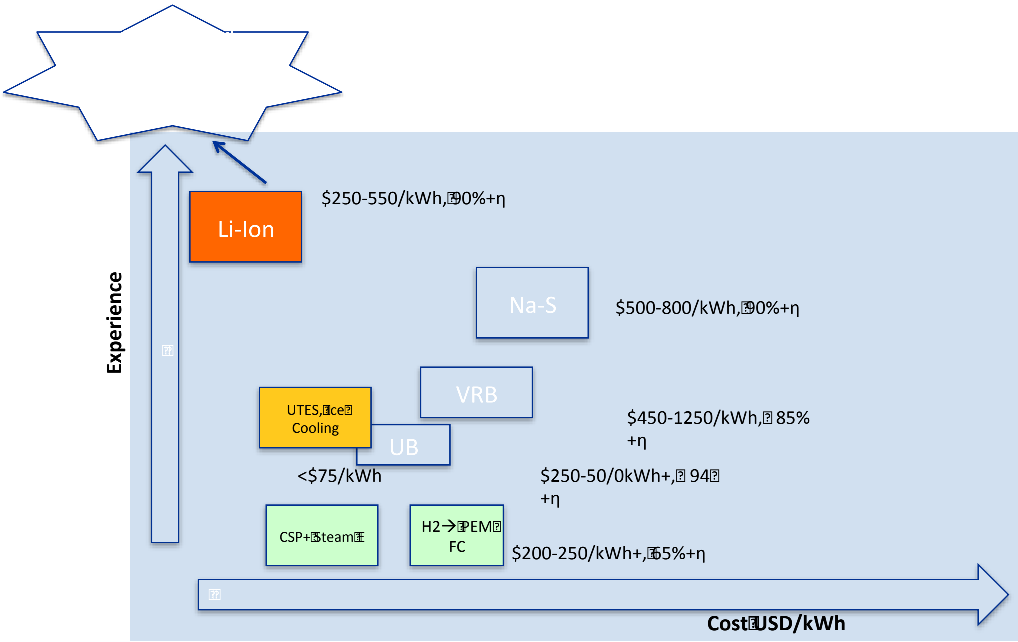

Figure 4: Emergence of Competing Energy Storage Technologies Compared to Lead Acid Batteries

Key applications where energy storage options can play a critical role were identified, including:

- Grid integration of renewable energy projects e.g. large wind, solar or hybrids;
- Village electrification and electrification of remote infrastructure including applications for defense, telecom and other uses;
- Energy management systems for large commercial and industry users, integrating onsite and off-site renewable energy generators; and
- Energy management systems for buildings, integrating on-site renewable energy.

3.2. Engagement with Energy Storage Stakeholders

The PACE-D TA Program engaged the full spectrum of key stakeholders playing a role in energy storage, including utilities, industry associations, government agencies, R&D agencies, technology players and private companies. The stakeholder engagement served the purpose of meeting several objectives.

- To underscore importance of storage for India’s energy needs,
- To seek stakeholder inputs on finalizing the roadmap for energy storage technology deployment in India, and
- To initiate a dialogue between industry and the government on storage applications.

Stakeholder consultation workshops also helped get inputs for the development of a roadmap for the energy storage sector, paving the way for launching demonstration projects. Discussions with stakeholders highlighted India’s need energy storage systems for accelerated deployment of renewable energy and meeting its RPO targets and identified drivers of energy storage in India.

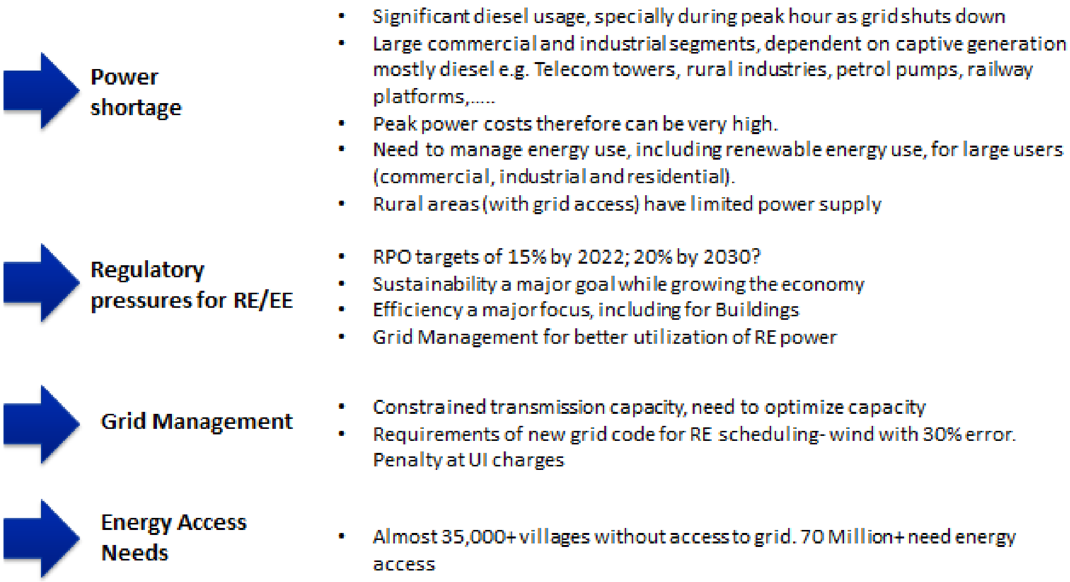

Figure 6: Drivers for storage usage in India

Key Learnings from Stakeholder Consultations

1. New ESS technologies must be evaluated and business models developed to ramp up addition of energy storage in India. Many storage technologies are available with capital cost under USD 500 per kW and USD 0.10 per kWh per discharge cycle (electrical storage), these can be employed in India.
2. Many drivers such as decline in renewable energy costs, inflation in fossil fuel costs, drop in storage costs and acceleration of smart grid implementation can drive adoption of storage technologies in India. However, more research is needed in areas of market research, application engineering, technology development, policies, financing and localization.
3. Stakeholders recommended development of an energy storage roadmap for India to guide policy makers and major stakeholders in accelerating the deployment.

3.3. Energy Storage Vision and Roadmap for Renewable Energy Deployment in India

As an important area for future energy systems, India needs a roadmap for energy storage, with detailed milestones and actions. The Program developed outlines and a framework for a national vision and roadmap on energy storage, along with the MNRE in 2015. The Program identified priority areas for action, based on research of successful programs on energy storage globally, drivers of Indian demand for energy storage, and detailed stakeholder consultations. This document summarized recommendations from various stakeholders and analytical work carried out by MNRE. The roadmap covered aspects such as applications, technology transfer and development and policy and financial support. Extensive stakeholder consultation and desk analysis was carried out. The roadmap identified seven streams of work:

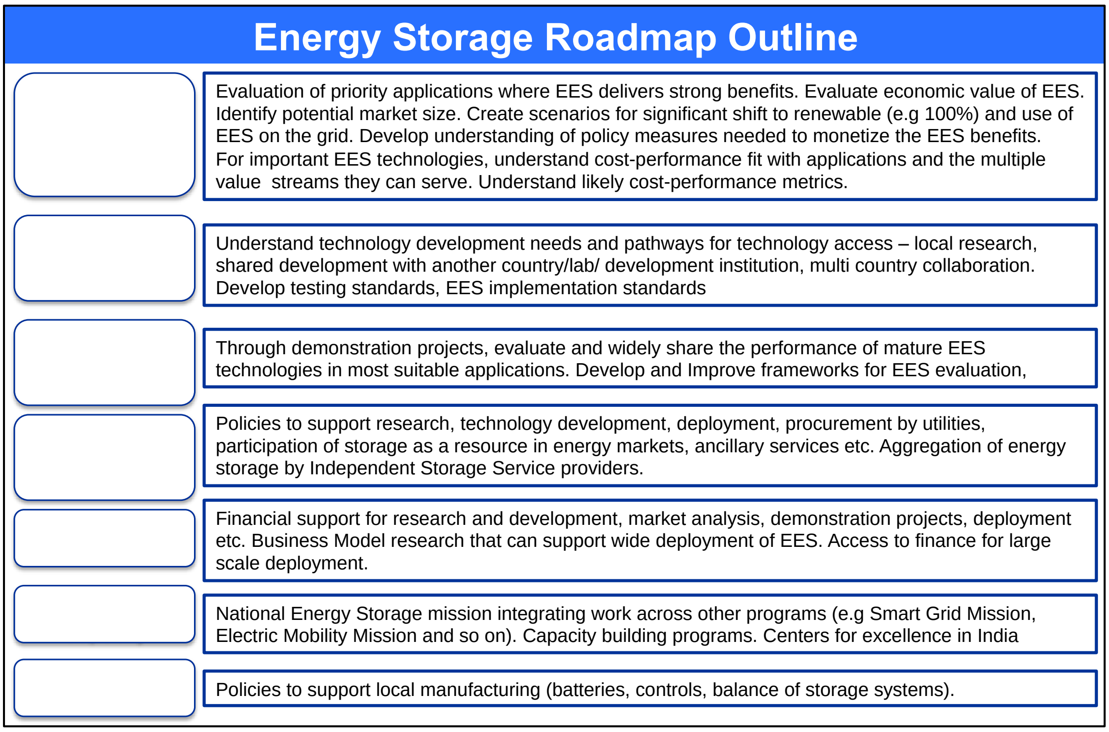

Figure 7: Energy Storage Roadmap Outline

The roadmap outlined important steps in the short, medium and long term to address the areas identified above. The objective of the roadmap was defined as "Through energy storage, enable development of a secure, flexible, high quality, cost effective, clean energy system for all by 2030"*.* For different stakeholders, key benefits associated with Energy Storage Technologies, which can be monetized were identified as listed below.

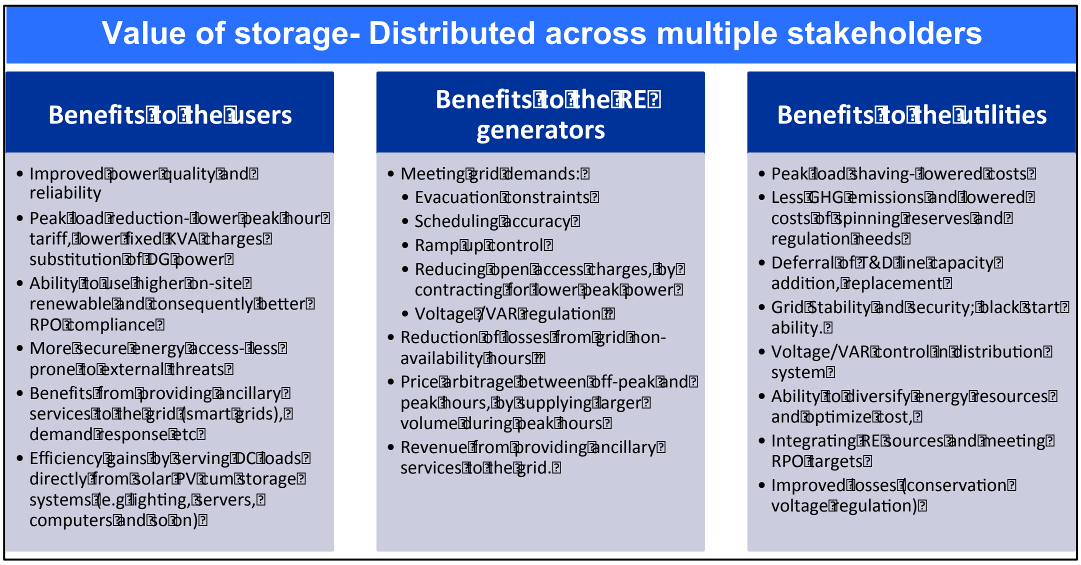

Figure 8: Benefits of Energy Storage for Various Applications

Key Learnings from Development of ESS Roadmap

The process of developing a roadmap for energy storage in India helped bring a number of learnings to the fore.

1. It is critical for India to develop a roadmap for deployment of energy storage technologies, the roadmap can be a useful tool in developing and refining appropriate regulatory framework necessary for scaling up.
2. The precise value of ESS can be arrived at only for specific applications and use cases, using detailed simulation or data from demonstration projects. Because such data is not yet available in India, MNRE should support demonstration projects, which can serve to foster a better understanding and generate data for future decision making.
3. Some markets are ready to benefit from storage applications and reduce cost, improve quality, reliability, safety and environmental footprint of energy systems. However, the current policy framework does not allow these markets to reap benefits offered by energy storage. There is a need for a supportive policy framework which allows deployment of storage for applications where it is economical, to give the sector a boost.

3.4. Recommendations for Scaling Up Energy Storage Technologies

Further action is needed in the following areas for accelerated uptake of energy storage technologies in India.

1. Creation of an expert industry forum with members including electricity service providers, utilities, renewable energy generators, storage system suppliers, research laboratories, academic institutions, consultants, regulators, policy makers, and investors.
2. Assessment of market drivers, potential demand, techno-economic feasibility, economic and financial value of storage systems for key applications.
3. Development of detailed pilot designs for the applications identified above to help develop overall recommendation on policies required to accelerate adoption of storage technologies.
4. Development of market rules, policies and regulations for integration of energy storage solutions.
5. Development of technical standards.
6. Development of India’s R&D capacity for energy storage.

4. PACE-D Technical Assistance to Demonstration Projects

Understanding the critical role that ESS technologies will play in the grid integration of RE, MNRE launched a Demonstration Program to evaluate and share the performance and economic value of ESS technologies in grid integration of RE. The program envisaged sharing of techno commercial analysis, bidding frameworks, and techno-economic performance from the projects and lead to enhanced commercialization. Selected projects would also help develop innovative approaches for financing energy storage technologies and develop capacity to test and verify performance. They may also help develop appropriate policies for supporting ESS, for example tariff for ESS supported micro grids.[6] The demonstration program had the following expected outcomes.

- ***Identification of scalable applications***: The program will identify applications where energy storage can improve effectiveness of RE integration, improve reliability and reduce cost of energy supply.
- ***Establish performance of new energy storage technologies:*** The demonstration program will share performance data and economics from a detailed monitoring, reporting and verification (MRV) plan for projects using these technologies. This would help enhance understanding of their long-term lifecycle costs and performance.
- ***Development of business models for deploying energy storage:*** High upfront cost of energy storage solutions can be reduced through design and deployment of service-based business models. The demonstration projects are expected to support applications which lend themselves to development of new business models.

4.1. Preparation of Expression of Interest (EOI)

In 2015, the Program assisted the Ministry in preparation of the Expression of Interest (EOI) to identify investible projects from a target audience consisting of public sector undertakings (PSUs), departments of central and state governments and private corporates. Projects were selected on basis of parameters such as the cost of energy saved, uniqueness, innovation, scalability, demonstrability, impact of application and business model for delivery of energy storage solutions and financial strength of the host agency (consumer). ESS applications identified rural microgrids, standalone applications, grid-interactive micro-grids for C&I customers and integration of large scale RE farms as areas for pilot projects.

4.2. Techno-commercial Evaluation of EOIs

The Program assisted MNRE in selection of prospective project proponents from approximately 40 EOIs received. Evaluation was carried out for each application area separately and projects selected based on final evaluation scores. Proponents were first assessed on basis of their technical qualifications on basis of the following criteria.

- Cost of energy saved
- Cost of storage as a percentage of the cost of energy delivered
- Scalability, demonstrability, impact of application and business model
- Quality of the overall proposal and methodology
- Financial strength of the end user

[6] One of the MNRE supported demonstration projects is seeking a tariff approval for micro grid composed of solar, diesel and ESS, in Andaman Islands.

A minimum 25% of overall rating on any of the dimensions was needed. Applications with unacceptable levels of risks, high level of grant needed, lack of scale, or lack of clarity or poor quality of information were rejected. In the second phase, final evaluation scores were calculated, and companies selected by a special committee appointed by MNRE, which presented its results to the MNRE standing committee on energy storage. MNRE selected three project proponents to develop RE-ESS hybrids under this Program.

Proposing Entity	Key Features of Pilot
Rajasthan Electronics India Limited (REIL) for establishment of solar PV-ESS hybrid projects in Andaman Islands	This project will demonstrate value of energy storage in off-grid mode, supporting solar and diesel generators and optimizing performance to reduce diesel costs. The energy storage capacity also supports smoothing of solar output keeping the grid stable. Solar output is highly variable in these islands due to unpredictable and heavy rains.
Indian Oil Corporation Limited (IOCL) for set up a solar PV-ESS project	This project will demonstrate use of energy storage in improving the delivered cost of energy and maximizing solar use when grid conditions are poor, blackouts are frequent, necessitating diesel use. These conditions prevail in many parts of India and C&I customers can use solar to replace expensive grid and diesel costs, supported by ESS.
Bharat Heavy Electrical Limited (BHEL) for set up of ESS project integrated with existing solar PV plant	This project will demonstrate the use of energy storage in peak load shaving and load firming applications, useful in urban distribution systems as well as large RE generators supplying to transmission grid.

4.3. Preparation of Model Documents

The Program conducted market based analysis and modeling in consultation with industry experts, to help investors analyze financial feasibility of projects, evaluate investment proposals, monitor performance and make performance based payments for operation of energy storage as a service. The development of model Monitoring and Verification protocol, Technical Specifications and Request for Proposal (RFP) documents will help future developers and project proponents in implementation of projects.

Model RFP Document: This document identified generic structure for developing the technical and system specifications for energy storage projects. The specifications included site conditions, system specifications, and requirements for remote monitoring. In addition this document also prescribed functional guarantees, performance tests and bid evaluation criteria for energy storage projects.

Model Monitoring Reporting and Verification (MRV) document: Four types of parameters for MRV plan for ESS were defined and the various indicators identified.

1. **Input Data:** These elements are captured through supervisory control and data acquisition (SCADA) and later analyzed to assess performance
2. **System Performance Parameters:** Output parameters which are directly linked to the system operation
3. **Impact of ESS on Grid/Application:** Outcome parameters related to energy level or system level outcome
4. **Community impacts:** Overall impact parameters related to the ESS for various applications.

This data and subsequent analysis can be used in several ways.

- To share with stakeholders and potential users to help assess ESS performance, e.g cost, technical performance to facilitate planning of future projects
- To compare technologies' fit with applications and identify areas for improvement
- Understanding the economic value of ESS
- Identify policy and regulatory measures for scaling up ESS

4.4. Technical Assistance to Public Sector Undertakings

The program is presently providing technical assistance to the three PSUs: REIL, IOCL and BHEL in implementing their demonstration projects through the following activities.

- Comprehensive site survey for projects
- Techno-commercial studies for assessment of energy storage feasibility in integration with RE, engineering design, and detailed feasibility reports for projects
- Technical specifications for the energy storage and solar PV system
- Bid management process
- Business models and financial analysis

These demonstration projects are helping PSUs understand the functioning and performance of energy storage systems, and how to leverage the storage technologies to make RE more competitive and scalable. While establishing the performance of new energy storage technologies, these projects can also help in developing new business models and creating a larger market for energy storage technologies in India. The three energy storage projects can be used as case studies for other institutions who want to use energy storage and for MNRE to roll out similar programs for other projects.

As we present the analysis in subsequent sections of this report, none of the projects have undertaken aggressive targets for reducing diesel consumption. At current ESS cost levels, and limitations of space and capacity constraints of net-metering policies for solar capacities set up in these project, complete elimination of diesel doesn't make financial sense. As ESS costs fall, projects that aggressively replace diesel or grid with RE will become more viable.

Table 2: Selected Energy Storage Demonstration Projects

Project Developer	Rajasthan Electricals and Electronics Limited (REIL)		Indian Oil Corporation Limited (IOCL)	Bharat Heavy Electricals Limited (BHEL)
Project site	Havelock island in Andaman	Neil island in Andaman	IOCL Lube Oil Blending Plant at Asaoti	BHEL R&D campus in Hyderabad
Peak Load Demand for Project	1.6 MW	413 kW	597 kW	
Solar PV Capacity	1 MWp	1 MWp	600 kWp	500 kWp (already installed)
Solar PV Technology	Polycrystalline module supplied by REIL	Polycrystalline module supplied by REIL	Polycrystalline (proposed)	Crystalline modules (by BHEL)
Energy Storage Capacity	1 MWh	1 MWh	300 kWh	1 MWh
Energy Storage Technology	Lithium ion	Lithium ion	Lithium ion	Lithium ion Ferrous Sulphate (500 kWh), Vanadium Redox Flow (200 kWh), Advanced Lead Acid (300 kWh)
Power Conditioning Unit	1 MW	1 MW	600 kW	500 kW for lithium ion, 50 kW for redox flow, 100 kW for advanced lead acid
Expected Capital Cost	INR 10.80 Crore	INR 10.80 Crores	INR 5.66 Crores	INR 7.3 Crores
Project IRR	12.40%	10.30%	10.70%	
Levelized Cost of Energy (Solar and ESS)	INR 9.11/kWh	INR 15.13/kWh	INR 10.66/kWh	
Diesel Reduction (liters/year)	371,000	211,966	29,950	N/a; No significant dependency on DGs
GHG Emission Reduction (kg/yr)	1,368,265	560,316	244,728	N/a; No significant emissions
Applications of Energy Storage	Diesel Reduction, reducing solar generation loss, smoothing the generation and providing grid support		Backup power, Diesel reduction, supporting higher solar use in captive mode	Peak load shaving, generation firming
Project Status	The EPC and O&M tender for the project has been released, and the bidding will close on 15.12.2017		Tender finalization in process	Procurement of batteries in process

I. *Island Microgrids: Diesel, Solar Microgrids with Energy Storage in Andaman Region*

The Program is assisting Rajasthan Electronics and Instruments Limited (REIL) in setting up of two projects of 1 MW solar PV coupled with 1 MWh battery energy storage in Havelock and Neil islands in the Andaman region. The key objective of the project is to reduce the diesel consumption in these islands, which are currently heavily dependent on diesel generators for fulfilling their power needs. Similar projects can be carried out in remote areas with no access to electricity, dependent on diesel generators for meeting their power requirements.

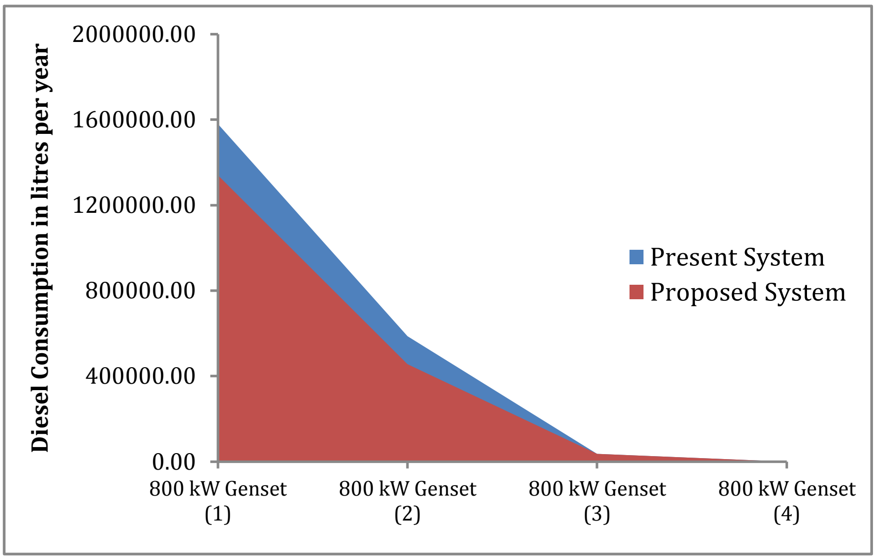

Figure 9: Diesel Consumption Using Proposed System Design For Havelock

Havelock Island: The proposed project can help reduce use of diesel generators to 12,790 hours/year instead of the current usage of 16,301 hours/year. This reduction in DG operating hours will result in diesel fuel savings of 371,000 liters/year, from 2,167,000 liters/year to 1,796,000 liters/year. In addition to savings from avoided fuel use, the system will also help reduced cost of DG maintenance, by reducing frequency of overhauling linked to number of hours of operations.

Table 3: Impact of Solar PV Hybrid with Battery Storage Systems

	Havelock Island Project		**Neil Island Project**	
	Annual Diesel Consumption	Annual Diesel Cost (Cr.)	Annual Diesel Consumption	Annual Diesel Cost (Cr.)
Baseline (No Solar PV, No ESS)	2,200,000	13.22	594,233	3.56
With ESS Project (With Solar PV & ESS)	1,830,000	10.99	382,267	2.29
Savings From Project	3,71,000	2.23	211.966	1.27

Diesel cost savings of about INR 2.23 Crore can be realized in the first year, and these savings will increase every year, with an increase of about 3.7 percent in diesel cost per year. If current trends of increasing diesel prices persist, the proposed project would result in INR 15.65 Crore worth present value of savings over a period of 25 years.

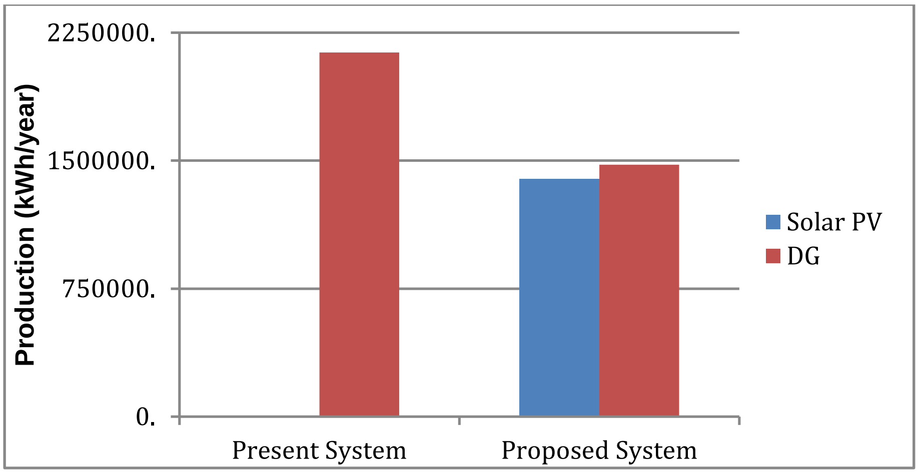

Figure 10: Diesel consumption using the proposed system design for Neil

Neil Island: The proposed 1,000 kWp solar PV coupled with 1,000 kWh ESS system will help reduce use of DG system from 8,760 hours/year to 2610 hours/year. Reduction in DG operating hours by 6150 hours/year would result in savings of 211,966 liters of diesel/year. The total diesel consumption reduces from 594,233 liters/year to 382,267 liters/year on installing the proposed system. In addition to savings from avoided fuel use, use of the system will also help reduced cost of DG maintenance. Diesel cost savings of about INR 1.27 Crore can be realized, with 3.7 percent increase in diesel cost yearly. If the current trend of increase in diesel price is observed, then the proposed project can result in INR 8.20 Crore worth present value of savings over a period of 25 years. The tender for REIL's Andaman Project is out and contract shall be awarded to the successful bidder in December.

Key Learnings from Implementation of Demonstration Project in Andaman Region

The process of tendering for demonstration projects for energy storage is ground breaking and unprecedented in the Indian context. The MNRE bidding process gathered several insights on business models, projects, and specific aspects of battery technology, which can be adopted by other organizations implementing similar programs. Key learnings include:

1. It was found that the initial system specification would result in high cost of generation, and based on feedback from local administration, the specifications were reworked with reduced storage in order to contain costs. Future programs should carefully study the feasibility of ESS applications to absorb energy cost while drawing up systems specifications.
2. Earlier drafts of the tender left battery technology choice open for bidders, but for sake of simplicity, specifications were modified to allow use of Li-ion batteries, which is a commercially successful storage technology.
3. It was felt that quality of bids would be improved, and non-serious bidders discouraged by including qualification criteria to allow only vendors meeting internationally recognized battery testing standards.
4. Given the unproven nature of ESS technologies, system availability specifications were relaxed from 99% to 96% uptime in order to contain costs and give suppliers realistic window for providing routine maintenance.

II. IOCL Bottling Plant: Grid, Diesel, Solar with Energy Storage for Industrial Entity

The Program is assisting Indian Oil in implementing an energy storage solution combined with solar PV for its Lube Oil Blending Plant in Asaoti, Haryana. The proposed system size is 600 kWp solar PV with 300 kWh energy storage system. The objectives of the project are to reduce diesel consumption and meet the backup requirements in case of power shortage.

Simulation results show that solar PV can contribute to 33% of the plant's energy use, the DG can contribute 7%, with the grid contributing the remaining 60% of demand. Here, grid export from total solar generation is about 10.9%.

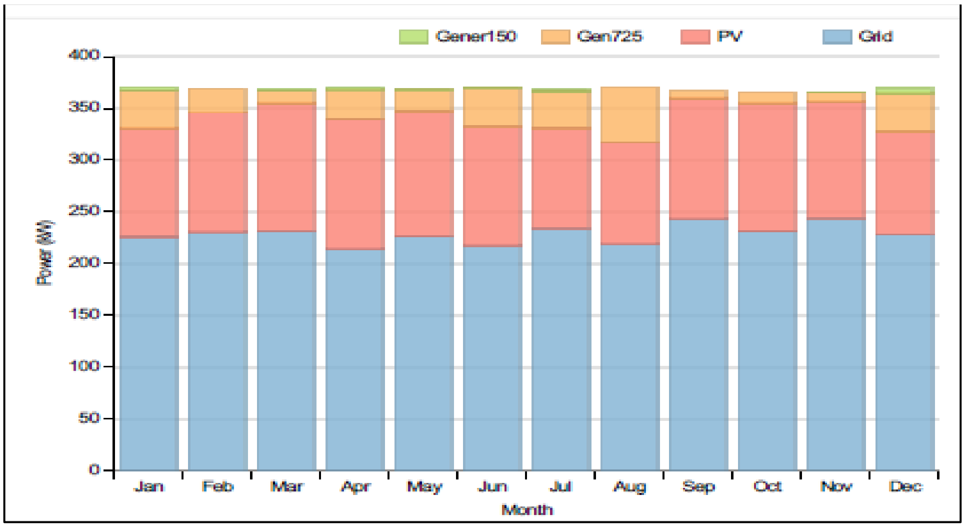

Figure 11: Simulation of Generation from Different Sources In Asaoti

For this scenario, the annual monthly break-up of power by different sources is generated by software simulation. Under this configuration, the dependency on DG sets decreases by 29,950 liters/year, reducing the amount of electricity purchased from the grid, and reducing cost of DG operation and maintenance. Similar projects can be implemented for other industrial and commercial establishments where quality power is required round the clock. IOCL is finalizing its tender specifications and shall be releasing their tender soon.

Table 5: Expected Impact of Proposed Project

Impact of Solar PV Plant With Energy Storage System			
	Baseline	**Scenario With ESS**	**Savings Achieved**
Diesel Consumption (liters/year)	87,124	57,174	29,950
Diesel Cost (INR crores/year)	0.52	0.34	0.18
Electricity Purchase from Grid (kWh/year)	2,650,000	1,790,000	760,000
Electricity Cost from Grid (INR crores/year)	2.20	1.48	0.71

III. Shaving of Peak Demand and RE Capacity Firming

Bharat Heavy Electricals Limited (BHEL) is proposing a 1 MWh energy storage system having a combination of three battery technologies, for their existing solar PV plant at BHEL R&D campus in Hyderabad. The Program is assisting BHEL in setting up an ESS to acquire technical know-how, performance evaluation, life cycle cost assessment, and application wise cost viability of various battery energy storage technologies. The major intended applications of the proposed 1 MWh ESS are as follows.

- **Peak load shaving:** Energy storage provides fast response and emission-free operation, making it the optimal solution for supply to peaks in demand caused by variable loads, helping avoid installation of additional capacity. Peak shaving installations are often owned by the electricity consumer, rather than by the utility. Their benefits include:
    a) Saving on electricity bills for commercial and industrial customers by reducing peak demand and fixed/demand charges linked to maximum sanctioned KVA rating;
    b) Reduced need for purchasing expensive power to meet peak loads for utilities; and
    c) Delayed investment in distribution and transmission infrastructure by discoms due to the flatter loads with smaller peaks. Peak shaving also helps avoid problems caused by distribution system burnouts, especially in congested grids.
- **Capacity firming:** The variable, intermittent power output from a renewable power plant, such as wind or solar can be maintained at a committed (firm) level for a period of time. The energy storage system smoothens output and controls the ramp rate (MW/min) to eliminate rapid voltage and power swings on the electrical grid.

BHEL has started procuring the three batteries required for their project at their R&D campus in Hyderabad.

The results from these demonstration projects will help develop overall recommendations on the policies required to accelerate adoption of storage technologies. The demonstration projects will serve as case studies for specific battery technologies and will help in selection of a battery which is more suited for a particular application.

5. Present Status of ESS in India

Energy storage deployment in power sector is at a nascent stage although ready to scale up. In India, as is the case elsewhere, Li-ion batteries are gaining traction for ESS, as costs have reduced by 70% in last 5 years and their performance has significantly improved. Because of their ability to work across the widest range of applications including transmission grids, distribution grids, small microgrids, electric vehicles (EVs), large investments have been planned for manufacturing of Li-ion batteries.

India still has gaps it must fill to domestically develop products meeting global benchmarks and cost effectiveness. Currently there is no domestic manufacturing capacity of modern and high performance batteries. Suzuki, Toshiba, BHEL and many other large PSUs and corporates in India are planning to install large scale manufacturing capacity of Li-ion batteries. Indian government has actively sought the interest of leading manufacturers such as Tesla.

A number of new battery technologies are also emerging. Central Electro Chemical Research Institute (CECRI) established a national battery-testing centre for lead acid batteries. ISRO has developed a Lithium Nickel Cobalt Aluminum Oxide battery life of 1500 cycles. However, it falls short of global benchmarks of over 7000 cycles. Bharat Heavy Electrical Ltd (BHEL) is working on developing efficient and competitive power controllers and battery management systems for variety of batteries.

5.1. PACE-D Recommendations for Scale of ESS in India

There are a number of issues that PACE-D TA program has highlighted in its initial reports and later validated in stakeholder consultations which can help accelerate deployment of ESS technologies across sectors in India.

- Reducing Indirect Taxation
  - Basic custom duties on batteries vary between 10%-40% at present. Uniform duties in the range of 5%-10% will encourage wide spread use of batteries, while the manufacturing capacity is set up in India.
  - Goods and Service Tax (GST, earlier sales tax and VAT) continues to be high (12%-28%). There is a need to make it uniform and bring it down to 5% same rate as for RE Systems.
- Extending direct tax benefits which are available for RE systems, to ESS
  - Accelerated Depreciation benefits available to solar or wind investments should also be made available to ESS investments. Our recommendation is to keep this benefit at 100% of investment made, for initial 5 years.
- Incentives for local manufacturing
  - Benefits such as GST waiver, for a limited number of years or up to value of investment made, and income tax exemptions. These can go a long way in overcoming investment risks of manufacturing in an emerging technology like ESS.
- Research and Development
  - Apart from batteries, the PACE-D TA Program has outlined the need to encourage development of Power Conditioning Units (PCUs), Controllers, Battery Management Systems (BMS) etc. which can make batteries widely deployable and at the same

time reduce overall investment cost. At present, electronics constitute 40-50% of ESS capital costs. This can be brought down significantly ~ 70-90% with scale and indigenous development.

- System modeling and Information sharing
  - The PACE-D TA team had recommended work on modeling the grid behavior and the usefulness of ESS in managing increased RE penetration. National Renewable Energy Laboratory (NREL) has carried out system level assessments for 160 GW wind and solar grid integration. A key finding is that for absorbing 160 GW of wind and solar (22% green energy in the overall generation mix), ESS may not be essential and viable due to current high costs[7]. There is a need for more analysis son scenarios of shifting 50%-80% or even 100% of energy needs to renewables and the value of ESS in supporting such shifts.
  - The Program's work on demonstration projects and analysis identifies areas where ESS is immediately viable and is needed, such as areas with limited grid access, poor power quality, ISTS transmission of RE and optimizing transmission costs, etc.
  - The Program had outlined the need for developing analyses for understanding the economic value of storage for different applications, which can help in setting guidelines for payments for storage services by various beneficiaries e.g. distribution utilities, transmission utilities, and customers. Detailed work still needs to be carried out to help develop the ancillary services market.
- Standards and testing facilities
  - This area was identified as essential, to help users evaluate battery systems, trust the performance claims of the manufacturers and gain necessary confidence for making long term investments in ESS.
  - The Program, through its demonstration projects has developed and documented insights on techno-commercial evaluation; performance based contracting; setting technical specifications; monitoring, reporting and performance verification (MRV) of ESS. This experience, as well as the experience of other users, needs to be integrated and standard documents to be published by the MNRE or a suitable technical institution for wider use.
  - It is also important to set up a high quality testing and benchmarking institution to evaluate and certify performance of batteries and ESS offered in the market.
- Need for Energy Storage Mission
  - Looking at the criticality of ESS, there is a strong rationale for setting up National Energy Storage Mission (NESM). The NESM should provide focus and integration across variety of applications, technologies, policy and financing issues relating to ESS.
  - In 2015-16, The Program developed a base document outlining the need, roles and roadmap for a NESM on behalf of MNRE. This needs to be revived and reinvigorated due to increasing need for such an institution.
- Policy Alignments

[7] Greening the Grid: India RE Grid integration Study by NREL June 2017.

- Apart from many areas for new policy, The Program has highlighted policies which prevent energy storage integration. For example, net-metering regulations in many states don’t allow energy storage to be integrated with roof top solar capacities. Similarly, current policies don’t support introduction of independent Energy Storage Service providers.