

# BATTERY ENERGY STORAGE SYSTEM (BESS) FOR ADDRESSING ENERGY TRANSITION IN INDIA

## Authors

**Ashish Kumar Sharma**  
International  
Finance Corporation  
World Bank Group, India

**Saurabh Motiwala**  
Indian Institute  
of Technology  
Bombay, India

**Ishan Purohit**  
International  
Finance Corporation  
World Bank Group, India

## I. INTRODUCTION

Being world's third-biggest emitter of GHG's India has targeted to reduce the emissions up to 45% of its GDP value of 2005 levels by the 2030. Since energy generation is one of the prime contributors of GHGs country also launched several missions and polices to reduce the fossil fuel-based electricity generation. Further, commitments have been made to reduce this share to 50% by 2030. In view of above commitments, commitments country has also targeted to install 500 GW renewable energy-based electricity capacity by 2030.

By end July 2023, total installed renewable energy capacity reached 130.86 GW followed by 71.11 GW solar, 43.94 GW wind, 49.80 small etc. There has been significant emphasis and adoption of large-scale renewable energy options and shift in focus from standalone to hybrid solutions that provide firm (or even "round the clock (RTC)") renewable energy<sup>1</sup>.

Despite of rapid growth, ambitious targets the typical arguments against renewable based energy generation are predominantly related to (i) integration into the overall power system (grid), (ii) dispatchability, (iii) scheduling and forecasting, (iv) curtailment, clipping and must run status (NREL, 2016)<sup>2</sup>. Compared with the conventional power generation (coal, gas, hydro and nuclear fired technologies) the power output from renewables (without energy storage) is not being controllable and thus have such challenges. Moreover, in the present scenario, emphasis is given on reliability and dispatch ability by the consumer as well as seller of electricity market. The reason being energy markets in India are moving from a fixed tariffs to demand based tariffs. Also, power producers are getting higher prices for meeting peak energy demand of consumers. Another trend prevailing in Global as well as in Indian energy market is procurement and selling of renewable based electricity which is govern by polices as well as RPOs. In view of the above, power producers' intended to providing high quality RE power as well whenever needed. However, the power output of renewable energy plants typically depends on intermittent resource (wind power density & solar insolation etc.) is again problematic for stability of electric grid due to continuous harmonics. Moreover, 500 GW of non-fossil fuel-based power would mean a substantial share in future total generation of energy in India. Such large share of intermittent sources will require reliable transmission

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<sup>1</sup><https://mnre.gov.in/the-ministry/physical-progress>

<sup>2</sup><https://www.nrel.gov/docs/fy18osti/71151.pdf>

infrastructure which again is a huge investment to ensure smart supply and demand management. Intermittent behaviours of renewable sources create un-stability and harmonics in the electricity grid due to reflection in voltage and power output and frequency responses which further affects the transmission and distribution systems of utility grid. Table 1 summarizes three key characteristics of renewable energy generation which affect the power grid. These characteristics itself are the major challenges to the green power producers whether technically or economically.

**Table 1: Characteristics of Renewable Electricity Generation and Associated Integration Challenges<sup>2</sup>**

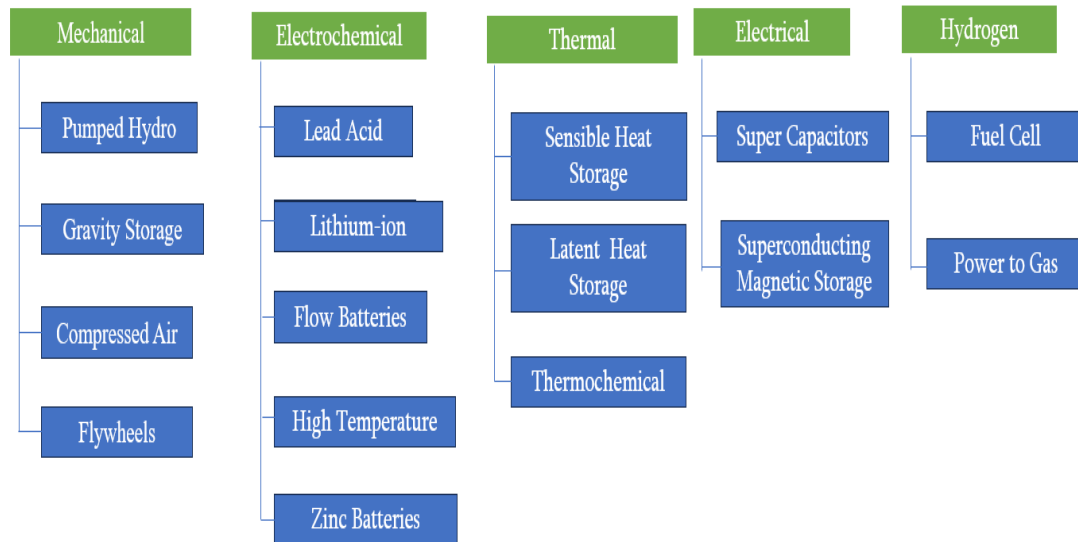
Characteristic Impact		Integration Challenge	
		Energy Value & Curtailment	Capacity Value
Variability	RE output can vary as underlying resource fluctuates.	Supply/demand mismatch coupled with generator inflexibility leads to curtailment.	RE may not be able to replace conventional capacity during periods of peak demand.
Uncertainty	Output cannot be predicted with perfect accuracy.	Part-load operation of thermal plants for operating reserves leads to curtailment.	Capacity needed for provision of operating reserves.
Non synchronous generation	RE does not currently help maintain system frequency.	Part-load operation of thermal plants for provision of frequency response leads to curtailment.	Capacity needed for provision of frequency response.

This is an established fact that energy transition (RE targets, coal Phaseout, coal repurposing etc.) is impossible without intervention of energy storage technologies. Govt. of India has come out with energy storage requirements to execute its 500 GW non fossil fuels-based energy generation target by year 2023 in its revised national electricity plan. In view of the above, it is evident that storage of energy is highly necessitated for smoother integration of RE sources into the electricity grid. whether it is at generation, transmission, or distribution along with the grid ancillary services. The provision of energy storage technologies not even reduce peak demand but also enhanced day-to-day reliability, and can also ensure power in case of interrupted generation. All these benefits of energy storage would reduce overall envisaged costs (consumer and utility) by consumer by easing load balance challenges.

## II. ENERGY STORAGE TECHNOLOGIES

Energy storage technologies can be described under five classifications based on the working principle. These include, mechanical, electrochemical (or batteries), thermal,

electrical, and hydrogen storage technologies. These technologies have different use case scenarios, capable of providing electricity within a fraction of seconds to hours. The suitable duration (long or short) of storage, scale of systems (in MW and MWh) and response time are technology dependent making it important to choose the appropriate technology as per the application requirements and constraints.



**Figure 1:** Classification of Energy Storage Technologies

**1. Mechanical Energy Storage:** This is the energy storage by applying force to an appropriate medium to deliver acceleration, compression, or displacement (against gravity); the process can be reversed to recover the stored kinetic or potential energy. This energy storage works in complex systems that use heat, water or air with compressors, turbines, and other machinery.

- **Pumped Hydro Storage (PHS):** Pump hydro system stores potential energy of water at higher elevation. During off demand of energy water is pumped to the reservoir located at higher elevation and stored in the form of potential energy. During the peak or regular energy demand this stored water is guided to run the turbine and generate PHS systems usually store energy for long durations (8-24 hours).
- **Gravity Storage Technologies:** Gravity based energy storage technologies based systems work on the same principle of PHS i.e. storing potential energy for later use. Only difference is in place of liquid medium water, cement, rocks and bricks are used thus prevail the advantage of higher density (of these solids) and reduces the size of energy storage system. In addition, unlike the PHS these systems do not require specific geological features.
- **Compressed Air Energy Storage (CAES):** A CAES system stores compressed air underground or in high pressure vessels. During off or excess availability of energy demand electric pumps compress the air at high pressure. During peak or regular energy demand, this stored compressed air is guided towards the blade of a modified gas turbine to generate electricity.

- **Flywheel Energy Storage (FES):** Flywheels are also mechanical energy storage system those store rotational or kinetic form of energy in a heavy cylindrical rotating mass. Flywheel are manufactured with the materials those can sustain high centrifugal forces and velocities. These systems can absorb as well as deliver energy in very short span of time, thus suitable for high power applications.
2. **Electrochemical Storage:** Electrochemical storage technologies include systems are basically the battery energy storage systems (BESS), where energy is stored in the form of electrochemical reactions. These batteries are of different materials and chemical compositions to work such as lead-acid batteries, lithium-ion (Li-ion) batteries, sodium-sulfur batteries (NAS), flow batteries, Zn-air batteries, and supercapacitors. Based on the type and sub-technology these batteries can be well used for a short duration (few minutes) or long duration (8+ hours) applications. For stationary storage applications, two of the main parameters are the cycle life and the roundtrip energy efficiency (%) of the batteries.
  3. **Thermal Storage:** Thermal energy storage system stores energy in the form of heat. Energy transfer takes place during heating and cooling process. Energy storage could be of sensible heat storage or latent heat storage.
    - **Sensible Heat Storage:** Energy is storage in the specific materials in a thermal gradient, which can be further utilized while its heating or cooling. One of the most well-known technologies of this type is molten salt storage, which is coupled with solar thermal power plants. During sun shine hour heat generated by the collector field is used to increase the temperatures of molten salts and stored in the insulated vessels. In the off-sunshine hours this stored heat is transferred to water which convert it into steam and finally steam is guided to the steam turbine to generate required electricity. There is no change in the phase of medium during heat energy storage and its release. Another important technology in this space is hot and chilled water storage. These are especially relevant where a large part of the electrical load is for space heating or cooling applications.
    - **Latent Heat Storage:** Latent heat storage is similar to sensible heat storage where energy is again stored through temperature gradient with in a material or substance, however, during this process this material undergoes a phase change (transition between solid and liquid) as it stores and releases energy. Examples of latent heat storage include ice stored for cooling applications, storage of saturated steam for industrial applications etc. During periods of excess energy and low demand (usually night-time), the liquid water is converted into ice and stored in large tanks. When the cooling load increases during the daytime and afternoon, the ice is melted to provide space cooling to the connected buildings.
    - **Thermochemical Storage:** The third category of thermal storage involves storing energy in reversible chemical reactions. Compared to the other two technologies these are much more compact and lightweight however, not commercialized yet and are in the nascent stage of research and development.

- 4. Electrical Storage:** Specially designed systems those works on engineering principles are capable of storing energy in the form of electricity directly. As an example, superconducting magnetic energy storage (SMES) systems store energy in the magnetic field created by the flow of direct current in a superconducting coil which has been cryogenically cooled to a temperature below its superconducting critical temperature. Again, these systems are not commercialized at large scale yet however mainly used for power quality control in manufacturing plants and microchip fabrication units. These technologies are ideal for storing and releasing high level of energy for short intervals.
- 5. Hydrogen Storage Technologies (Power-to-Gas):** The basic concept of hydrogen storage technologies is to use electricity to perform electrolysis of water to produce hydrogen and oxygen. The hydrogen produced is stored in high pressure containers and can be used as a fuel for direct combustion (cooking and heating applications) or for electricity generation via PEM Fuel Cells. A detailed comparison between various technologies of energy storage is presented in this section based on various technical and non-technical parameters. Table 2 can be referred to further understand the strength and weakness of each energy storage system.

**Table 2: Technical features of various energy storage technologies**

Key tech. Parameters	PHS	CAES	FESS	SCES	BESS
Power range (MW)	upto3000 MW	~300MW	0.01~0.25	0.01~0.3	~500MW
Energy rating (kWh)	upto24x10 <sup>6</sup>	upto2x10 <sup>6</sup>	25~5000	~5	~2.5x10 <sup>4</sup>
Energy density (Wh/kg)	0.5to3	30~60	5~80	0.05~15	~230
Lifetime (years)	75	20~40	15~20	25~30	<15
Lifecycles (cycles)	>30k	8k~13k	20k~100k	100k~500k	~10k
Roundtrip Efficiency (%)	75to85	40to75	90~95	85~95	85~95
Reaction time	minutes	minutes	milli-seconds	milli-seconds	milli-seconds
Discharge time	6to8+hours	6to8+hours	Secto15mins	milli-secondstomins	secondstohours
Self-discharge (%/day)	Nil	Nil	1.3 ~100	10 ~40	~0.15
Nominal Voltage (V)	Systemvoltage	Systemvoltage	Systemvoltage	2.3 ~400	1~ 4.2
Operating temperature range (°C)	Ambient	Ambient	20 ~50	-40 ~85	-20 to60
Power Cost (\$/kW)	500to 700	500~1800	100~ 300	100~ 300	350~ 600

Energy Cost(\$/kWh)	5~ 100	50 ~400	1000~5000	300~ 5000	~500
Scalability	Scaledown/upwithin operating range ofPTG units	Difficulttoscaleup/Down	ApplicableonlyforlowE/Pratioapplications	Scalablebyconnecting inparallel	Easily scaledup/down
Limitations	Topographical andgeologicalconsiderations	Topographical andgeologicalconsiderations	Higherself-discharge andcost	Higherself-discharge andcost	Nosuchrequirements
Application	High energy storageand peakingpowerapplications	Bulkenergystorage applications	Onlyforveryshort durationpower applications	Onlyforveryshort durationpower applications	Both energy andpowerapplications
Renewableintegrationapplications	Energy& Powershifting	Energy& Powershifting	Smoothing,Ramp ratecontrol	Smoothing, Ramp ratecontrol	Smoothing, Ramp rate, Loadshifting
ApplicationRestrictions	OnlyGrid/Utilityscal applications	Applications withlongerdischarge duration.	Only Shorterdurationdischarge applications	Only Shorterdurationdischarge applications	Compatible forall type of applications
Installationperiod(years)	>4	>4	0.5 ~1	~0.5	0.5 ~1.5
Landrequirement(m <sup>2</sup> /MW)	Sitespecific	Sitespecific	~5	~2	~10

Among EES technologies described above government policies in India are only revolving around PHS and BESS. Present Chapter focuses on battery energy storage systems (BESS) mainly.

### III. APPLICATIONS OF BESS

Batteries are one of the established options of energy storage for shorter to higher duration based on the type of application. Due to their availability in various sizes and system mobility features, Electro Chemical Energy Storage System (ECSS) are commercially successful in grid scale utility applications. The most prominent types of BESS are presented in Table-3.

**Table 3: Minimum Technical Specifications of BESS Technologies**

No.	Parameter	Units	Lithiumion	Sodium Sulfur	FlowBatteries	LeadAcid
1	CellVoltage	V	3~4.2	2.1	1.5	2~2.35
2	Specificenergy	Wh/kg	120~230	150~240	25~75	30~50
3	SpecificPower	W/kg	150~350	150~230	NA	200~400
4	CoulombRate	-	0.5~4	<0.17	<0.2	>0.2
5	DischargeTime	Hours	0.25~2	>6 hours	>5 hours	sec~5hours
6	CycleLifeMaximum	No	6000	4000	12000	2000
7	Self-DischargeDaily	%	0.15~0.3	0.05~20	Negligible	0.1~0.4
8	Installationease	-	Containerized/Easy	Non-standard containers /Complex	Containerized/Easy	Timeconsuming /Easy
9	WorldwideinstallationrankingforBESS	-	1	2	3	4
10	Bottomline	-	Proven bothcommerciallyandtechnically	Commerciallyviable for longdurationapplications	Commerciallyviable for longdurationandlifetimeapplications	Not preferable duetolowercycleandperformance

BESS can be used as an easy alternate with lower Merit order Dispatch (MOD) cost for several application. These applications are briefly described in the following paragraphs.

- 1. Peak Load Management:** Peak load management deals with curtailing peak power demand at a given interval of time to optimize the electricity charge. Ideally, to reduce the peak demand, loads need to be scheduled in such a way that all of them are not operated simultaneously to avoid high load demand. However, practically this is challenging as the utility have no control on consumer loads. Therefore, implementation of BESS can reduce the peak demand from the grid and support the load from energy storage system. Batteries can regulate the power flow by its charging and discharging process. It gets charged when the grid is running in off -peak period at lower electricity cost and get discharged to during peak periods at higher cost.

2. **Energy Arbitrage:** Energy arbitrage application is aimed at maximizing the net revenue of utility by purchasing the energy at lower prices and selling it during high-priced time. Conventional electricity market works on real-time scenario of supply and demand. Cost effective ways of storing electrical energy can help the grid to be more efficient and reliable.
3. **Electricity Market (to Avoid DSM Penalties)<sup>3</sup>:** Unscheduled Interchange (UI) mechanism in general is the difference between actual and scheduled generation/demand in a time block. UI charges levied under grid regulations are further utilized for serving as investment on grid strengthening schemes and ancillary services. Frequency of the grid is a function of supply demand imbalance. Penalties are imposed on utilities for deviations in frequency response under both under drawl and over drawl scenario to maintain the grid performance. To attain maximum profit, the entity needs to ensure that the actual demand follows closely with scheduled demand which is highly challenging. Incorporating BESS will be advantageous for utilities, as it can serve the load with better response time and reduce the penalties under sudden load fluctuations or unpredictable scenarios.
4. **Distribution Upgrade (Capex) Deferral:** Distribution system shall update its capacity to match with the load growth known as distribution upgradation. Distribution system majorly includes substation transformer and feeders to feed the loads. Upgrading the distribution assets with higher capacity will involve huge capital expenditure. Energy storage at utility scale during will help in making the load profile flat and reduces the burden on existing transformers and feeders by shifting the peak demand. In such scenario, need to upgrade the existing equipment can be avoided by extending the life and deferring the investment for few more years ultimately saving effort of replacing equipment and intermittency in the network.
5. **Reactive Power Management:** Reactive power management is an important aspect of power system operation. The prime sources of reactive power in a utility grid are generators, transmission line susceptance and capacitor banks<sup>4</sup>. Excessive flow of reactive power in the grid network may result in voltage instability and poor power supply. Thus, utilities may face both high voltage and low voltage issue due to unbalance in the network at different operating conditions. Thus, it calls for dynamic compensation as an effective solution against traditional static compensation using reactors/capacitors. Battery energy storage system with an appropriate inverter can operate in both inductive and capacitive mode like STATCOM. The inverter can act as a voltage source and operate in all four quadrants to supply or consume reactive power apart from its basic role of energy charge and discharge. The design of system allows the inverter to provide reactive power to the LV grid and/or downstream load connections which reduces the overall reactive power requirement from the grid. Thus, use of BESS can avoid instability and uneconomical operation of Grid by controlling excessive reactive power.

<sup>3</sup>[https://www.wrpc.gov.in/wrpc/DSM\\_REPORT\\_MSLDC.pdf](https://www.wrpc.gov.in/wrpc/DSM_REPORT_MSLDC.pdf)

<sup>4</sup><https://www.sciencedirect.com/science/article/abs/pii/S0038092X20300992#:~:text=The%20main%20objective%20of%20the,the%20inverter%20is%20not%20violated.>



- 6. Asset Optimization:** By placing battery energy storage system at appropriate locations, overloading of transformers and cables can be significantly reduced which will also provide saving in terms of technical losses. Operational costs can also be lowered through effective monitoring of equipment degradation with BESS support.
- 7. Renewable Energy Based Electric Vehicle Charging:** BESS are essential for EV integration and utilized as spinning reserve to meet the power requirement, since it should supply energy at any point of time irrespective of system conditions<sup>5</sup>. During off peak period EV can be directly charged from the grid, whereas during peak period battery can assist in EV charging to avoid the penalty due to higher peak demand and maintain grid stability and reliability. It will also help to maintain huge variations in energy is to be handled in an effective manner to ensure grid reliability, stability and managing huge number of source & load points to maintain system frequency.
- 8. Off-Grid/Standalone Power Supply:** BESS could be the essential part of a renewable energy system which is standalone and not connected to external electricity grid such as rooftop solar, micro grid systems etc. These systems reduced the consumption of oil-based fossil fuel options where electricity grid is not available or have certain constraints for its expansion. Compared to oil-based generations, batteries are environment friendly and also their response time is quick.

#### IV. STATUS OF BESS DEPLOYMENT ACROSS THE GLOBE

BESS seems to be the best eliminator to tackle the power intermittency behaviour of renewable energy sources. Therefore, acceptance of this technology coupled with RE generator noticed across the globe. US based organization, Energy Information Administration (EIA) predicted a 10 GW increase in battery storage capacity, especially coupled with solar power plants<sup>6</sup>. Major factors, those aiding to this growth include decline in battery costs, and globally favourable policies for wind and solar energy. The notable BESS projects across the globe are briefly summarized in Table-4 below.

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<sup>5</sup><https://www.sciencedirect.com/science/article/pii/S1364032121010066>

<sup>6</sup><https://www.iea.org/energy-system/electricity/grid-scale-storage>

**Table 4: List of representative grid-BESS projects Project<sup>7</sup>**

	Battery Type	MWh	MW	Hour of Storage	Country	Location	CoD	Remark(s)
Moss Landing Vistra Battery	lithium-ion	1,600	400	4	United States	Moss Landing, California	2020	300 MW / 1,200 MWh Phase 1 commissioned in 2020, 100 MW / 400 MWh Phase 2 in 2021
McCoy Solar Energy Project	Battery, lithium-ion	920	230	4	United States	Blythe, California	2021	Battery storage paired with 250 MW solar project <sup>l</sup>
Moss Landing PG&E Elkhorn Battery	Battery, lithium-ion	730	182.5	4	United States	Moss Landing, California	2022	256 Tesla Megapack battery units
Slate Project	Battery	561	140.25	4	United States	Kings County	2022	Paired with 300 MW solar plant
Valley Canter Battery Storage Project	Battery, lithium-ion	560	140	4	United States	Valley Canter, California	2022	
Victorian Big Battery	Battery, lithium-ion	450	300	1.5	Australia	Moorabool	2021	
Alamitos Energy Center	Battery, lithium-ion	400	100	4	United States	Long Beach	2021	
Dalian VFB	Battery, vanadium redox flow	400	100	4	China	Liaoning, Dalian	2022	
Buzen Substation	Battery, sodium-sulfur	300	50	6	Japan	Buzen	2016	Buzen Substation
Minety Battery Energy Storage Project	Battery, lithium-ion	266	150		United Kingdom	Minety	2021	
Rokkasho Aomari	Battery, sodium-sulfur	245	34	7	Japan	Rokkasho	2008	
Gateway Energy Storage	Battery, lithium-ion	230	230	1	United States	Otay Mesa, California	2020	
Huanghe Hydropower Hainan Storage	Battery	202.8	202.8	1	China	Hainan, Qinghai	2020	Connected with adjacent 2.2 GW photovoltaic Huanghe

<sup>7</sup>[https://en.wikipedia.org/wiki/Battery\\_storage\\_power\\_station](https://en.wikipedia.org/wiki/Battery_storage_power_station)

## BATTERY ENERGY STORAGE SYSTEM (BESS) FOR ADDRESSING ENERGY TRANSITION IN INDIA

								Hydropower Hainan Solar Park
Crossett Power Management	Battery	200	200	1	United States	Crane County, Texas	2022	
Crossett Power Management	Battery	200	200	1	United States	Crane County, Texas	2022	
Flower Valley II	Battery	200	100	2	United States	Reeves County, Texas	2022	
Gambit battery storage project	Battery, lithium-ion	200	100	2	United States	Angleton, Texas	2021	
Kunshan Energy Storage Power Station	Battery, lithium-ion	198	111	?	China	Kunshan	2020	
Pillswood	Battery, lithium-ion	196	98	2	United Kingdom	Cottingham	2022	
Hornsedale Power Reserve	Battery, lithium-ion	193.5	150		Australia	South Australia, Jamestown	2017	Tesla Powerpack is charged using renewable energy and delivers electricity during peak hours
Hokkaido Battery Storage Project (provisional name)	Battery, vanadium redox flow	60	15		Japan	Hokkaido	2015	Vanadium redox flow battery from Sumitomo near several solar energy projects on Hokkaido Island, operational in December 2015.
Lake Bonney Battery Energy Storage System	Battery	52	25		Australia	Millicent, South Australia	2019	
Gannawarra Energy Storage System	Battery	50	25		Australia	Kerang, Victoria	2018	Co-located with Gannawarra Solar Farm
Jardelund	Battery, lithium-ion	50	48	1	Germany	Jardelund	2018	
National Wind and Solar Energy Storage and Transmission Demonstration Project (I)	Battery, lithium iron phosphate	36	6	6	China	Hebei, Zhangbei		

## V. UTILITY SCALE BESS INTERVENTIONS IN INDIA

India's first MW scale BESS project was installed in 2019, it has capacity of 10 MW with one hour of storage<sup>8</sup>. The project installed on the distribution network of a private discom TATA power Delhi and used advanced scale lithium-ion- batteries. The BESS system charged during off-peak hours and discharged the power during peak hours. Prime motive of installation is to support the distribution transformers to manage peak load, regulate voltage, improve power factor, regulate frequency, settle deviations, support grid stabilisation, prevent overload, manage reactive power and defer CAPEX (capital expenditure). More recently Tata Power also received a letter of award from the Solar Energy Corporation of India (SECI) for the engineering, procurement and construction (EPC) of an INR 9.45 billion (US \$126 million) 100 MW solar project with a 120 MWh BESS storage in Chhattisgarh state of India. In India BESS is also being supported by dedicated policies and regulations described in the following section<sup>9</sup>.

## VI. REGULATORY REGIME OF BESS IN INDIA

Mentioned in the previous section India has ambitious target of installing 500 GW of non-fossil fuel-based power generation capacity by 2030<sup>10</sup>. To tackle the intermittent of RE sources and associated impacts described in the above sections, utility scale applications BESS is also projected as the most suitable option for India. Several policy and regulatory regime prevail in India to support and promote the use of BESS at generation as well as transmission and distribution levels of utility grid. Majority of these interventions are briefly summarized in Table

Solar Energy Corporation of India (SECI), a CPSU under Ministry of New and renewable energy, has called for the expression of interest for procurement of 1000 MWh BESS. <sup>11</sup>This will be published along with the RFS bid document and the draft comprehensive guideline for procurement and utilization of BESS as a part of generation, transmission and distribution assets and with all ancillary services.

Central Electricity Authority (CEA) suggests the use of Pumped Hydro Storage System (PHSP) and Battery Energy Storage Systems (BESS) for commercial deployment<sup>12</sup>. Further, the study by CEA, under its planning model selected the BESS from the year 2027-28 onwards and a BESS capacity of 27,000 MW/108,000 MWh (4-hour storage) is projected to be part of the installed capacity in 2029-30. This is in addition to 10,151 MW of PHSP anticipated to be a component of the installed capacity in 2029-30. Later, on March 11, 2022, the MoP notified new guidelines on procurement and utilization of BESS as part of generation, transmission and distribution assets, along with ancillary services. Apart from this, few business cases have been identified in the MoP guidelines in which BESS can be utilized. This includes BESS coupled with RE/ with transmission infrastructure, storage for

<sup>8</sup><https://www.tatapower.com/media/PressReleaseDetails/1899/indias-largest-solar-and-battery-storage-project-awarded-to-tata-power-solar-of-inr-945-crore>

<sup>9</sup><https://www.seci.co.in/whats-new-detail/2226>

<sup>10</sup><https://www.eqmagpro.com/wp-content/uploads/2021/10/BESS-Guidelines-final.pdf>

<sup>11</sup><https://www.seci.co.in/whats-new-detail/2205>

<sup>12</sup>[https://cea.nic.in/wp-content/uploads/irp/2023/05/Optimal\\_mix\\_report\\_\\_2029\\_30\\_Version\\_2.0\\_\\_For\\_Uploading.pdf](https://cea.nic.in/wp-content/uploads/irp/2023/05/Optimal_mix_report__2029_30_Version_2.0__For_Uploading.pdf)

distribution/ for ancillary services. Thus, the new guidelines are furnished with the aim of facilitating the procurement of battery storage systems to be utilized either in combination with renewable energy or as a standalone asset. With the falling battery prices, the BESS guidelines will serve as a base to streamline future developments in this sector. These guidelines will also play a critical role in achieving the nation's renewable energy and decarbonisation goals i.e., to reach net zero emissions target set by India. As per the report of NITI Ayog in India, report India's annual market could surplus \$ 15 billion by 2030 and the battery demand expected to rise 260 GWh in the accelerated scenario by 2030<sup>13</sup>.

## VII. UTILITY SCALE USE CASES OF BESS IN INDIA

BESS projects are in the nascent stage of implementation in India. Government India is coming out with several policy and regulatory interventions on time-to-time basis. However, choice of appropriate business model is still important to make investment viable. Following use cases have been identified regarding potential use of BESS.

1. **RE Supply with BESS:** In this case, the BESS is coupled with a renewable energy project at generation site. Thus, ownership of BESS also lies with the RE project developer itself (Fig). During lower demand or excess generation BESS is charged and utilized to meet the peak power demand and ensure firm dispatchability. In brief, for charging purposes, BESS developer can procure input energy from the generation (wind/solar/both) owned by it.
2. **BESS with Transmission Infrastructure:** Prime focus of this model is stability of electric grid, reduction in grid network congestion and optimum utilization of the storage. All this benefits, reduce the investment which may require on augmentation of evacuation and transmission infrastructure, otherwise.
3. **Storage as an Asset for Balancing Services and Flexible Operations:** This application of BESS is particularly suited for frequency control, load interchanges and load balancing as BESS systems response quickly even in second-to-second basis. The system operator such as Load Despatch Centres could use BESS system to maintain frequency and to manage inherent uncertainty/variations in demand and generation.
4. **Storage for Distribution Networks:** This model aims to strengthen the distribution network of utilities/discoms. In such case, BESS systems may deploy at load centres and distribution sub-stations. BESS may help discom in managing peak demand grid resilience, portfolio management and flexible operations. BESS can also be used as an optimum tool to achieve asset shifting by the Discoms, thereby increasing asset life.
5. **BESS as Merchant Power:** Along with these cases of BESS described above, it's also possible to sell the energy stored in BESS in an energy market on merchant basis. However, this component only be traded in the energy market if such regulation prevails.

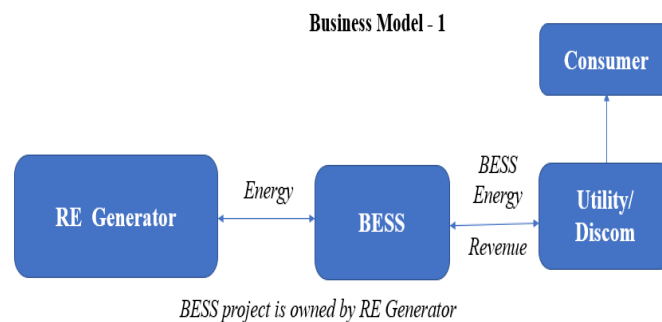
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<sup>13</sup><https://www.niti.gov.in/making-india-aatmanirbhar-advance-battery-storage>

## VIII. BUSINESS MODEL FOR BESS

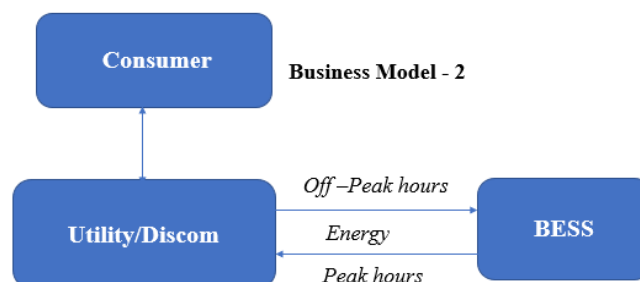
Unlike the only solar or only wind type of utility scale RE projects, BESS projects' viability depends on applicable use cases and appropriate business models. There are several businesses as per the regulatory environment in various markets. Since the major boost behind the aggregation of BESS across the globe is the penetration of variable RE, therefore in the present section business models of BESS keeping renewable energy in focus are briefly described.

- 1. Business Model 1:** In this model for charging purposes, BESS developer can procure input energy from the energy generation (/wind/solar etc.) owned by it(Figure 2). and may sell it to discom/utility during peak power requirement. In this model, energy generator itself will make investment in the BESS project, it could be Capex or Opex. Utility or discom will pay the BESS developer for the energy received.



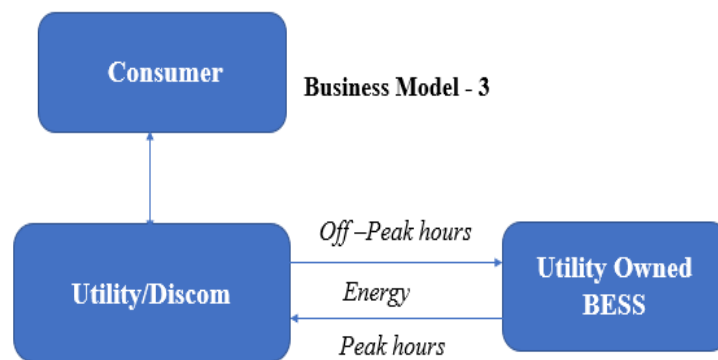
**Figure 2:** BM 1 of BESS

- 2. Business Model 2: BESS for Distribution Purpose:** This would be tolling arrangement where BESS developer would procure power from the buyer (local distribution licensee/open access consumer) during off-peak period and give it back during peak period after discounting for cycle efficiency of the BESS(Figure 3). The tariff for such an arrangement shall be mutually agreed by the BESS developer and the buyer. In case of tolling arrangement by the distribution licensee, it shall obtain approval for the arrangement from the appropriate authorities.



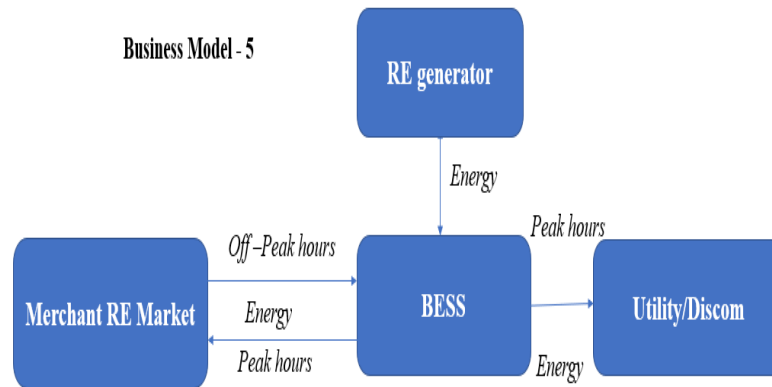
**Figure 3:** BM 2 of BESS

- 3. Business Model 3: Business Model (BESS as a Distribution Asset):** This model is almost similar to Model 2, the only difference is of ownership or investment in the BESS system. Here, BESS could be owned and operated by the distribution utility itself. Thus, Discoms can establish BESS either through Capex or OPEX /Energy Storage Service Agreement (ESSA) route. In case of Capex route, discoms would undertake competitive bidding for procurement of the system. Discoms may supply power to BESS for charging and scheduling of ESS shall be the responsibility of discoms. Such BESS shall primarily be charged from RE sources and Discoms shall utilize such ESS for compliance towards RPO as per applicable norms.



**Figure 4:** BM of BESS as Distribution Asset

- 4. Business Model 4: (BESS as a Transmission Asset):** BESS could be useful for congestion management, ancillary services, and deferral of new investment. These applications would require BESS at transmission level. The transmission licensee shall not enter into any contract or otherwise engage in the business of trading of electricity on exchanges. Model is almost similar to BM 2, &3 only difference is ownership and capital investment, which will be managed by the Transmission entity in place of distribution utility.
- 5. Business Model 5: Independent BESS:** In this model, BESS developer would procure power for charging from the energy market (during off peak hours) or by entering into a PPA with any RE generator (Fig. 5). The tariff for procuring power from the BESS shall be discovered primarily through mutual negotiation of both parties. In this model, BESS developer will only invest in project and may sell the energy to utility or to consumers directly through merchant energy markets during peak hours.



**Figure 5:** BM of BESS as Independent System

## IX. DRIVERS AND BARRIERS FOR BESS DEPLOYMENT IN INDIA

Energy storage have several advantages mentioned in the previous sections. In addition, power plant operators are more interested in using cost effective and TaylorMade solutions to tackle variability of RE. Thus, it is clearly evident that BESS can remove the constraints associated with renewable energy. Storage also has indirect benefits even to conventional plants as during excess energy generation plants may charge the storage system, which could increase the PLF of such plants otherwise they need to shut their operation in the low demand period. Irrespective of all these benefits. Nascent technologies always have certain drivers and barriers those play major role in the large-scale dissemination of such technologies. These drivers and barriers could be the technological, regulatory, or financial etc. Important drivers and barriers of BESS deployment especially in the context of India are briefly summarized here.

### 1. Policy & Regulatory Drivers:

- **National Energy Storage Mission<sup>14</sup>:** The Government of India has created the draft National Energy Storage Mission to promote energy storage
- **National Tariff Policy<sup>15</sup>:** Mandatory procurement of RE power for DISCOMs and Waiver on inter-state transmission charges for RE power transmitted through the grid to promote open access for large end customers (1 MW and above)
- **National Programme on Advanced Chemistry Cell (ACC) Battery Storage<sup>16</sup>:** The Government approved INR 18,100 Crore PLI scheme for building manufacturing facilities for battery storage in India. The plan is to set up a 50 GWh manufacturing capacity

<sup>14</sup><https://e-amrit.niti.gov.in/assets/admin/dist/img/new-fronend-img/report-pdf/India-Energy-Storage-Mission.pdf>

<sup>15</sup><https://powermin.gov.in/en/content/tariff-policy>

<sup>16</sup><https://pib.gov.in/PressReleasePage.aspx?PRID=1846078#:~:text=The%20Government%20has%20approved%20the,outlay%20of%20%E2%82%B9%2018%2C100%20crore.>



## 2. Barriers for BESS Deployment:

- Unavailability of high tariffs for BESS integrated VRE. Higher tariffs are difficult proposition for already financially weaker DISCOMS (Distribution companies)
- Even if peak rates in India are higher than off-peak rates by 15 to 20%. This is far less than when compared to US, UK, Australia where the difference is around 200-400%
- Traditionally India has manufactured Lead Acid Batteries. India domestic manufacturing for Lithium-ion and other technologies is at nascent state. Almost 70-75% Lithium-ion batteries are imported from China and Hong Kong. Increasing shipping costs increases the project costs.
- Higher import duties is another hurdle for large scale adoption
- The ancillary market services by BESS including (Voltage regulation, Frequency regulation, Black start facility, Inertia) needs to open up further.
- **Technological Constraints:** The NTPC tender (500 MW/3,000 MWh) requires a 6-hour BESS solution, while BESS is not a viable option beyond a 4hour solution. There is a focus to increase the duration to 6- 8 hours, these are still not on a commercial scale resulting in the need for redundancies.
- **Lack of standardization:** On account of diverse technical requirements and different policy processes there is a lack of standardization within BESS. Each supplier has different tech specs which can be a hindrance to scale.
- **Electricity losses (Transmission & Distribution in India)<sup>17</sup>:** As per one of the working papers from Center for Social and Economic Progress, *India has highest transmission losses (technical + non-technical) in the range of 21%* compared to 6% in France & Australia and 10% for South Africa and Indonesia. Commercial losses are higher than the typical AT&C losses, which are only reported for the distribution networks. Overall rates of loss can be affected by a number of factors, including maintenance requirements, quality of infrastructure, distance between generator and consumer, poor monitoring and the occurrence of theft. This creates another hindrance in wide scale adoption of BESS
- **Restriction to open access:** Only end consumers with sanctioned load of 1MW and above are eligible to procure power through open access route. Few states try to limit purchase through open access to protect state-owned DISCOMs. This decreases avenues for dispatchability of power by BESS.
- **BESS charging with coal:** India's grid infrastructure has been developed with coal plants in mind. So, to mitigate additional infrastructure for grid evacuation, utility scale BESS would have high prospects of charging via thermal power (coal + gas). This would have implication on the prospect of BESS being green energy to be used with VRE -thereby creating ESG issues and subsequently reduced investments.

<sup>17</sup><https://pib.gov.in/PressReleasePage.aspx?PRID=1846078#:~:text=The%20Government%20has%20approved%20the,outlay%20of%20%E2%82%B9%2018%2C100%20crore.>

## X. MARKET OF BESS & KEY PLAYERS

The grid-scale battery market size is projected to grow from \$7.72 billion in 2022 to \$30.95 billion by 2029, at a CAGR of 21.9% during the forecast period<sup>18</sup>. Reason being is the technological advancement, which has led to a sharp increase in the energy density of the lithium-ion battery market even while decreasing the overall cost of lithium-ion batteries, has enabled the increase in the grid-scale battery deployment. Owing to the aforementioned factors, the lithium-ion battery segment is expected to witness the fastest growth rate during the forecast period.

Asia-Pacific is the fastest-growing market owing to the rapid rate of industrialization and urbanization, which has led to an increase in demand for electricity<sup>19</sup>. Developing countries like India are aiming to create 275 GW of total wind and solar capacity by 2027. Favourable policies, such as the energy efficiency standards and increasing peak demand charges, is expected to drive the demand for grid-scale batteries in the region. Renewable energy's share of installed capacity is forecast to rise to 43% by 2027. With the growing renewable sector, the demand for grid-scale batteries, to address the challenges related to intermittency in renewable power generation, is expected to grow. Furthermore, due to technological innovations and improved manufacturing capacity, lithium-ion battery chemistry has experienced a steep price decline of over 80% from 2011-2018, and prices are projected to decline further. Furthermore, the recycling of Li-ion batteries is expected to secure the supply of raw materials, such as cobalt and lithium, and reduce the dependence on extracting and refining materials from mineral resources. Recycling of lithium-ion battery that is currently being used in EVs offers an opportunity for companies to utilize the refined constituent materials, for manufacturing lithium-ion batteries that are to be used for Energy Storage Systems (ESS). The grid scale battery market is moderately fragmented and classified under three categories Manufacturer, EPC's, Service providers. The global grid-scale battery market size is projected to grow from \$7.72 billion in 2022 to \$30.95 billion by 2029, at a CAGR of 21.9% during the forecast period.

In this market the players in the manufacturing sectors are mostly global companies some of the leading players in the grid-scale battery manufacturer are listed in Table 4

**Table 4: Key Market Players of BESS<sup>20</sup>**

Category	Key Market Players	Country
Battery Manufacturer	LG Chem, Samsung, Kokam	South Korea
	Siemens Energy	Germany
	Panasonic, GS Yuasa,	Japan

<sup>18</sup><https://www.globenewswire.com/news-release/2023/04/11/2644107/0/en/Grid-Scale-Battery-Market-to-Reach-USD-30-95-Billion-by-2029-at-21-9-CAGR-Advantages-of-Grid-scale-Battery-Adoption-to-Propel-Market-Growth-Fortune-Business-Insights.html#:~:text=Pune%2CIndia%2C%20April%2011%2C,during%20the%202022%2D2029%20period.>

<sup>19</sup><https://www.iea.org/news/global-electricity-demand-is-growing-faster-than-renewables-driving-strong-increase-in-generation-from-fossil-fuels>

<sup>20</sup><https://www.marketsandmarkets.com/Market-Reports/battery-energy-storage-system-market-112809494.html#:~:text=BYD%20Company%20Limited%2C%20SAMSUNG%20SDI,portfolio%20and%20so lid%20geographic%20footprint.>

	Toshiba, NGK Insulator	
	Fluence, Tesla, GE,	US
	BYD, Narada, EVE energy Ltd.	China
	ABB	Switzerland
	Saft	France
	S&C Electric, Black & Veatch	US

## XI. WAY FORWARD

Despite several challenges, policies of government and increase round the clock RE power demand are ensuring the bright future of BESS in India. This will also boost by the technological advancement and large-scale investments. Segments like electric utilities, and C&I are seeming to be the most favourable sector for BESS. However, cost of BESS still is a barrier and its difficult to predict the future reduction due to gap in demand and supply globally. Battery cells share 80%-85% cost of overall system and presently, country is totally depended on the import. However, its expected that globally the prices of li-ion will reduce and affordably in India will also increase. Moreover, GoI. of India has also come out with progressive policy and regulation measures in terms of tax rebate and excise duty relaxation. Initial capital subsidy/viability gapfunding and performance linked incentives could also play an important role to tackle the hurdle of higher capital investments in BESS. It was predicted that Govt. energy projects will need 51 GW capacity of BESS in Indi by 2030. Thus, it means every year country require 6GW-8GW of capacity addition annually till 2030. According to a RE research firm Maricom corporate funding for energy storage companies rose from 55% to \$ 26.4 billion until 2022 reported as highest ever. With ground-breaking technological developments, government initiatives, and stakeholder participation, the possibilities for achieving an energy storage system ecosystem will significantly expand in the future. Bloomberg NEF (BNEF) research implies that India may emerge as the third largest country in terms of BESS installation by 2040<sup>21</sup>. The rate at which the energy storage sector grows in the future will depend on how quickly market participants move to build trust in the safety of their technologies.

<sup>21</sup>[https://energy.economicstimes.indiatimes.com/news/power/opinion-how-india-can-effectively-utilize-energy-storage-systems-to-address-energy-challenge/95419026#:~:text=BloombergNEF%20\(BNEF\)%20research%20implies%20that,power%20flows%2C%20which%20increases%20revenues.](https://energy.economicstimes.indiatimes.com/news/power/opinion-how-india-can-effectively-utilize-energy-storage-systems-to-address-energy-challenge/95419026#:~:text=BloombergNEF%20(BNEF)%20research%20implies%20that,power%20flows%2C%20which%20increases%20revenues.)

