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SHAKTI SUSTAINABLE ENERGY FOUNDATION

Dispelling Myths: Battery storage is an expensive technology with limited immediate usage

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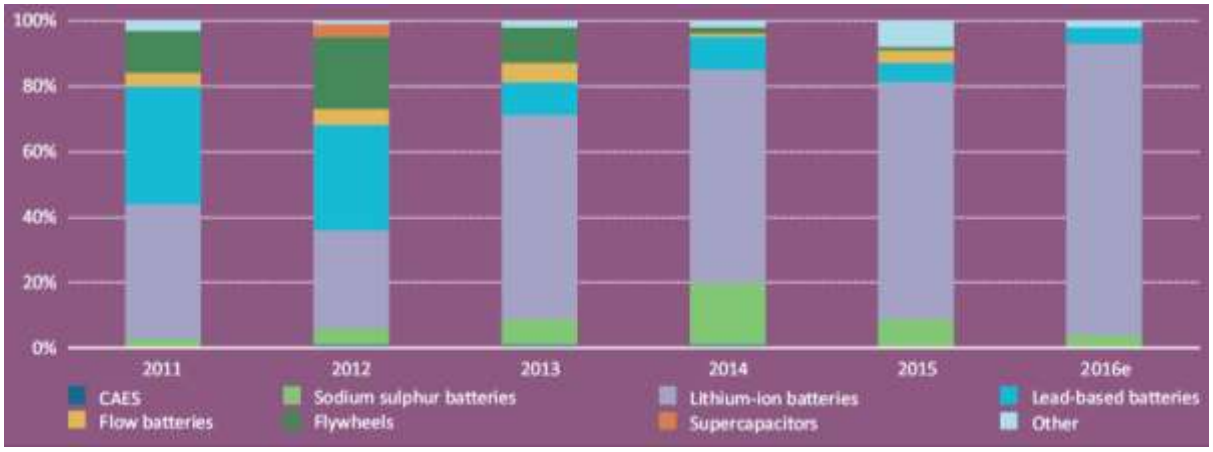
Emerging market for energy storage systems

Increasing focus on clean energy and steep fall in cost of renewable energy technologies have globally led to growth at 70 per cent CAGR in solar capacity and 24 per cent CAGR in wind capacity installations during 2010-16[1]. In 2016 alone, across the globe, around 76 GW of solar power capacity and 55 GW of wind power capacity[2] was installed in comparison with 50 GW of coal capacity addition[3]. With such high increase in penetration of renewable energy, power management solutions such as Energy Storage Systems (ESS) are required to address the variability in electricity supply due to wind and solar power.

With declining cost curve and improving maturity of technologies, the installation of non- Pumped Storage Hydropower (PSH) solutions have increased significantly globally in last six year[4].In non-PSH ESS, lithium ion batteries (LIB) are increasingly becoming more popular due to rapid fall in prices as evident in the trend of ESS installation in past few years. Lithium ion battery installation has increased from 100 MW[5] in 2010 to 1,394 MW in 2016[6]. IRENA estimated that the total installation of battery based energy storage systems is expected to increase to 250 GW by 2030[7].

Figure 1: Share of Lithium ion batteries increased from 40% to 90% in last six years



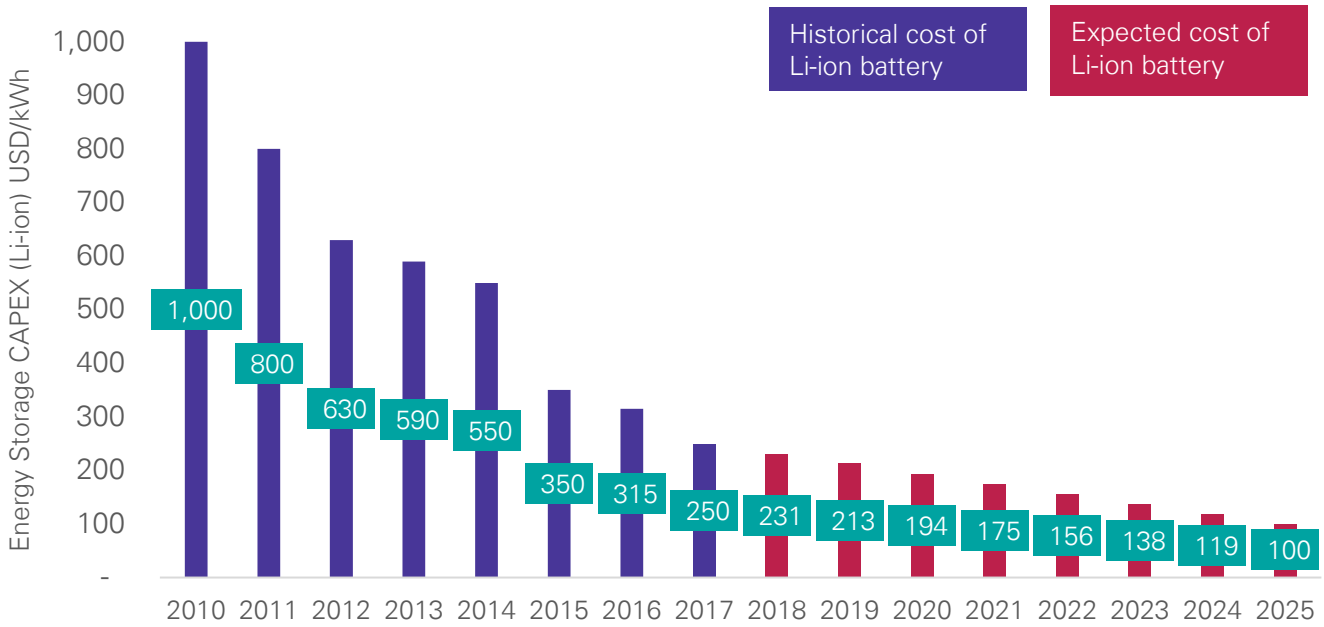
Source: IEA Tracking the clean energy progress, 2017

[1] BP statistical review of world energy, 2017
[2] Advancing the global renewable energy transition, REN21, 2017
[3] Boom and Bust 2017, Tracking the global coal plant pipeline, Coalswarm / Sierra Club / Greenpeace, March 2017
[4] Total non-PSH solutions has increased from 976 MW in 2010 to 3,400 MW in 2016
[5] IEA technology roadmap for energy storage
[6] IEA Tracking the clean energy progress, 2017
[7] IRENA REthinking Energy 2017 estimate for 26 major countries

Declining cost of lithium-ion batteries

In past seven years, cost of LIB technology has fallen by 75 per cent from USD 1,000 per kWh in 2010 to USD 250 per kWh today. In the next decade, the price of li-ion batteries is further expected to drop by 60 per cent to USD 100 per kWh[8] as shown in Figure 2.

Figure 2: Declining cost of Lithium ion batteries



Source: Rising Sun, KPMG in India

The improvements in LIB were initially driven by smart phone industry. Post 2010, automotive sector is driving efficiencies in manufacturing of batteries as their share in LIB market has increased significantly[9].

According to various analyst reports, the future cost reduction in LIB will be driven by the following factors[10]:

- **Economies of scale**: With upcoming Giga-factories, the cost of LIB will decrease due to consolidation of supply chain in one geography. Also, the material cost is expected to reduce as the bargaining power of manufacturers will increase with the advent of Giga-factories. Around 8 per cent of cost reduction is expected from economies of scale
- **Cell architecture change**: Technology improvements including changes in battery chemistry/ cathode composition will help reduce the overall costs of energy storage. It is expected that cell architectural change can reduce the cost by around 6 per cent from present levels[10]
- **Experience curve**: Several costs such as overhead costs, labour costs, supply chain etc. reduce with increasing supply/deployment. This learning curve effect

[8] Bloomberg; Rising Sun, KPMG in India, 2015
[9] https://www.marketresearch.com/product/sample-8323376.pdf
[10] Auto and auto parts, Jefferies Franchise Note, December 2015

has already reduced the costs by around 6-9 per cent per annum over the last 8 years[10]

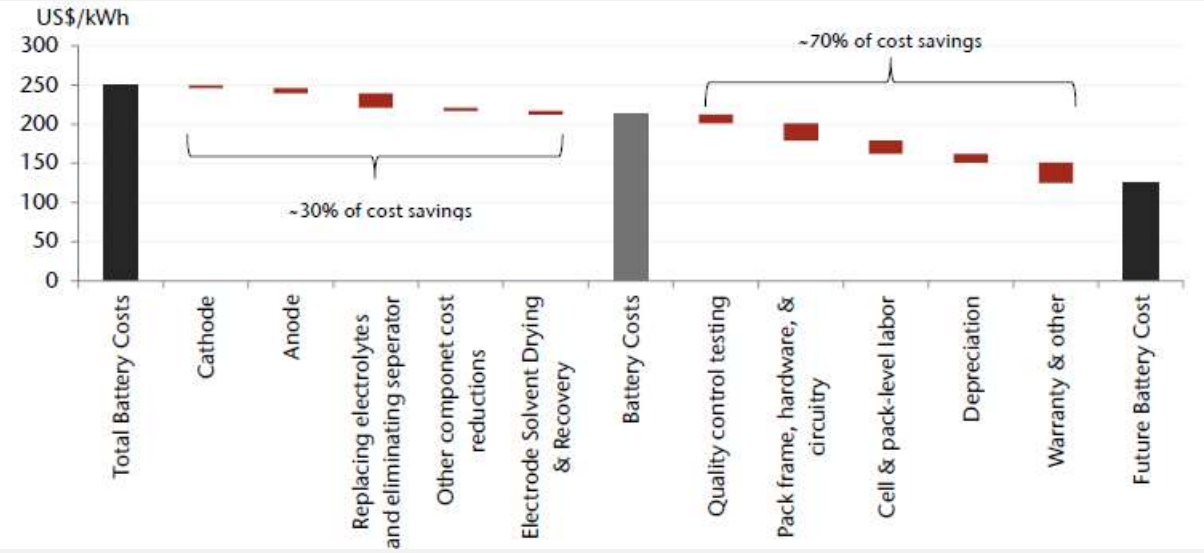
- **Reduction in over-engineering**: Batteries are over-engineered to ensure the safety and reliability. With increasing standardisation and rise in deployment, the over-engineering will reduce leading to lower cost.

The last two factors are expected to reduce the cost of batteries by around 35 per cent[10].

Box 1: Industry targets for cost reduction in LIB

Tesla is leading the industry in driving downward the cost curve of batteries. Going forward, it is expected that Tesla may achieve US DOE target of USD 125 per kWh by 2020[10]. It is expected that around 30 per cent cost reduction will be achieved by improving the cell-level architecture of LIB and 70 per cent of cost reduction will be achieved by reducing the battery pack level costs. The below waterfall chart explains the elements leading to cost savings for Tesla batteries.

Figure 3: Possible factors driving the fall in Tesla's batteries



Source: Jefferies Franchise note

Future of batteries

- **US DOE** has set a target to achieve a cost of USD 125 per kWh by 2022 (DOE EV goals)
- **GM** announced cost of USD 145 per kWh for battery cell and expect battery cell to drop to USD 100 per kWh by 2022 (Media reports)
- **Tesla** has already achieved a price of USD 190 per kWh and expected to achieve less than USD 125 per kWh by 2020 (Jefferies Franchise note)

While the storage cost trajectory is clearly set to decline sharply, battery solutions for storing power is considered largely uneconomical today. In reality, battery storage is fast emerging as economical solution under various applications and are already economical under certain scenarios as discussed below:

Current applications for battery storage

a. Diesel generator replacement

Upon interactions with few commercial building operators in a large city in South India, it was observed that consumers typically deployed Diesel Generators (DGs) for usage of around 30 hours per month (average one hour per day), when grid power in not available.

Variable cost to generate power from diesel generator as charged by building operators is around INR 18 - 25 per unit. Total fixed cost of diesel generator is around INR 2.2 per unit[11]. Hence the total cost of power from diesel generator is around INR 20.2 – 27.2 per unit (fixed plus variable cost) which is significantly higher than the cost of power from the grid at INR 7.8 per unit[12] and alternative sources such as solar roof top at INR 5-6 per unit.

This merits evaluation whether Energy Storage System (ESS) can be economically deployed to store (and subsequently retrieve) grid power or power from sources such as solar roof top, as an alternative to drawing power from DGs when the grid power is not available.

At today's battery pack prices, the cost of energy storage is estimated at around INR 10.9 per unit[13]. At this price, storage solutions combined with power sources such as grid power or solar can actually be cheaper than power drawn from DG set as shown below:

[11] Life of DG set is assumed to be 20 years. Cost of DG to be INR 35 lakh per 500 kVA and O&M expense of INR 37,500 per year.

[12] Energy charges for commercial category at 11kV for a South Indian state

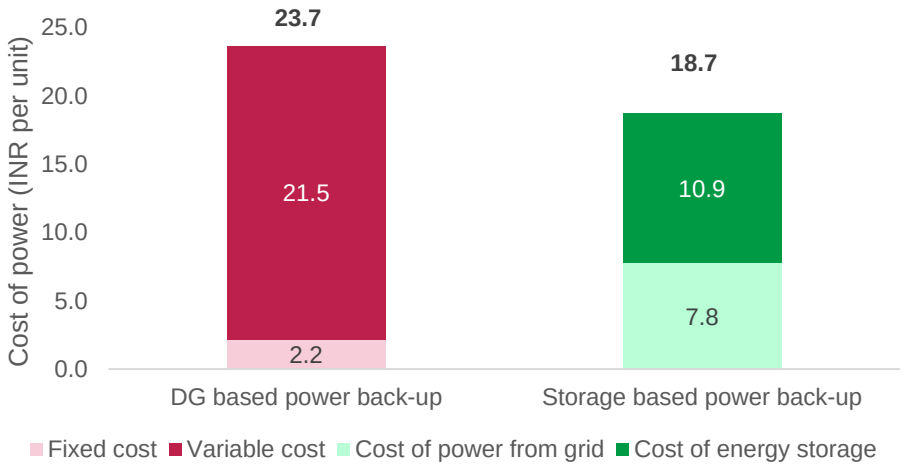
[13] Assumptions taken to compute cost of energy storage:

- Cost of Li-ion battery is taken as shown in Declining cost of lithium-ion batteries

In past seven years, cost of LIB technology has fallen by 75 per cent from USD 1,000 per kWh in 2010 to USD 250 per kWh today. In the next decade, the price of li-ion batteries is further expected to drop by 60 per cent to USD 100 per kWh as shown in Figure 2.

- Figure 2. Total cost of battery storage including inverter and other equipment for residential complex is around USD 492 per kWh for residential purpose.
- Life of battery is assumed as 10 years and straight line depreciation is assumed with zero salvage value
- 75:25 ratio is assumed for debt and equity. ROE is assumed at 18 per cent and interest rate on debt is assumed at 11 per cent with working capital loan interest rate of 11.50 per cent
- Exchange rate of INR 65 per USD is assumed
- For power back-up, it is assumed that battery would be utilized on an average 1 hour per day at peak load

Figure 4: Replacing diesel generators with energy storage (Energy storage usage for 1 hour/day)



Source: KPMG in India's analysis

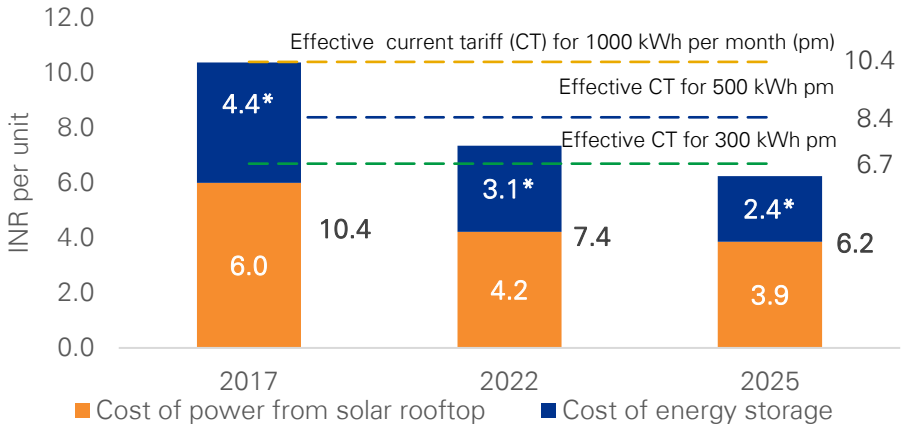
Replacing DGs

According to recent Policy Brief released by Centre for Science and Environment (Replacing diesel generator with residential societies), it would be cost effective for residential societies to use ESS along with solar roof top to provide power back-up when compared with use of diesel generators.

b. Solar PV-storage solutions for high end residential consumers

In India, domestic consumers are paying more than INR 8 per unit for power consumption of more than 250 units per month. The effective current tariff for domestic consumers consuming more than 1000 units per month today for some discoms is comparable to the cost of power from solar roof top coupled with storage solutions, even today, as illustrated in following figure[13].

*Figure 5: Solar house is almost economical for certain consumer categories - an illustration**



***Assumptions:** It is assumed that battery storage would be required to store 60 per cent of power produced from solar PV. Cost to store power is around INR 7.3 per unit[14]. However since only 60 per cent of power produced from solar PV is stored, the effective cost of energy storage is INR 4.4 (60%*7.3) per unit.

Source: The Rising Sun, KPMG in India's analysis, Lazard's levelized cost of storage — version 2.0

As storage and solar PV costs decline, this market for storage solutions is likely to open up. Going forward, by 2022, solar roof top solution integrated with storage can make economic sense for a larger consumer base in many states. As per KPMG's Rising Sun, 2015 "Disruption on the horizon", grid independent solar houses could become a reality in FY 2025.

c. Energy access in rural areas through decentralized solutions

Similarly, batteries are also finding increased usage in decentralized supply of electricity in rural areas integrated with RE based mini-grid solutions, where cost of grid extension or centralized supply through the grid can be higher than decentralized supply with mini grid solutions combined with optimal storage solutions. Furthermore, decentralized solutions combined with storage can help manage local load requirements better in terms of reliability, time of supply, hours of supply, etc.

Future opportunities

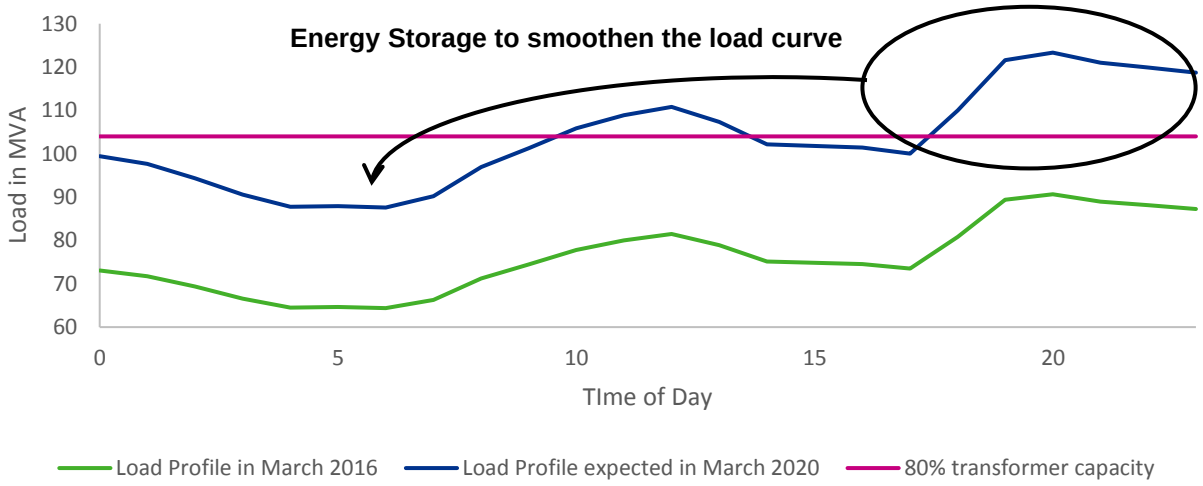
As the cost of energy storage decreases, many market avenues will open up for ESS. Market off-take will depend on the regulatory position on energy storage and costs of alternative investments. One such application is transmission and distribution (T&D) investment deferral.

Typically a new sub-station is planned when the peak load through substation reaches around 80 per cent of its maximum capacity. However when the maximum load reaches around 80 per cent, the average utilization of sub-station is just 50-60 per cent. Better load management (as explained in below figure) with the help of ESS can help improve the average utilization of sub-station by an estimated 10-15 per cent[15]. ESS can help smoother the load curve by storing energy in off peak hours and releasing energy in

[14] The difference in cost of storage in figure 4 and 5 is due to different utilization of the battery capacity
[15] KPMG in India's analysis

peak hours. This would help in deferring the network upgradation investment by 3-4 years.

Figure 6: Typical load profile of a sub-station



Source: KPMG in India's analysis

At battery costs less than USD 150 per kWh (expected before 2023), energy storage technologies can be economically deployed to defer T&D investment. India can thus save on capital costs for building the network in future.

Case-in-point

Distribution upgrade deferred in New York

As part of Brooklyn-Queens Demand Management (BQDM) program, Consolidated Edison (ConEd) filed for a proposal to defer two substation upgrades in Brooklyn and Queens. The upgrade was expected to cost around $1 billion. To avoid the investment, ConEd proposed spending $200 million on behind-the-meter load management and an additional $300 million on traditional substation upgrades. At projected rates of load growth, ConEd needs to reduce or realign the timing of 52 MW of load by 2018 to avoid overloading the

Other applications

In developed economies, energy storage is already used to manage the demand charges and frequency regulation. In a recently concluded tender by National Grid, UK for Enhanced Frequency Response (EFR), all of the 201 MW required EFR capacity was allocated to ESS at roughly half of the current EFR equivalent tender prices[16]. Low demand charges and absence of regulations on energy storage hinders the take-off of these markets in India.

[16] National Grid Website

Conclusion

Today, energy storage technology is already economical for certain market segments such as T&D investment deferral and diesel generator back-up capacity segments. Declining cost curves for energy storage will open up more market applications such as managing intermediate and peak load, grid independent solar houses, RE integration and Electric Vehicles.

The evolution of energy storage technologies heralds a new paradigm of sustainable energy deployment globally. Cost effective storage technology solutions will help meet the objectives of energy security and clean environment for India.

About Shakti Sustainable Energy Foundation

Shakti Sustainable Energy Foundation works to strengthen the energy security of India by aiding the design and implementation of policies that encourage energy efficiency as well as renewable energy. Based on both energy savings and carbon mitigation potential, we focus on four broad sectors: Power, Transport, Energy Efficiency and Climate Policy. We act as a systems integrator, bringing together key stakeholders including government, civil society and business in strategic ways, to enable clean energy policies in these sectors.

For further information, please contact deepak@shaktifoundation.in or anveshathakker@kpmg.com