Deloitte.

WORLD ENERGY COUNCIL INDIA
7th INDIA ENERGY CONGRESS
ENERGY 4.0: ENERGY TRANSITION TOWARDS 2030
1-2 FEBRUARY 2018 | NEW DELHI, INDIA

Variable Renewable Energy Sources Integration

February 2018

Table of Contents

List of Figures

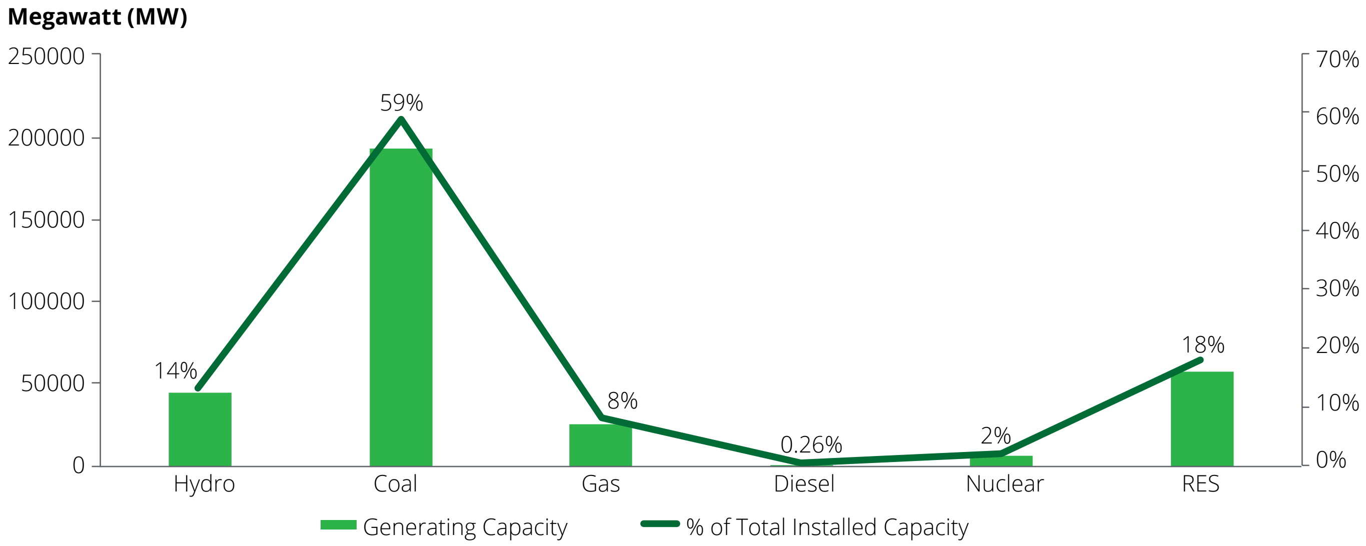
List of Tables

1. Introduction

1.1 Power Sector Overview

India is one of the fastest growing economies in the world. India relies heavily on conventional fuels to meet the energy demand. Out of the total installed capacity of 329 GW[1], the share of coal, gas and diesel power projects is close to 67% in the overall capacity mix, while the share of renewable energy in the overall capacity mix is 18% (~ 57 GW) as of March 2017.

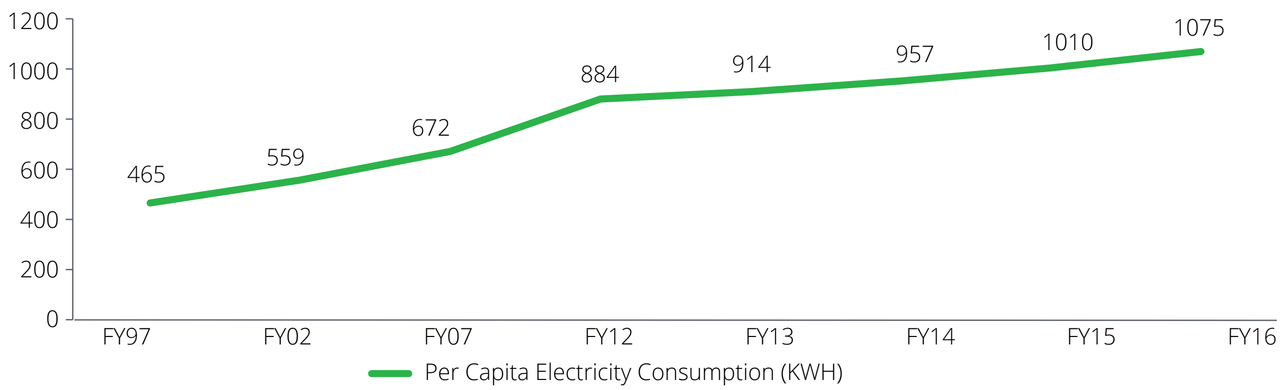
Figure 1 : Power Installed Capacity Mix (MW)



Source: CEA (as on 31.03.2017)

Ensuring adequate availability of energy is a crucial requirement for sustaining economic growth. There have been significant investments in power generation in the last few years, which resulted in reducing the energy and power demand deficit. In March 2017, country witnessed energy deficit of 0.3% and power demand deficit of 0.5%[2]. The per-capita electricity consumption has also increased steadily over the years. The figure below indicates the increase in country level per-capita electricity consumption.

Figure 2 : Per capita electricity consumption trend



Source: Central Electricity Authority (CEA)

1. http://www.cea.nic.in/reports/monthly/executivesummary/2017/exe_summary-04.pdf
2. http://cea.nic.in/reports/monthly/executivesummary/2017/March

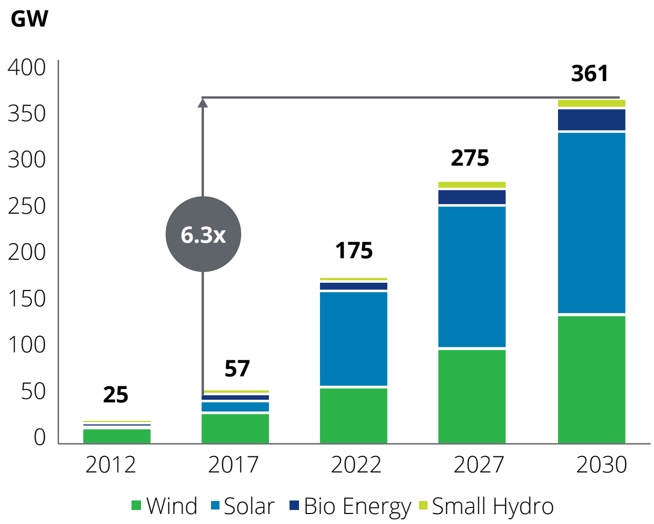
1.2 Renewable Energy (RE) Overview

Renewable energy sector is expected to grow significantly in India:

Policy support, technology improvements and cost reductions are transforming renewable energy sector. A virtuous cycle is unlocking the economic, social and environmental benefits of renewables in the country. Over the past few years the share of renewables capacity in the India has increased from 12% in 2012 to over 18% in 2017. Going forward, with renewables achieving grid parity or even becoming cheaper than conventional power and technological advancements across the eco-system, the renewables are staged to play a bigger and a deeper role in the country's electricity mix. Between 2017 and 2030, the share of renewables is expected to reach over 43% in capacity terms.

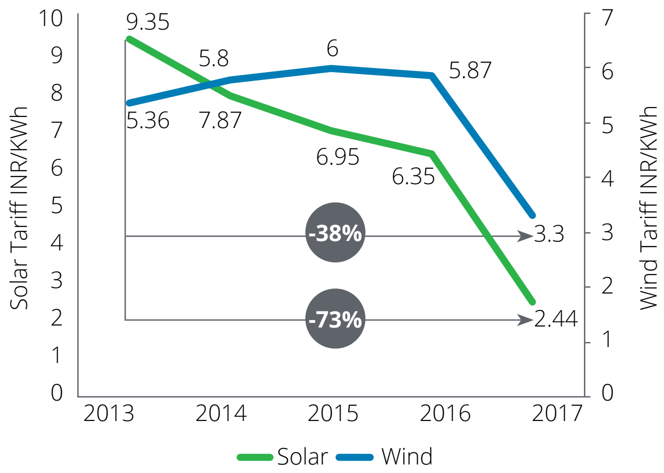
Figure 3: Renewable Energy Capacity Addition Projection (GW)

By 2030, the overall renewable capacity in the country will be upwards of 361 GW



% share of RE in overall capacity	12	18	33	43	43

..decreasing tariff of RE has been the key driver for Renewable Energy adoption



"Green future: Latest Solar power auction at Bhadla Solar Park 3 sets new record with electricity tariff of Rs 2.44/unit.

".. **Piyush Goyal, Ex Power Minister**

Source: National Electricity Plan, CEA – Executive Summary, MNRE, Lit Research, Media News and internal analysis

1.2.1 Key Drivers for RE

Apart from falling tariff, increasing regulatory support for renewable energy procurement and declining cost of equipment are key among the factors for renewables energy growth in the country

It is well recognized globally that early commercialization of RE technologies is highly dependent on support from the government through a mix of policy and regulatory instruments. Over the years, the Government of India has introduced a number of policy and regulatory initiatives for promoting RE. Some of the key initiatives have been illustrated in the figure below:

Table - 1: Policy and Regulatory Framework for RE

Year	Instrument/ Initiative	Key Features
1982	Creation of Department of Non-conventional Energy Sources	An independent department for development, demonstration and application of RE. RE sources were recognized as potential alternative energy sources and received special consideration.
1992	Creation of MNRE	The Department of Non-Conventional energy Sources was upgraded into a full-fledged ministry.
1993	MNRE Policy and Tariff Guidelines	Introduction of RE tariff guidelines by MNRE - states to purchase RE power at Rs 2.25/ kWh with 5% annual escalation with 1993 as base year. Introduction of Tariff guidelines offered relatively higher price for RE than what was prevailing, and thus triggered development of RE sector, especially wind.
1993-94	Introduction of Accelerated Depreciation	Introduction of Accelerated Depreciation (100% AD) for promotion of wind projects (altered to 80% AD in 1999). This program led to the successful commercial development by involving the private sector in wind equipment manufacturing as well as its application.
2002-03	Electricity Act 2003	Recognized the role of RE for supplying power to the utility grid as well as in standalone systems. Provided an overall framework for preferential tariff and quotas for RE.
2004 onwards	Preferential Tariffs for RE from SERCs	Following the enactment of the EA-2003, states adopted preferential tariff mechanisms to promote RE. Since it provided differential tariffs for the development of different RETs, it brought in a balanced approach to RE development across states.
2005-06	National Tariff Policy	Directed SERCs to fix a minimum percentage of purchase of energy consumption from RE sources (RPO). This created a demand side stimulus for RE development.
2005-06	Integrated Energy Policy Report 2006	Suggested a path to meet energy needs in an integrated manner. Recommended special focus on RE development and set specific targets for capacity addition through RE sources.
2008-09	Introduction of Generation Based Incentives (GBI) for solar and wind energy	This scheme offers fiscal incentives along with tariff on power generation from solar and wind. It shifted investment interest from installation to generation.
2008	National Action Plan on Climate Change (NAPCC)	NAPCC advised that starting 2009-10, RPO's be set at 5% of total grids purchase, and be increased by 1% each year for 10 years.
2010	Jawaharlal Nehru National Solar Mission (JNNSM)	Targets 20,000 MW of grid-connected solar power capacity and 2,000 MW of off-grid solar power capacity by 2022.
2010	REC regulation	Introduction of REC mechanism in which sale and purchase of solar and non-solar renewable energy certificates can be traded in an open market for meeting the RPO (renewable purchase obligations) by designated entities.
2015	Revision of National RE capacity addition targets till FY 2022	India's RE target revised to 175 GW capacity by year 2022
2016	Amendment to National Electricity Tariff Policy, 2016	National electricity tariff policy 2016 mandates solar RPO targets of 8% (excluding hydro power) Renewable Generation Obligation on conventional power projects No inter-state transmission charges for wind & solar power

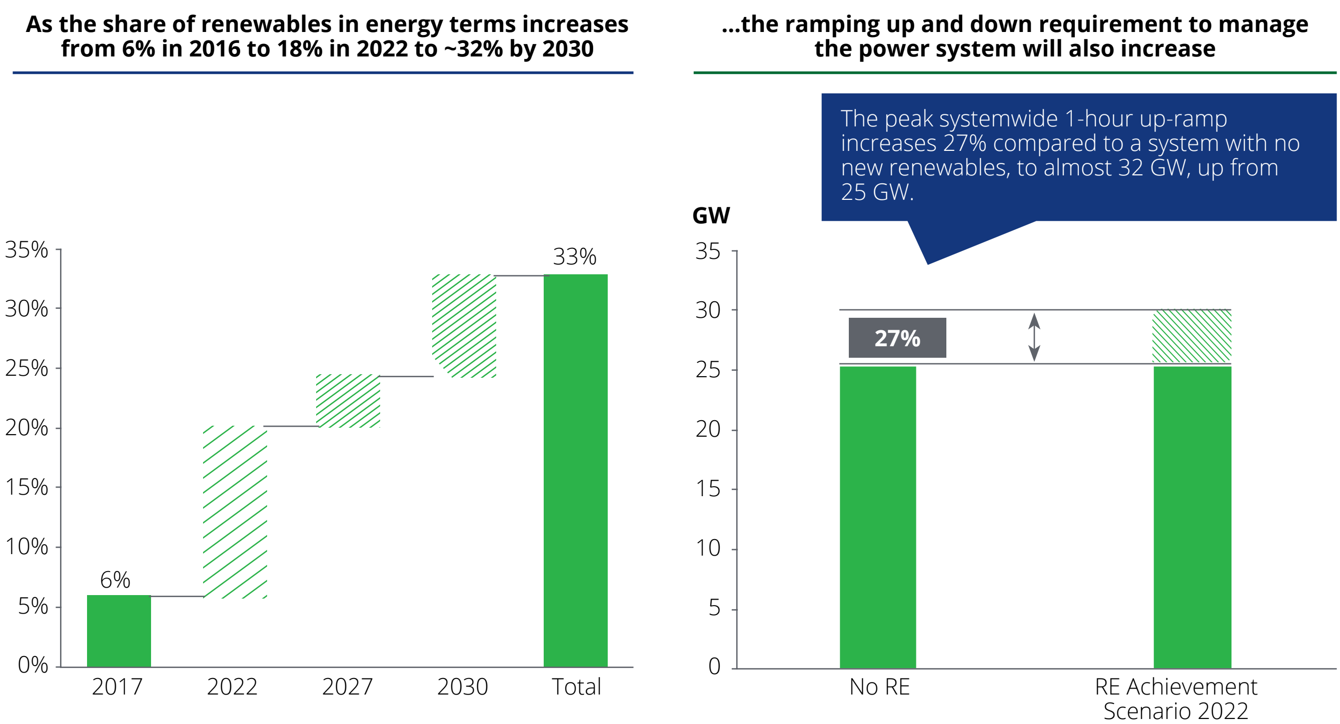
1.2.2 Renewable Energy and its impact on the Grid

The growth of renewables is likely to also increase the variability in the system thereby making grid operation challenging:

Renewable energy sources such as wind and solar are intermittent in nature, as their output is dependent on external conditions such as sunshine and wind. This variability in the electricity generation along with the changes in load has to be taken into account for smooth and efficient functioning of the grid. The figure below highlights that as the share of renewable in electricity mix, in energy terms, increases from under 6% in 2017 to ~21% by 2022 the ramping requirement of the system increases by 27%[3]. The peak system wide 1 hour ramp-up increases to 32 GW from 25 GW under no renewable scenario[4]. This underscores the fact that as the penetration of renewables in the system will increase, so will the variability and thereby inflating the ramping (up and down) requirements to manage the grid operations.

Higher the penetration of renewable generation the higher will be the requirement of load following generating stations to manage the system. However, under a high renewable rich scenario, the one shown in the figure above, the balancing of the grid through the conventional load following generating stations such as hydroelectric plant and gas based thermal plant would not be adequate and therefore would require additional interventions such as better system operations, energy storage system etc.

Figure 4: Renewable Energy Growth and Balancing Requirement



Assumptions:

- The total electricity demand for the year 2030 is 2499 TwH - India's INDCs target.
- CEA estimates have been used to estimate total energy generated from RE sources for the year 2027 and the same has been extrapolated to estimate numbers for 2030
- It has been assumed that RE capacity will grow at an annualized rate of 10% between 2027 and 2030

Source: CEA's National Electricity Plan – Transmission and Generation, Greening the Grid – Pathways to integrate 175 GW of RE

3. Greening the Grid: Pathways to integrate 175 GW of Renewable Energy into India's Electricity Grid, Vol. I – National Study
4. Greening the Grid: Pathways to integrate 175 GW of Renewable Energy into India's Electricity Grid, Vol. I – National Study

2. Renewable Energy Integration: Key Issues, Focus Areas And Initiatives

2.1 Importance of Renewable Energy Integration

While economic, environmental and energy security concerns have been the key influencers for promotion and development of Renewable Energy sources, these sources are characterized by inherent issues like variability, intermittency and fast ramping, etc. Various countries have been facing concerns with respect to these issues with the increasing proportion of renewable energy sources in the grid. The variability on account of generation from RE sources impose a threat on effective management of the system operation and management. The growing proportion of renewable energy (especially wind and solar) in the power system further adds to these challenges. The need to effectively integrate such large scale Renewable Energy in the Grid has been one of the key concern for all stakeholders including the policy makers, planners and regulators.

Countries such as the US and Germany have innovated technical and procedural solutions that enable their grids to accommodate increasing volumes of RE, even as research continues on improved grid management and storage technologies. India is on its way to build from this international experience and develop and apply local grid integration solutions that are both cost effective and scalable.

2.2 Review of International Practices for Large Scale Renewable Energy Integration

Insights from grid operational practices from the advanced nations like Germany and United States, where grid operators are already managing large scale Renewable Energy integration, can provide significant inferences.

This section presents the key insights from Germany and United States from the perspective of the grid integration of Renewable Energy sources.

2.2.1 System Planning:

Large scale Renewable Energy generation is location specific, and takes much lesser time for commissioning as compared to the conventional power plants and construction of transmission system. Thus, planning process of transmission system significantly differs from the conventional plants. In United States, high potential Renewable Energy Zone (REZ) has been identified, and construction of transmission lines begins years before[5].

Advance network planning and construction, reduced off-take risk and network congestion due to inadequate network capacity acts as a catalyst to large scale renewable integration.

2.2.2 System Operations

Grid frequency is an indicator of demand generation imbalance. Variable power demand and variable Renewable Energy generation increases the complexity to manage the grid reliability. Germany and United States are using various tools and techniques to manage the variability of the grid, which are briefly describe, below:

Forecasting

Germany, having more than 75GW installed wind and solar capacity, is focusing on integrated RE forecasting[6]. The Independent Power Producers are required to forecast the RE generation for their installed capacities, however the grid operator carries out aggregated independent forecast for the overall system and there is no mechanism to penalize independent power producers for the forecast error.

In United States, Electric Reliability Council of Texas (ERCOT) carries out RE forecasting in the capacity of system operator for the balancing area and generates market pricing signals for meeting the variability in real time through various ancillary market products through automated dispatch.

Scheduling

ERCOT increased the dispatch resolution from 15-minutes time interval to 5-minutes[7]. Short-term scheduling, significantly reduced the requirement of the Ancillary Services. Improved system information enable system operator to identify the trend in the generation and demand in advance and more accurate manner, so it reduces the mismatch in demand and generation variation.

Development of Ancillary Market

Solar and wind energy sources are having less inertia as compared to the conventional energy sources. Germany and United States have developed ancillary (balancing) market, in order to introduce the synthetic inertia to respond to the increased variability due to variable renewable generation. Ancillary services, manage short-term mismatches between electric supply and demand, with fast-ramping gas-fired generation, demand response,

5. Review and Status of Wind Integration and Transmission in the United States: Key Issues and Lessons Learned, National Renewable Energy Laboratory, USA
6. Report on Forecasting, Concept of Renewable Energy Management Centres and Grid Balancing, GIZ India
7. Integrating Renewable Energy into Electricity Grid, Advanced Energy Economy Institute

storage, and other technologies. Germany developed ancillary market and modified intraday electricity market, to incentivize the market participants to provide the additional power in time frames, to address the power generation and demand imbalance. Though such kind of operations increase the complexity in transactions, but market rule and design, improved the flexibility and opened market to more participants.

In United States, independent system operators like CAISO, ERCOT are continuously engaging the large industrial and commercial consumers to participate in the demand response program. Under the demand response program, variability is induced on the demand side to manage supply side uncontrollable variability, or response to market price or any other factors. So, demand response program are also kind of ancillary services, to manage the integration of the large scale penetration of Renewable Energy.

2.3 Renewable Integration: Key Issues & Focus areas

There are a host of challenges which relate to the fundamental characteristics of both the majorly deployed renewable electricity generation system - wind and solar. Experience in other systems has shown that when penetration of RE reaches significant levels, the capacity of the grid to manage has to be addressed in order to avoid challenges to the reliability and affordability of electricity. Apart from variability of RE resources other integration issues include their integration cost, frequency response/ system stability, and system balancing, forecasting tools and methodology, improving mechanism for scheduling and dispatch, etc. which are covered in detail below.

Major issues and focus areas for mitigation of these challenges in Indian context are discussed below.

2.3.1 Technical Challenges

Increasing flexibility of the Conventional Plants

As wind and solar generation depend largely on external factors (i.e. wind speed, solar insolation, etc.), higher volumes of renewable energy sources in the power system become difficult to manage owing to their temporal fluctuations and geographical dispersion. This variability affects the power systems with the increasing penetrations of RE sources. Further, the fluctuations in demand and the flexibility of the conventional system are important aspects which would impact large scale grid integration of the renewable sources. The current conventional sources are old and are technological incapable of responding to quick ramp up and back down emerging from fluctuations in RE generation.

Therefore, it is important to build flexibility in the existing fleet of conventional generating plants as well as develop gas, hydro and pump storage plants which could be utilized for meeting the fluctuations in load profile as well as maintain system stability. Adequate incentives are required to be built in the regulations for plants which could demonstrate flexibility.

Estimation of Balancing Reserve Requirement

A recent report released by PGCIL in December 2016 (Renewable Energy Integration- Transmission and enabler), highlights that due to high penetration of solar energy, grid will witness high ramp down and ramp up requirements. Solar generation increases in morning, and fall in early evening (4-6 PM). The study finds the requirement of the balance capacity for the two scenarios, 15% (74 GW) & 30% (116 GW) RE capacity penetration by year 2019. In order to meet ramps in 15% and 30% RE scenario, assessment of balancing resources is presented in below table,

Ramp	15% RE Scenario (MW/min)	30% RE Scenario (MW/min)
Solar Morning Ramp(Down) 7-11 am	33	150
Solar Evening Ramp (Up) 4-6 pm	17	125
Demand Evening Ramp(Up) 6-8 pm	250	275
Total Balancing Reserve Required during evening ramp (4-8pm)	32 GW in 4 hours	48 GW in 4 Hours

Source: PGCIL

Though, above analysis indicates the sufficient availability based on pan India requirement of the balancing reserve for the 74 GW RE penetration, but operability of these reserves is an issue due to PPA contracts with state DISCOMs, scheduling of power plants through SLDC etc..

Forecasting and Scheduling

Forecasting of renewable energy takes on an increasingly important role in the power grid with the increase in proportion of wind and solar energy. Solar, wind and hydro energy are dependent on highly variable weather conditions and shall lead to high fluctuations in the power injected. Forecasting (both Load, RE generation as well as Net Load) is therefore essential for ensuring resource adequacy during operation and grid security. Thus developing improved forecasting systems and corresponding decision support tools which are key solutions to enable a clean, reliable and cost efficient future electricity grid driven by renewable resources becomes necessary.

Suitable regulatory framework for Forecasting, Scheduling and Imbalance Settlement for RE generators at both inter-state and intra-state level needs to be in place. Such a framework at inter-state level has already been put into place by the Central Commission and can be used as a reference for intra-state framework. Aggregators should be introduced to coordinate with several RE generators and be responsible for scheduling, real time operation and settlement of imbalances with the State/Regional Pool and RE generators.

Improved forecasting of RE is also essential to enable System Operators to manage grid operations. Equipping all States with the latest state of art load forecasting tools and facilities is required along with capacity building of the system operators. A roadmap for establishment of Renewable Energy Management Centres (REMC) in RE rich states with the provision of external forecasting service providers is already envisaged. Greater focus needs to be accorded to weather forecasting in India to make it useful for RE forecasting.

Improved Market Operations (including ancillary services)

As the renewable sources are concentrated in some of the States, adequate market operations and support services needs to be put in place which would encourage inter-state trading of the RE. Currently, there are significant barriers for such inter-state trading of RE including lack of reserve sharing between control areas / States, absence of products / markets for primary and secondary response for ancillary services, etc. These are essential areas of focus for RE integration and strategies adopted in other countries provide insights for devising workable solutions in the Indian context.

In a competitive electricity market, it is essential to not only carry out regular transactions of energy and power but also to arrange or procure certain services required for maintaining the security and reliability of supply. These services are called ancillary services and are required for maintaining acceptable frequency and voltage levels in the system. Also, ancillary services provide a framework for operationalizing the spinning reserves and the modalities of scheduling, metering and settlement of the reserves. While the ancillary services have been implemented at the inter-state level, a similar framework is required to be implemented at the State level for efficient operations.

Resource Planning and Storage

In view of the intermittency associated with the RE energy (especially solar and wind), adequate generation reserve are required to be maintained in the system to handle the contingencies. The total quantum of reserves and its segregation into primary, secondary and tertiary reserves is extremely important in the context of balancing. While the National Electricity Policy does talk about 5% spinning reserve, currently the reserves are insufficient to respond to grid fluctuations. The Government of India target of 175 GW of RE would require significantly larger quantum of reserve capacity.

To meet up for the additional requirement, flexible generators such as reservoir hydropower plants, gas based generating plants which could respond and adjust to the demand-supply fluctuations in a short time frame would be required. Also, storage as well as automated demand side management are flexible energy services which may help in shifting the generation or load as necessary to meet the gap between the renewable generation and demand.

Cost estimation of building generation flexibility

For flexible generation the technical capabilities of power plants such as minimum load, rate of change of generation (to follow the load gradient), start-up time and down-time (hot and cold start) as well as minimum stand still times are important. These parameters influence the quantity of available balancing power at any given moment of time. One of the most challenging issues in India with regards to integration of RE today is backing-down conventional generation. Power plants need to run on partial load or to be shut-down completely and be disconnected from the grid. High minimum load or low turndown capability reduces the balancing potential. Stakeholders at the SLDC level in various Indian states declared that the minimum load of most thermal power plants is around 70%. Thus, turndown capability is only 30% which is much lower than required as per International standards. Thus enhancing the flexibility parameters (i.e. by retro-fits) towards state-of-the-art values or beyond is recommended to increase the balancing capability.

Retrofitting needs an initial investment in technical improvements. Cycling and running coal power plants at technical limits also increase the impact on equipment and thus, the costs of operation and maintenance. Retrofit solutions from manufacturer usually address the following options:

1. Lower turndown (minimum load)
2. Faster ramping
3. Faster and less expensive starts
4. Keep emissions low despite increase in flexibility

Costs for retrofitting power plants very much depend on the individual set-up of the plant. In any case hardware adjustment is needed, which is usually costly and may lead to interruption in power plant operation. Parameters which are subject for improvement are especially the minimum load (turndown), start-up and down time improvement and ramp rate improvement.

The table below provides cost estimation of various retro-fit measures.

Measures	Cost Range (Million $, small sub-critical [200MW] / large sub-critical [500 MW] / supercritical 750 [MW]
Boiler Retrofits	0.3 – 3 / 0.5 – 5 / 1 – 7
Coal Mill Retrofits	0.5 – 10 / 1 – 12 / 1.5 – 16
Emissions Control Retrofits	0.5 – 2 / 1 – 3 / 1.8 – 4
Balance of Plant Retrofits	0.57 – 4 / 1.5 – 7.5 / 2.25 –
Turbine Retrofits	0.25 – 1 / 0.75 – 2 / 1 – 4
Chemistry-related Improvements	0.3 – 1.5 / 0.5 – 3 / 3 – 4

*** Source:** NREL 2013

2.3.2 Lack of Regulatory and Policy framework

Development of policy and regulations for market evolution that enables and rewards the system flexibility is an important area which needs to be focused upon. The current market rules and regulations needs to be modified to achieve operational efficiency in system with increasing penetrations of variable RE. In order to facilitate the RE integration and overcome challenges with regard to the integration of RE sources in the power system, CERC has already undertaken a number of measures including changes to Grid Code, Regulations with respect to Deviation Settlement Mechanism, Ancillary Services Operations, etc. However, electricity being a concurrent subject, limited initiatives have been undertaken at the State level. Barring a few renewable rich states, not many states have undertaken adequate steps for aligning the state regulations with the central regulations. Few of the concerns relating to the regulatory and policy framework include:

Limited long term clarity on applicable Open access charges:

For RE generators and DISCOMS to take part in inter-state trading of RE power, it is important to have a clear visibility of the various charges that sellers and buyers would incur. Currently, there is high volatility in open access charges and are typically changed on yearly basis by the State Electricity Regulatory Commissions. In several instances, SERCs have increased open access charges to restrict inter-state trade. Buyers and Sellers need to receive clear visibility on long term open access charges.

Delay in implementation of Deviation Settlement Mechanism (DSM) at State level:

Reducing the risk of DSM charges for participating states will be important to incentivize sharing of RE resources between the states. Since the implementation of DSM at state level is still pending, it is unclear on how DSM charges would be levied on generators and DISCOMS which shall be taking part in interstate trade of RE power. There should be clarity on how DSM will be operationalized at a state level.

Lack of regulatory framework for trading surplus power:

As penetration of RE power increases in the future it is likely that RE curtailment will increase in states which have high RE installed capacity. DISCOMs face low demand in certain time period resulting in generation back-down. Majority of the RE capacity is already tied up under long term PPA. There is a lack of clarity in regulation on participation of generators and DISCOMS which are already

under PPAs to sell surplus RE power in the market. There is also a need for clarity on accounting of such trades, especially in scenarios where DISCOMs are not able to meet their RPO but have surplus RE power during select time slots. Lack of commercial framework to allow RE trade of this surplus power is important, especially how the cost will be borne by DISCOMs.

Buyer risk:
There will be scenarios when RE generators would fall short of their deliveries due to variability. In this case, consumers would have to draw power from state DISCOMs and pay additional charges like temporary connection charge/standby-charge. The regulatory framework varies from state to state, however puts a risk of increased landed cost of RE delivered power after accounting these additional charges. With lack of accurate RE forecasting, the probability of payment of the additional charges will be high in RE traded power.

Redefining of balancing framework:
In India, at present, balancing requirement is at the state level. Due to high concentration of renewable energy sources in designated area, state power system witnesses high variation, which is problematic to manage. Enlargement of balancing area will increase the diversity in the renewable energy generation, absorption of variability in large grid is relatively easy. Also, a market based instrument needs to be developed to incentivize the balance reserve provider to participate in grid operation, to handle the generation-demand imbalances.

Lack of clarity on balancing cost:
The increased RE penetration will result in increased requirement of balancing. Currently, the State utilities do not have clarity of framework for balancing, balancing cost and how the balancing cost will be accounted. The current regulatory framework does not have charges related to balancing. In case of higher proportion of RE trade, who undertakes balancing and how the balancing cost will be accounted needs to be clarified.

2.3.3 Improving Transmission capacity and System Operations

Until now, India's transmission grid and system operation has followed the conventional approach of planning for and interacting with only the large generators and demand aggregators (DISCOMs) with well-defined protocols for intervention and grid management. But integrating a large number of small RE generators will necessarily involve ancillary services, technology, investment and solutions from a large array of smaller players, in the form of RE developers and the need to build in very high levels of flexibility in system operations. With no past experience, planning for or interacting with a large number of smaller players, adequate capacity building is required at the transmission planning level.

Further, renewable capacities are concentrated in a few states and therefore it is important to have expanded transmission capacity for accommodating higher RE generation at few locations and its evacuation to load centers. While India has integrated its regional networks, the limitation in inter-regional capacity still results in restriction in demand in some regions/ states. Considering the small gestation period of the RE projects it is important to plan and execute the transmission projects for speedier implementation. Adequate planning and coordination between the various agencies (generation, transmission, system operator, etc.) would be required for overcoming the transmission constraints and derive value for the consumers. Also, implementation of technology and installation of devices for better communication and real time monitoring would be required.

2.4 Key initiatives undertaken in RE integration in India:[8]

The following technical requirements have been identified that are important at all levels for integrating large quantities of RE generation in the Indian grid:

i. Robust transmission services to ensure that RE generation backing down is minimal.
ii. Adherence to Grid Standards and Regulations by RE generators.
iii. Load forecasting at DISCOM, SLDC, RLDC and NLDC levels.
iv. RE generation forecasting at pooling station, groups of Pooling Stations, SLDCs, RLDCs and NLDC levels.
v. Establishment of REMCs at SLDC, RLDC and NLDC level with full real time data availability from RE sources including forecast data.
vi. Need for primary, secondary and tertiary generation reserves

8. Report of technical committee on Large Scale integration of Renewable Energy, Need for Balancing, Deviation Settlement Mechanism

vii. Ancillary Services framework at inter-state and intra state level to operationalize the reserves.

viii. Primary, secondary and tertiary frequency control

ix. Automatic Generation Control (AGC) to implement secondary control on a regional basis.

x. More flexibility from conventional generation fleet comprising coal, gas and hydro.

xi. More flexible resources like pumped storage hydro resources in the country.

Post the issuance of the report of technical committee, a number of steps have already been undertaken by various agencies/ utilities/ authorities/. Some of the steps undertaken are mentioned below:

1. Power System Operation Corporation Limited (POSOCO) has come out with a report on Operational Analysis for Optimization of Hydro Resources & facilitating Renewable Integration in India under which hydro plants have been identified which would contribute to the reliable and secure operation of the grid by means of its inherent flexibility viz. overload capacity, fast ramping and peaking support.
2. Amendment to the Tariff Policy has also been notified by Government of India which mandates implementation of Ancillary Services.
3. Model Regulations has been issued by the Forum of Regulators for adoption by the SERCs:
   a. Model Regulations on Forecasting, Scheduling and Imbalance Settlement for Renewable Energy (RE) generators in November, 2015
   b. Model Regulations for Deviation Settlement Regulations at the State level in March, 2017
4. Few SERCs like Madhya Pradesh and Gujarat have notified regulations for Deviation Settlement Mechanism at the state level
5. Draft Connectivity Standards for Renewables
   a. Provision related to frequency response, HVRT, LVRT, ramping requirements, voltage regulations requirement, compliance monitoring, etc.
6. Upgradation of control centres and dedicated control centre for renewables
7. India is currently piloting flexibility interventions at both the Central level (NTPC) and state level (GSECL).
8. A number of studies are being undertaken to assess the impact of high RE on the power system and number of pilots are being undertaken with help from multilateral agencies to develop alternates for effectively handling large scale integration of RE sources in the grid.

Some of the key discussion points for the congress:

- What are the key interventions to make grid integration effective with least curtailment of renewables?
- How do we see power systems planning and resource adequacy requirements changing in the future with higher levels of RE in the grid?
- What electricity market related changes are essential to enhance reserves and energy sharing across control areas in India?
- Is there a role for battery energy storage systems yet in the Indian grid?
- How effectively can the secondary ancillary market be operationalized in India?
- How do we utilize the existing stranded gas based capacity in the country to improve system flexibility?

3. Importance of Energy Storage System for India

Indian power system is undergoing a phase of transformation with the vision of the GOI for integration of 175 GW of renewables by 2022. Renewable energy is characterized by inherent issues like variability, intermittency & fast ramping etc. Thus, commensurate amount of flexible power reserves are necessary to take care of such variations in demand in coming years. Hence, reliable operation of the synchronous all India Grid in the envisaged RE-rich scenario calls for availability of adequate reserves & flexibility services in the form of conventional storage system like pumped storage hydro plants and non-conventional energy storage system viz. battery storage etc.

3.1 Overview and Types of Energy Storage Technologies

Energy storage is emerging as a viable solution to ensure sustainable grid operations, especially due to the technology improvements

Energy storage is the key component for creating sustainable energy systems. Current technologies, such as solar photovoltaic and wind turbines etc. can generate energy in a sustainable and environmentally friendly manner; yet their intermittent nature poses issues in power quality, dependability and grid stability. The increase in renewable energy generation can cause several issues in power grid. First, in power grid operation, the fluctuation in the output of renewable generation makes system frequency control difficult, and if the frequency deviation becomes too wide system operation can deteriorate. Secondly, renewable energy output is undependable since it is affected by weather conditions. Energy storage technologies have the potential to offset the intermittency problem of renewable energy sources by storing the generated intermittent energy and then making it accessible upon demand.

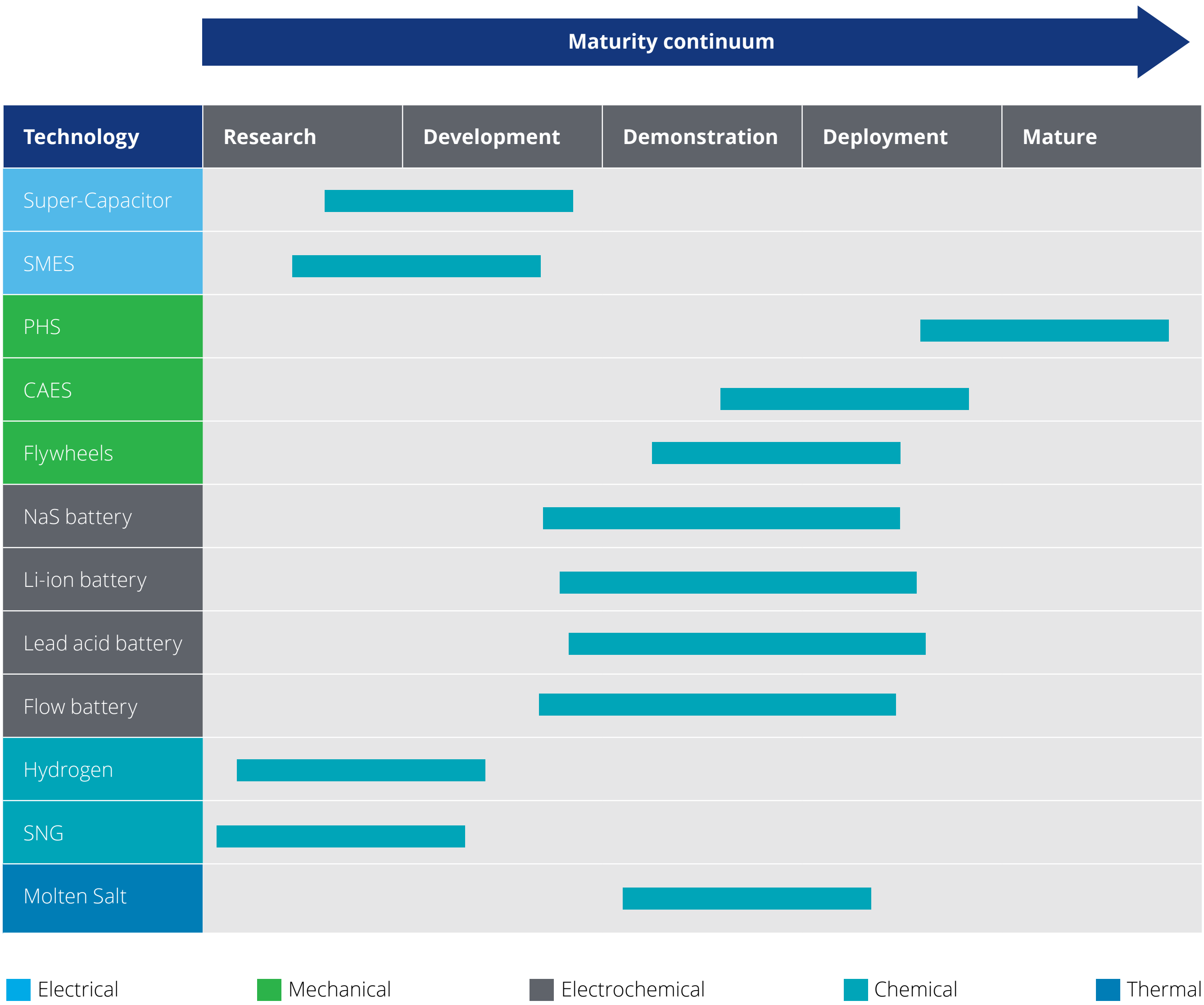
A widely-used approach for classifying EES systems is the determination according to the form of energy used. The figure below compares several storage technologies as per their commercial maturity. Pumped hydro and compressed air energy storage are the most advanced electricity storage technologies (in terms of commercial and technical maturity and deployment); others bring cost and risk premium due to their lower levels of commercial maturity. As technologies move from demonstration and deployment stage to commercialization, the cost of the technology reduces and the technical characteristics are often enhanced. For example, in certain technologies such as Batteries, technical progress to date has seen the overall improvements in efficiency and lifetime of the storage system. The time in which technologies mature is driven by many factors such as market incentives, installation volumes, technical constraints and geographical restrictions.

At present, world over around 1643 energy storage projects have been installed with an accumulated capacity of 193 GW[9]. The vast majority ~ 94% of this capacity is based on pumped storage technology. Others include electro-chemical, electro mechanical, thermal storage etc. There are approximately 1000 electro –chemical (batteries) storage projects that have been installed world over with an overall capacity of 3.4 GW[10]. This is mainly due to falling cost of batteries and improving technology, batteries as a means to store energy is likely to scale up significantly.

9. https://www.energystorageexchange.org/
10. Department of Energy Global Energy Storage Database

In India ~ 16 energy storage projects, using different technological solutions, have been installed of which ~9 are pumped storage projects with an installed capacity of 4.7 GW[11]. Others include electro-chemical which includes 7 projects[12] with an overall capacity of. 125 GW.

Figure 5: Types of Energy Storage Technologies



Source: SBC Energy Institute and Deloitte Centre for Energy Solutions

11. Report on Operational Analysis for Optimization of Hydro Resources & facilitating Renewable Integration in India, June 2017
12. Department of Energy Global Energy Storage Database

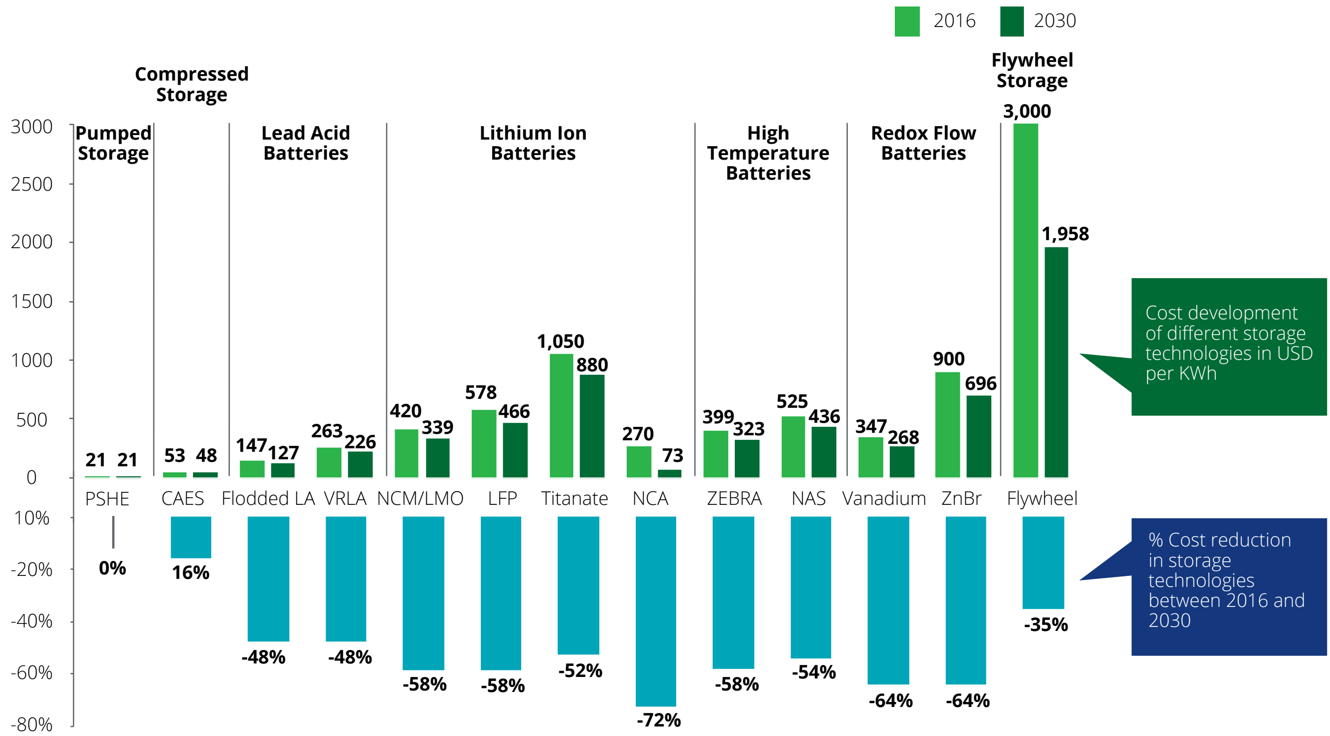
3.2 Economics of Energy Storage Technologies

...and due to expected improvements in economics of the storage solutions over the next few years

Technological improvements are one of the major drivers of falling costs of energy storage system world over. The figure below compares the cost of energy storage across major energy storage technologies – Pumped Storage, Compressed Storage, Lead Acid Batteries, Lithium Ion Batteries, High temperature batteries, Redox flow batteries and Flywheel. The cost of most of the energy storage solutions in today's context is considered expensive. However, for several storage technologies, there is reason to believe that costs will fall as production volumes increase. This belief is supported by historical cost developments such as the one for Lithium-ion batteries. The prices of lithium ion batteries have fallen by 73%[13] between 2010 and 2016 driven mostly by demand form electrical vehicles and improving technology, and are likely to fall by another 72% by 2030, bringing the overall cost of lithium ion batteries down to USD 73-74/KWh[14]. This correlation, between cost and volume of production can be attributed to economies of scale, as well as manufacturing and engineering improvements that are likely to emerge by 2030. Given this trend, the prices of energy storage technologies are likely to fall between 30-60% range[15], depending upon technology under consideration.

Thus, the falling cost of storage and improving technology in terms of life and range clearly can enable greater penetration of wind and solar in the grid, especially for India. However, policy and regulatory mechanisms will be required to facilitate integration of energy storage in the Indian Power System. **A debate is required around how to incentivize capacity market for grid balancing in the interim period, while continuously promoting Energy Storage as a long term solution for Grid Integration.**

Figure 6: Cost Comparison of Various Storage Technologies



Source: IRENA, Battery University and BNEF

13. BSCE 2017 Factbook, p. 148
14. Bloomberg New Energy Finance
15. IRENA Presentation titled: Battery storage technology improvements and cost reductions to 2030: A Deep Dive

3.3 Applications of Energy Storage

Energy storage can play a significant role in meeting challenges of intermittency by improving the operating capabilities of the grid, lowering power purchase cost and ensuring high reliability by maintaining unscheduled interchange as well as deferring and reducing infrastructure investments in new projects. The Energy Storage System (ESS) has a wide range of applications which can be deployed from consumer level, connected to distribution system, to bulk storage system connected to the grid. Moreover, a move towards an energy storage market will also help in reducing the need for major augmentation of new transmission infrastructure and balancing reserves.

Some of the applications of energy storage system are:

- **Optimize Generation:** Energy storage solutions will provide generating companies with an option to shift their output from one time to another. This will be particularly useful for Renewable Energy developers as they will have the flexibility to store electricity generated during the day time and use the same power to supply electricity during time of no wind or solar.
- **Reliable Operation of Power System Operation:** Energy storage can also be used as a storage facility to store generation output to maintain flow of power over tie-line. This will be particularly useful to address the congestion in the transmission system and for reliable operation of the transmission system. It also helps to maintain area control error by managing unscheduled interchange transfer within the regulatory limit.
- **Seasonal storage:** Storage of energy for longer time periods (e.g. months) to compensate for seasonal variability on the supply or demand side of the power system. The reservoirs of conventional hydro stations are often used in this way.

Figure 7: Potential Application and Locations of Energy Storage

Some of the potential application of energy storage

Grid Services

- Enhanced Frequency Response
- Frequency Containment Response
- Frequency Restoration Response
- Energy Shifting

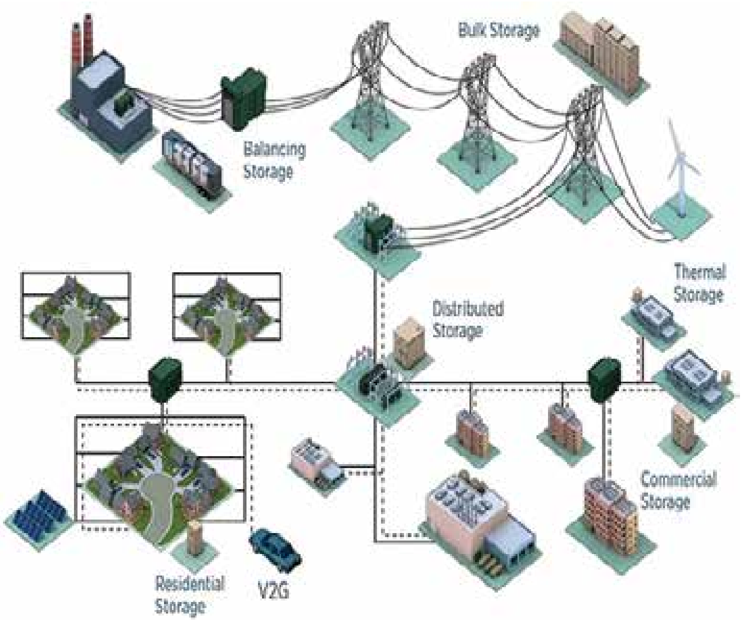
Behind the Meter

- Solar Self Consumption
- Community Storage
- Increased Power Quality
- Peak Shaving

Off-Grid

- Nano Grid
- Village Electrification
- Solar PV (roof-top)

Potential locations of energy storage



Source: IRENA

- **Frequency regulation:** The operator of the power system continuously has to keep the balance between supply and demand, in order to regulate the frequency of the system (nominally 49 - 50 Hz). Suitable technologies for such application are batteries with fast response, and flywheels.
- **Asset Optimization:** Generally, power plants are used for providing power and grid stabilization services. However, while providing grid stabilization services these plants more often operate at sub-optimal or inefficient way which is cost ineffective. Coupling power plants with energy storage solution, especially batteries, will enables the conventional generation plant to react quicker and more effectively to grid operator needs.
- **Balancing market:** Balancing refers to the situation after power markets have closed in which a grid operator acts to ensure that demand is equal to supply, in and near real time. This situation occurs at the sub fifteen-minute timescale. Because of this, energy storage is particularly well suited for load following due to the technology's fast ramping capability. Traditional thermal power plants providing this service often have sufficient capacity for load following, but they cannot ramp up or down nearly as fast as energy storage system providing the same service. Furthermore, energy storage is a very capable mid-merit generation facility since its output can be adjusted throughout the day to respond to load and demand fluctuations with no penalty to efficiency.
- **Peak shaving:** Commercial and residential customers can reduce power draw from the grid during specific time periods in order to reduce the demand charge component of the electricity bills. Depending on the utility and country, demand charges are set based on the highest 15- minute demand period of the month
- **Secondary reserve:** Secondary reserve is power generating capacity available to the grid operator within a short interval of time to meet demand in case a disruption of supply or an unexpected grid situation. Reserves require a storage device to maintain a minimum discharge duration to meet hourly commitments in case of a contingency event. Since these events are infrequent, energy storage devices can provide reserve capacity while simultaneously providing several other services, so long as they maintain a certain charge level. This makes energy storage a ripe technology for provision of this particular service.

- **Increase PV-self consumption:** Batteries are the primary method being used by households (and increasingly commercial customers) today to maximize solar self-consumption and become grid independent. Energy storage technology allows customers to shift as much of a load under a solar production curve as possible, dramatically increasing the value generated by a customer under either of these proposed rate structures.
- **T&D deferral:** Batteries can delay or entirely avoid utility investments in transmission and distribution system upgrades that are necessary to meet load and supply growth on specific regions of the grid. When peak demand at a transmission or distribution node is at or near its rated load-carrying capacity and load growth forecasts indicate that the system may soon be overloaded, utilities invest in system upgrades to meet the forecasted load growth. These upgrades are normally driven by a small number of peak hours throughout the year that cause load to exceed the system capacity of certain equipment. Instead of investing a large, lump sum to upgrade a transmission- or distribution-level substation, utilities can defer or completely avoid this investment by installing batteries.

3.4 Hydropower – a source of flexibility and reliability

The need for flexibility services for integrated & reliable operation of electricity grid is well established & it is imperative, especially from the perspective of renewable energy (RE) integration. Among conventional sources, hydro-electricity is a source of reliable and flexible energy. Despite its seasonal nature, the flexibility rendered by hydro generators has immense value for the system operators. Apart from being a source of low cost energy it has, over the years contributed to the reliable & secure operation of the grid by means of its inherent flexibility viz. overload capacity, fast ramping & peaking support etc. Its ability to run as a synchronous condenser has significantly helped in managing reactive power imbalance & controlling voltage excursions thereby ensuring power quality & voltage stability. Further, the hydro power stations with black start capability have proven as one of the most reliable resources for fast system recovery after a grid disturbance or blackout.

India is endowed with rich hydropower potential of about 150 GW out of which 44.6 GW (30%) potential has been tapped. Out of this 44.6 GW of the installed capacity, 27 GW belongs to the state sector, 3 GW is with the private sector and around 15 GW lies with the central sector power utilities. However, the capacity harnessed for peaking is of the order of 30-32 GW.[16] One of the reasons behind such inadequate response could be lack of adequate incentive schemes & market mechanisms to value the flexibility rendered by the hydro power stations which are classically multipurpose projects in India. Further, a considerable number of hydro stations are having a single part tariff structure that recovers the cost based on design energy.

3.4.1 Pumped Storage Capacity in India:

Pumped storage hydro plants are one of the most deployed grid level conventional energy storage devices which can provide active and reactive energy to cater to the flexibility requirement of the grid. These are considered as one of the most flexible generators. They render a number of flexibility services such as managing demand & generation variability, imbalances & deviation in real time operation, congestion management, replacing high-cost peak energy with stored energy, optimum utilization of water resources etc.

At present out of the 44.6 GW installed hydro generating capacity, 4785 MW is designed and capable of operation as pumped storage units. However, due to various reasons only 2450 MW of PSP capacity is presently under operation in SR, WR and ER of the country.[17]

Table - 2: Pumped Storage Capacity (>=25 MW) as on 30.03.2017

S.No	Station	Capacity (MW)	State	Region	Present Operational Status	Remarks
1	Ghatghar	2x125	Maharashtra	WR	Operational	
2	Bhira	1x150	Maharashtra	WR	Non-operational	Reservoir constraints & tariff issues
3	Kadana	4 x 60	Gujarat	WR	Non-operational	Turbine vibration
4	Sardar Sarovar (RBPH)	6 x 200	Gujarat	WR	N/A	Dam under construction
5	Purulia	4 x 225	West Bengal	ER	Operational	
6	Panchet Hill	1 x 40	DVC	ER	Non-operational	Tail Pool dam yet to be constructed
7	Srisailam Left Bank	6 x 150	Telangana	SR	Operational	
8	Kadamparai	4 x 100	Tamil Nadu	SR	Operational	
9	Nagarjuna Sagar	7 * 100.8	Telangana	SR	Non-Operational	Tail Pool dam yet to be constructed
	Total (MW)	**4785.6**				

Source: Report on Operational Analysis for Optimization of Hydro Resources & facilitating Renewable Integration in India, June 2017

16. Report on Operational Analysis for Optimization of Hydro Resources & facilitating Renewable Integration in India, June 2017, page 25
17. Report on Operational Analysis for Optimization of Hydro Resources & facilitating Renewable Integration in India, June 2017, page 115

The 2x125 MW Ghatghar PSP is owned by Water Resources dept. (WRD), Govt. of Maharashtra. It has been given on long term lease to MSPGCL (Maharashtra State Power Generation Co Ltd.) who is responsible for its operation and maintenance (O&M). Each 125 MW unit absorbs 150 MW during pumping & generates 125 MW as a generator. Under normal conditions, it operates for 7 hours pumping mode during off peak hours and for 6 hours during peak in generation mode as instructed by SLDC Maharashtra. On Sundays the units are operated in pumping mode as per instructions of system operator i.e. SLDC.

The units are capable to reach full load (125 MW each) in generation mode within 3 minutes and in pumping mode (150 MW) within 5 minutes. Ghatghar PSP Maharashtra State Electricity Distribution Company Ltd. supplies pumping energy to during off-peak & Ghatghar (MSPGCL) supplies power to MSEDCL during peak. The energy accounting occurs in the form of a barter arrangement between MSPGCL & MSEDCL where in MSEDCL does not raise any bill for energy consumed by Ghatghar PSP & MSPGCL does not raise any bill for energy consumed by Ghatghar PSP to MSEDCL. Only operation and maintenance and lease rent charges are payable to MSPGCL. It is purely hydro-electric project used for power generation & pumping with no obligation towards irrigation water supply requirement.

3.4.2 Issues and Challenges with existing pumped storage hydro stations

Following are some of the issues and challenges that utilities come across in running the pumped storage units:

- Pumped Storage hydro power stations (PSP) involve generator-motor/pump-turbine combination and thus are more complex than normal hydro power stations.
- Operational viability of a PSP counts on availability of low cost off-peak energy
- Lower cycle efficiency (~66-78%) on account of hydraulic losses in the water conductor system & losses in motor, pump, generator turbine etc. need to be factored in the tariff regulations.
- Older units have lower efficiency. Hence vintage based norms are required
- Efficiency is dependent on design specific parameters for power station like length of the water conductor system, head levels of the upper and lower reservoir and optimum operating range of the electro-mechanical equipment.
- Complex equipment's are deployed compared to conventional hydro turbines.
- Relaxation in Availability Norms for full recovery of annual fixed cost may be considered.
- Incentive may be considered for PSP for attaining higher than normative availability
- Higher normative auxiliary consumption may be allowed, since pumped storage hydro units operate for more than double the duration of conventional hydro units.
- More wear and tear and operating expenditure occurs due to extended operation hours. Typical equipment operation hours are more than double that a conventional hydro unit.
- Higher operation and maintenance cost is incurred – due to frequent start-stop of PSP units for their load following & quick start capabilities for which these hydro units frequently operate in rough zones & at variable pumping heads.
- More wear and tear may require more outage hours for maintenance.

Conclusion:

The integration of renewable energy into the electric power system can cause problems of output fluctuations and unpredictability. This means that the future energy supply or electricity production (to some extent) will be influenced by weather conditions and the deficit in demand and supply of energy will need to be balanced. Energy storage can thus play an important role in matching demand and supply of energy as also in grid stability (from addressing power quality to providing energy arbitrage or seasonal storage). The current grid uses pumped hydro to some extent for the purpose of time shifting. While the use of pumped storage hydro plants can be extended for multiple other applications (such as time shifting, peak shaving, integration of variable power in the grid etc.) - as they have the ability to ramp-up and down (for longer time periods) within a matter of 10 min - its application and adoption will be limited to geographically appropriate sites. Batteries on the other hand offer another means of grid level energy storage by converting electricity to chemical energy during times when electrical supply exceeds demand. Unlike pumped storage, batteries storage system is feasible for any geographical location and can be used to balance the grid for a minute to second time scale among other applications. For a country like India, where electricity is a concurrent subject and where grid stability within the boundaries of the state lies with the state, combination of energy storage system options can enable smooth integration of renewables in the grid at an effective cost.

Some of the key discussion points for the congress:

- Who will own the energy storage systems – Transmission licensee, Distribution licensee or Generating Company etc. or should there be multi stakeholder ownership?
- There is a need to discuss whether the owner of the storage system have the right to take title of stored energy or energy stored in the storage facility is legally owned by others?
- How is electricity storage envisaged to develop in India as a grid energy service?
- What would be the pricing mechanism for storage facility – would it be time based pricing or volume based pricing?
- What are the policy and regulatory framework required to jump start battery storage market in India?
- What policy, regulatory and commercial measures are required to bring Pumped Storage Hydro Stations under the ambit of ancillary services?
- Is there a need to have a re-look at the hydro power tariff structure to factor in the value of hydropower on the basis of flexibility rendered by these power stations?

4. Electric vehicle and its importance for power sector/RE integration

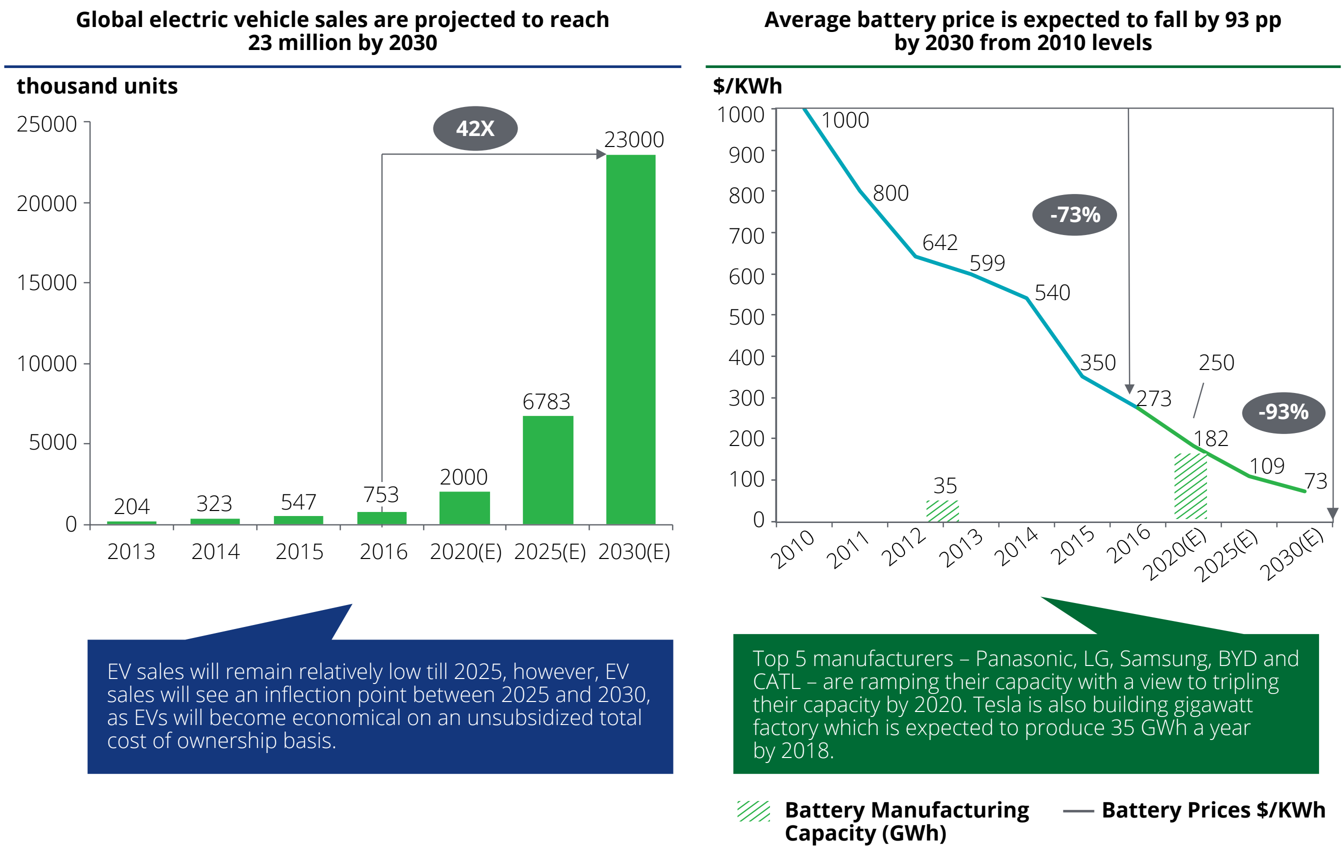
4.1 Global Scenario

Electric Vehicles sales have risen and battery prices have fallen. By 2030, the global EV sales are forecasted to increase by 42x and battery prices are expected to fall by ~14x:

Global electric vehicle (EV) sales have risen quickly over the past five years, fueled by generous purchase subsidies, falling battery costs, fuel economy regulations, growing commitments from car companies, and rising interest from consumers. Sales rose 2.68 times in 2015 alone to nearly 547,000 units up from 204,000 units in 2013 (figure below)[18]. Most of these sales have come from developed countries such as United States, Europe among others, but over the past few years China has emerged as an important country where adoption of EVs has significantly ramped up. In most markets, though, EVs still represent fewer than 1 percent of total vehicles sold, but pockets of much higher penetration exist – including Norway, where electric vehicles represent more than a quarter of new vehicle sales.

Falling battery prices, improving battery range and battery chemistry are the biggest drivers of EV across jurisdictions. Between 2010 and 2016, the average price of lithium ion battery pack has fallen from USD 1000 per KWh to under USD 273 per KWh[19], a decrease of 73 percentage points during the same period. This trend of falling battery prices over the next decade is likely to continue as battery manufacturers across the world are ramping their capacity with a view to tripling their capacity by 2020. This coupled with improving battery management system and technology will further reduce battery pack prices. Going

Figure 8: Global EV Sales Projections and Average Battery Prices



Note: Global Electric Vehicle Sales projection does not take into account the new Indian scenario of achieving 100% vehicle electrification sale by 2030
Source: IEA, EV Outlook 2017 and BNEF

18. Global EV Outlook 2017, IEA, Clean Energy Ministerial and Electric Vehicles Initiative
19. Lithium-ion Battery Costs and Market, Bloomberg New Energy Finance

forward, by 2030, the battery prices are expected to drop further in the next decade and could possibly fall as low as USD 73 per KWh.

These changes, both technological and costs, will make private EVs competitive with comparable internal combustion engine (ICE), thereby increasing the adoption of EVs world over. By 2030, the annual global EVs sales are expected to touch 23 million units[20] (this projection does not take into account the new Indian scenario of achieving 100% vehicle electrification sale).

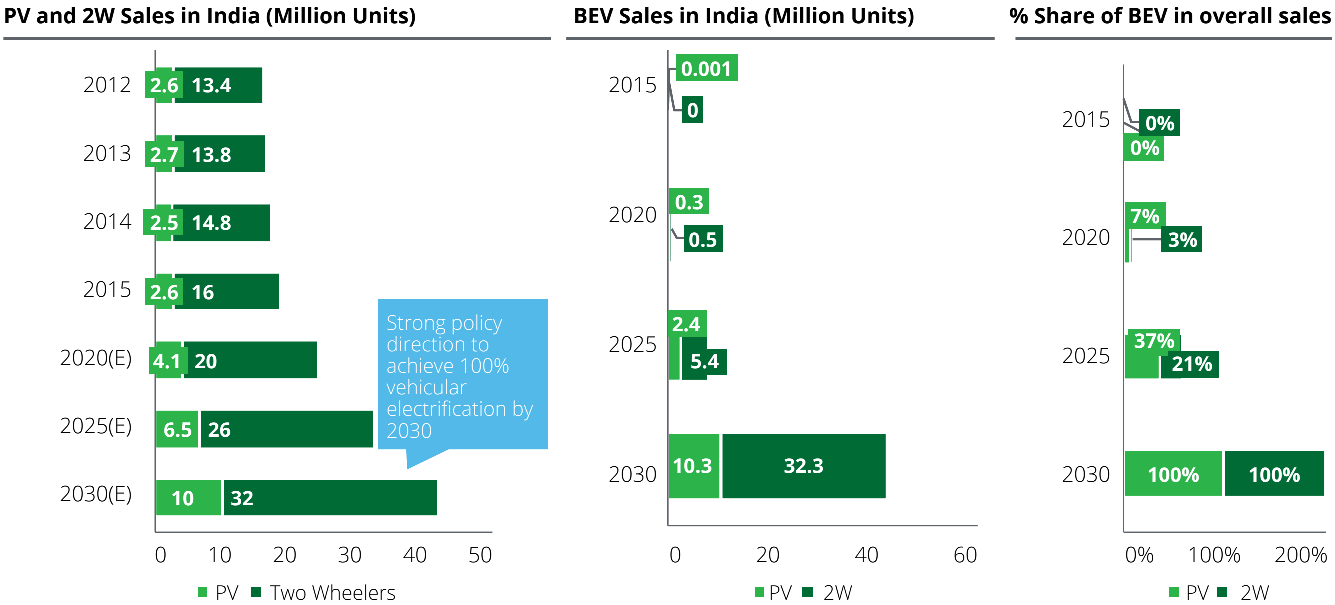
4.2 Indian Scenario

In India, the BEV Sales is projected to grow exponentially, given the new policy direction by the Govt. to achieve 100% vehicle sale electrification by 2030

The Government of India recognizes the urgency to look at sustainable mobility solutions to reduce dependency on imported energy sources, reduce GHG emissions and mitigate adverse impacts from transportation. In order to achieve these objectives, the Government has announced an aspirational goal of moving towards 100 percent electrification of passenger vehicles in India by 2030. Keeping the new policy directive in mind, the figure below projects the number of electric vehicle sales in the country by 2030.

Between 2000 and 2015, the sale of cars and two wheelers in the country has increased at an annualized rate of 10%. For the purpose of this exercise we have assumed that the sale of vehicles in India will continue to grow at historical rate of 10%. Thus, the annual sale of passenger vehicles and two wheelers in India will reach ~32 million and ~10 million respectively[21]. Given the new policy direction of 100% vehicle sale electrification, it has been assumed that all vehicles sold in India by 2030 will use battery technology.

Figure 9: EV Sales - Indian Scenario



Key Points	
	• Between 2000 and 2015, car and two-wheeler sales have more than quadrupled, indicating a compound annual growth rate (CAGR) of 10%. During the same period, the number of registered vehicles quadrupled as well. • To achieve the 100% vehicle sales electrification goals, two-wheeler BEV sales must increase from about 2,000 in 2015 to about 32 million in 2030, and BEV car sales must increase from about 20,000 in 2015 to about 10 million in 2030.

Source: LBNL (Techno-Economic Assessment of Deep Electrification of Passenger Vehicles in India)

20. EV Outlook, Bloomberg New Energy Finance
21. Techno-Economic Assessment of Deep Electrification of Passenger Vehicles in India

4.3 Electric Vehicles Impact on Power Sector

This shift to 100% electrification of vehicles will have a knock on effect on the power system:

The electrification of vehicles at global and local level will blur boundaries that exists today between and within sectors. This increasing trend of moving towards electrification will not only impact automobile sector but will also have a knock on effect on the energy sector. In this section we aim to discuss the impact of electrification of vehicles on the power system. In order to fully understand the impact in the Indian context, we have made certain high level assumption which includes achieving 100 percent vehicle electrification sale by 2030, vehicular KM travelled and growth of the automobile sector till 2030. These numbers have not been fully reflected in the global context, given the scale effect.

Electric vehicles will have a limited impact on the power system during the initial years, but it is likely to rise thereafter. The figure below identifies four areas where EV will impact the power system.

First, by 2030, even if we assume 100 percent vehicle electrification the EV would represent just 3-4% of the overall electricity demand in the country. However, depending upon the usage pattern higher share of EVs can have a sizable impact on demand during certain time of the day.

Figure 10: Impact of EV on Power System

	Impact of increasing EV Penetration on power system			key considerations
A	**Increase in demand of electricity and peak load demand**	• Additional load added from BEV in 2030 will range between 70-111 TWh/yr. • Peak BEV charging load will be ~23 GW, approx. 6% of the peak load by 2030 • EVS may represent 3-4% of the electricity demand by 2030	1	**Depending upon usage pattern, higher share of EVs can have a sizeable impact on electricity demand at certain time of the day**
B	**Reconditioned batteries will be used for grid and off-grid applications**	• Second life batteries can be used for stationary application in Off Grid, Commercial & Industrial, Utilities and Residential sectors	2	**Cost of repurposing used batteries will play a major role in utilizing second life batteries, but will require suitable business model and policy support**
C	**Additional revenue source for Utilities**	• The addition of BEV in the system will be an incremental source of revenue for utilities • Assuming marginal electricity tariff of INR 8/KWh, the incremental revenue for supplying power to BEV could earn ~89,000 Cr/yr	3	**Migration of consumers to off-grid application can neutralize the positive aspects of additional demand from EVs**
D	**Falling cost of battery storage will enable faster RE integration**	• EV batteries can store excess electricity and can provide ancillary services to the grid, such as frequency regulation, shaving peak demand and power support to enhance the operation, and reserve capacity to secure the grid. • Batteries can be integrated with RE stations to smooth the ramping of output to the grid	4	**What will be the operating framework for storage services?**

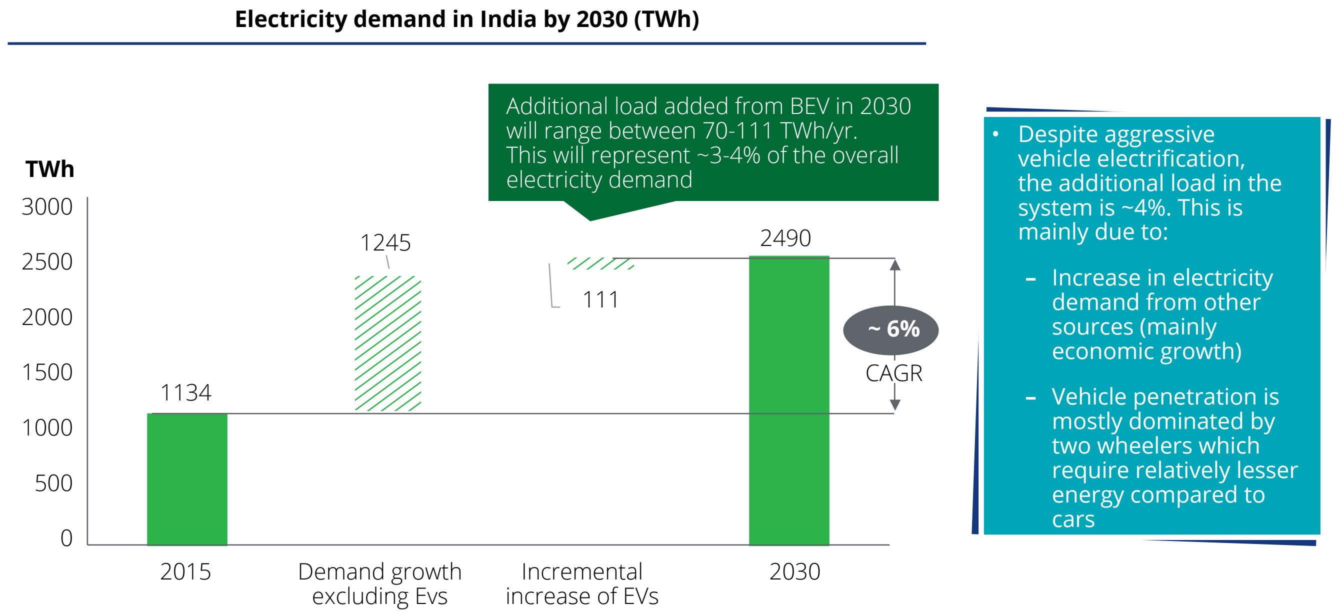
Second, by 2030 the number of second life batteries will increase significantly which can be used for various stationary applications grid, off-grid, balancing etc. Third, increase in electricity demand by EVs will serve as an additional revenue source for the Utilities. And finally, higher penetration of EV will result in lower battery prices thereby enabling faster RE integration.

A. EV may represent 3-4% of the electricity demand by 2030, if uptake of EV can accelerate to achieve 100% vehicle electrification

Despite aggressive electrification of vehicles by 2030, the incremental demand from EV will be in the range of 3-4% of the overall demand in the country. This is mainly because of two reason. First, most of the vehicular electrification will be dominated by two wheelers which requires relatively lesser energy as compared to passenger vehicles. In order to estimate the electricity demand from two wheelers and passenger vehicles, it has been assumed that for each KWh passenger vehicles can travel for 7 Km and two wheelers can travel for 31 KM. Secondly, the demand for electricity from other sources, mainly on account of economic growth, will be much higher thereby doubling the electricity demand between 2015-2030.

While incremental electricity demand from EVs is in the range of 3-4%, it may have significant impact on peak demand during certain time of the day. Thus, in order to minimize the impact of incremental load on the grid, **there is a need to discuss measures required to shift Electric Vehicles load to minimize the costs and impact on the grid.**

Figure 11: Incremental Electricity Demand from EV



Assumptions:

- Total BEV stock for cars and two wheelers will be 39 and 49 Million units in 2030.
- Average vehicular kilometer travelled has been estimated to be ~ 12,800 KM/yr for two wheeler and 12,200 Km/yr for passenger vehicles (4W) by 2030
- A single KWh of electricity is enough to power a passenger vehicle for 7 KM and 31 Km for two wheelers. However, under a high efficiency scenario the numbers of KM travelled per KWh will be 12 Km and 43 KM respectively.

Source: National Electricity Plan, Techno Economic Assessment of Deep Electrification of PV in India, LBNL, team analysis

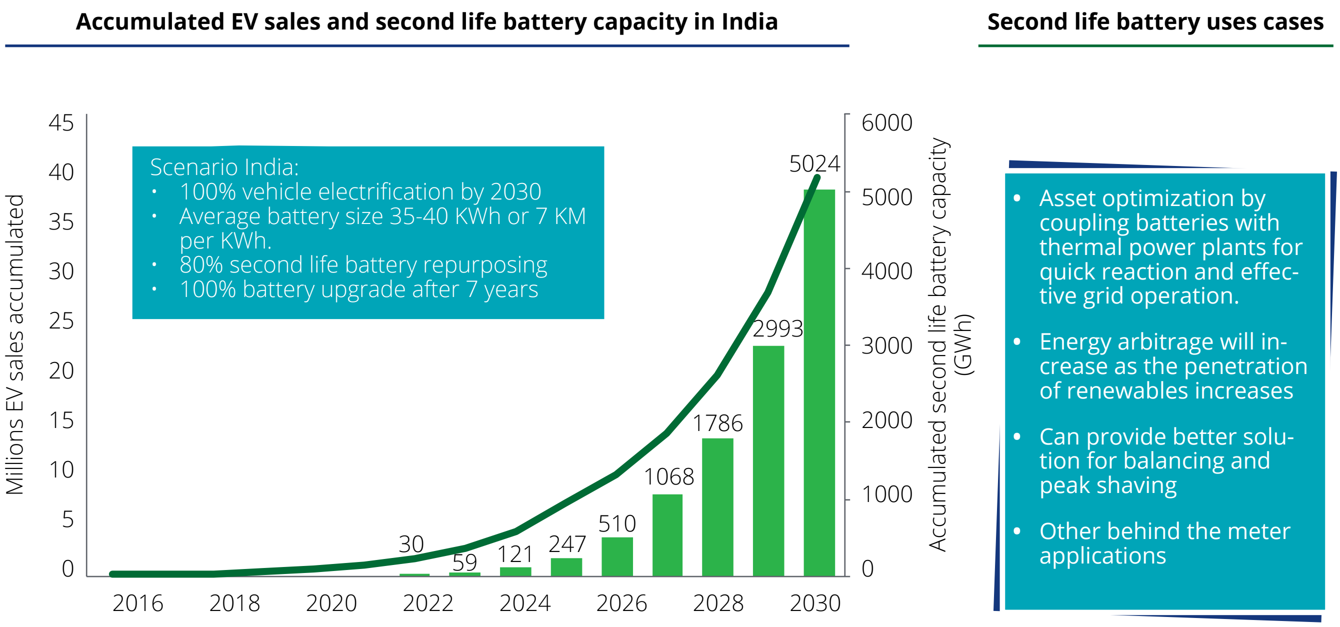
B. By 2030 a large quantity of used EV batteries will become available for stationary applications:

As electric vehicle sales increase, the number of batteries that will become available for a second life usage will increase. Though it is difficult to predict the exact size of the second life battery, the market is expected to grow from 247 GWh in 2025 to over 5024 GWh by 2030. The growth of second life batteries will be strongly influenced by four factors: sales of EVs; average and type of battery; customer's behavior on battery upgrade; and percentage of second life batteries coming to the market.

For these factors we are assuming realistic values based on certain assumption as per figure below. These batteries can be used for a second life applications in the stationary sector such as asset optimization, balancing reserves, behind the meter applications etc.

But, in order to kick start the second life battery market and to ensure investments in the segment, **there is a need to discuss regulatory barriers for second life batteries, if they exist in the current framework and the suggested business models.**

Figure 12: Projected Second Life Batteries Capacity (GWh)



> "Another very interesting option is the secondary use of retired batteries from electric vehicles for building GW scale energy storage to support the grid with increasing share of renewable".. Live Mint 6 April 2017

Source: Techno Economic Assessment of Deep Electrification of PV in India, LBNL, team analysis

C. BEV charging load can provide additional revenue for Utilities, while flexible charging can enable faster RE integration

Although the additional load due to BEV charging is minor, it could still provide a valuable additional revenue source for the financially distressed distribution utilities, as shown in figure below. Assuming a marginal electricity tariff (average) of Rs 6/kWh between 2020 and 2025, the additional revenue to utilities from BEV load will increase from 800 Cr to over ~10,000 Cr. Moreover, assuming a marginal electricity tariff of Rs 8/KWh by 2030, BEV charging load could generate about Rs 90,000 Cr/yr of additional revenue for utilities.

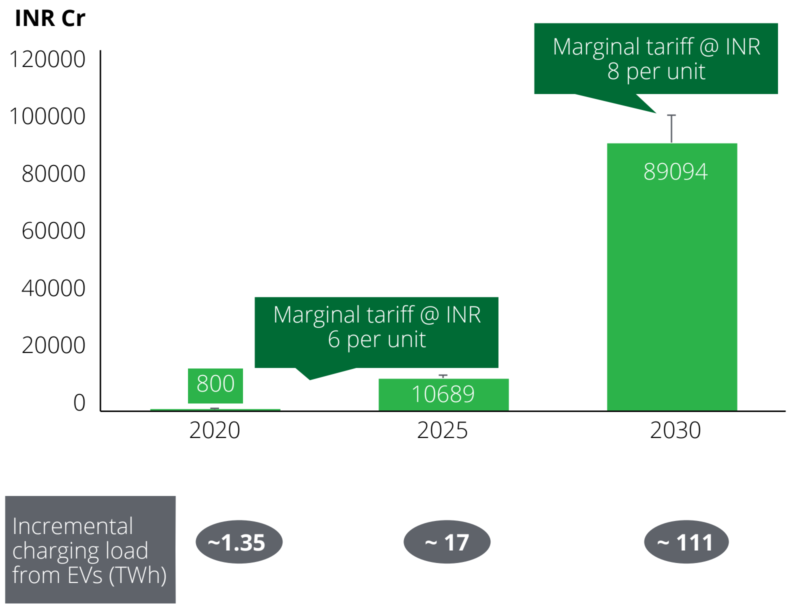
In addition to additional revenue from BEV charging, the increase in EV sale also offer business opportunity for utilities to provide operating charging infrastructure. However, the extent and composition of public charging infrastructure needed is still unclear and will likely remain so until there is more certainty on average vehicle range.

Key discussion points for the congress:

- What policy and regulatory framework are required to promote adoption of EV batteries for grid-support applications?
- To what extent investments should be promoted to create charging infrastructure, given the specific policy objectives of the Government?
- How to discriminate between fast and slow charging infrastructure and whether to have a time based as against KWh based rates as an option
- How do we discriminate EV charging networks from individual charging stations and whether to incentivize charging networks for additional services they offer?

Figure 13: Impact of EV's on Utilities

Incremental charging load from BEV can provide additional revenue for utilities



EVs can be used to enable higher share of variable RE in the power system by

- Actively using the mobile battery storage system in the vehicle in V2G applications
- Use second life batteries in a second life role as stationary battery storage system
- Widespread use of charging technologies and infrastructure
- Modifying customer behavior by using smart or flexible charging
- Provision of other ancillary services from EVs to the grid. This can happen by making use of EV batteries to store excess electricity and provide ancillary services to the grid.

Source: Team Analysis

References

1. Bloomberg New Energy Finance, EV outlook
2. Global Electric Vehicles Market
3. Techno-Economic Assessment of Deep Electrification of Passenger Vehicles in India, LBNL
4. Market Models for the Roll Out of Electric Vehicle Public Charging Infrastructure, concept paper
5. Revolutionizing fast charging infrastructure, ABB
6. From Gas to Grid, Building fast charging infrastructure to power electric vehicle demand, RMI institute
7. Global EV Outlook, 2017
8. Electric Vehicles Technology Brief, IRENA
9. BNEF Lithium ion battery costs and market
10. CERC Staff Paper on Introduction of Electricity Storage System in India
11. Battery Storage technology improvements and cost reductions to 2030: Deep Dives, IRENA
12. The role of energy storage with Renewable Electricity Generation, NREL
13. Technology Roadmap, Energy Storage IEA
14. Report on Operational Analysis for Optimization of Hydro Resources & facilitating Renewable Integration in India, June 2017
15. Renewable Energy Integration- Transmission an Enabler (PGCIL Report)
16. Report on Forecasting, Concept of Renewable Energy Management Centers and Grid Balancing (GiZ Report)

Deloitte.