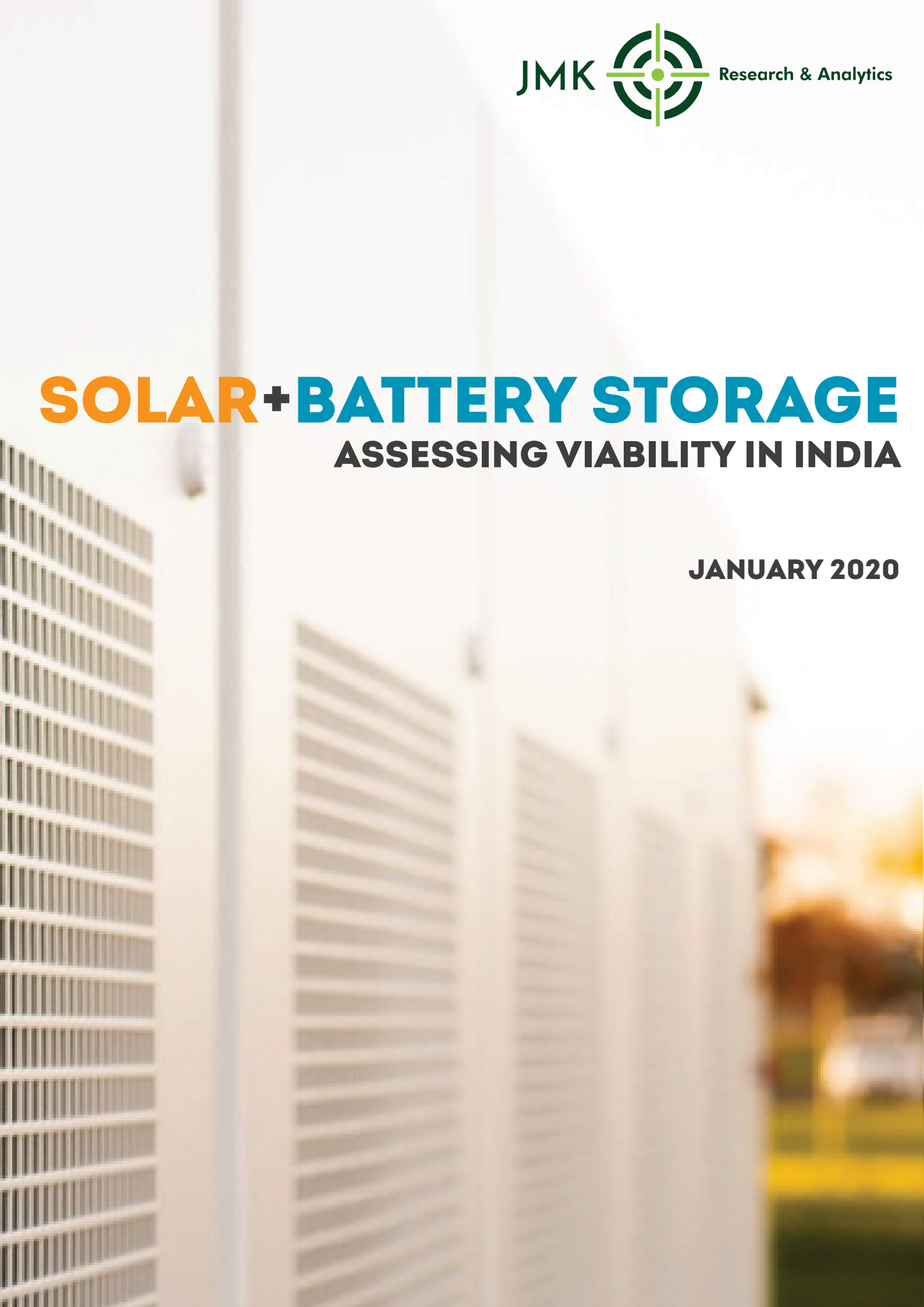
JMK Research & Analytics

SOLAR+BATTERY STORAGE

ASSESSING VIABILITY IN INDIA

JANUARY 2020



ReneSola

BRINGING SOLAR POWER TO THE WORLD

Regional Office
1604, Regus, Tower -B, World Trade Tower
Sector -16, Noida -201301, UP (INDIA)
manoj.tanwar@renesola.com I +91- 120 682 9475

WWW.RENESOLA.COM

WAAREE BATTERIES™

HIGH PERFORMANCE LITHIUM-ION RANGE

2000*+
LIFE CYCLE
★★★★★

EXCLUSIVE FEATURES:

- High Energy Density
- Lightweight & Compact Size
- Fast and Efficient Charging
- Long Storage Life
- High Temperature Performance

** Images of product are for representative purpose only and actual product may differ from the images depicted.

waaree@waaree.com
1800-2121-321

About JMK Research & Analytics

JMK Research & Analytics is a boutique consultancy for all kinds of research and advisory services for Indian and international clients focusing on Renewables, Electric mobility and storage markets. We employ our interdisciplinary team, strong industry network, existing databases as well as vast project experience in the Indian power sector to create substantive business value for our clients. Our subscribers include, equipment suppliers, investment agencies, multi-lateral and bilateral agencies, project developers, government authorities.

Authors

Jyoti Gulia

Jyoti is a renewable energy enthusiast with expertise in policy and regulatory advocacy, opportunity assessment studies, and competitor analysis. Her professional career spans leading market research companies such as Bridge To India, Tecnova, Infraline and CRISIL. She holds Masters in Business Administration from FORE School of Management, Delhi and a Bachelors in Engineering from Indira Gandhi Institute of Technology, Delhi.

Shilpi Jain

Shilpi is a power sector expert with extensive experience in Business strategy, Business Development, Risk Assessment and Management, Project Appraisal, Finance, Mergers & Acquisitions with leading companies such as IL&FS, Lanco, MoserBaer and Laymeyer Group. She completed her Masters in Power Management from NPTI, Faridabad and Bachelors in Engineering from College of Engineering, Roorkee.

JMK Research & Analytics

27/ 2C, Palam Vihar, Gurugram, Haryana- 122017
7428306655
www.jmkresearch.com

Glossary

APPC	Average Power Purchase Cost
BESS	Battery Energy Storage System
BHEL	Bharat Heavy Electricals Ltd.
C&I	Corporate and Industrial
CAPEX	Capital Expenditure model under which a consumer pays for installation costs
CEA	Central Electricity Authority
CERC	Central Electricity Regulatory Commission
COP 21	Conference of Parties, the 2015 United Nations Climate Change Conference
CSS	Cross subsidy surcharge
DHBVN	Dakshin Haryana Bijli Vitaran Nigam
DISCOM	Distribution companies
EOI	Expression of Interest
EPC	Engineering Procurement and Construction
EV	Electric Vehicles
FGD	Flue-gas desulfurization is a set of technologies used to remove sulfur dioxide (SO2)from exhaust flue gases of fossil-fuel power plants
LCOE	Levelized Cost of Energy
Li-ion	Lithium ion
MNRE	Ministry of New and Renewable Energy
MPPMCL	Madhya Pradesh Power Management Company limited
NREL	National Renewable Energy Laboratory
NTPC	National Thermal Power Corporation
O&M	Operation and Maintenance
OPEX	This is an operating expenditure-based model in which an investor invests the upfront capital cost of the project and the consumer pays for the electricity consumed/supplied by the project developer
REIL	Rajasthan Electronics & Instruments Limited
SECI	Solar Energy Corporation of India
SPV	Solar Photo Voltaic
T&D	Transmission and Distribution
TPDDL	Tata Power Delhi Distribution Ltd.
UDAY	Ujjwal DISCOM Assurance Yojana
UHBVN	Uttar Haryana Bijli Vitaran Nigam
VGF	Viability gap funding
VRE	Variable renewable energy
WWSIS	Western Wind and Solar Integration Study

JMK Research & Analytics

Contents

1. Introduction

At COP 21, the Paris Climate Conference 2015, India made a commitment that by the year 2030, India would increase the share of electricity generated from non-fossil fuels to about 40% of its total generation. To meet the commitment a major transformation is underway to replace thermal based generation with Renewable Energy (RE) complimented with energy storage technology.

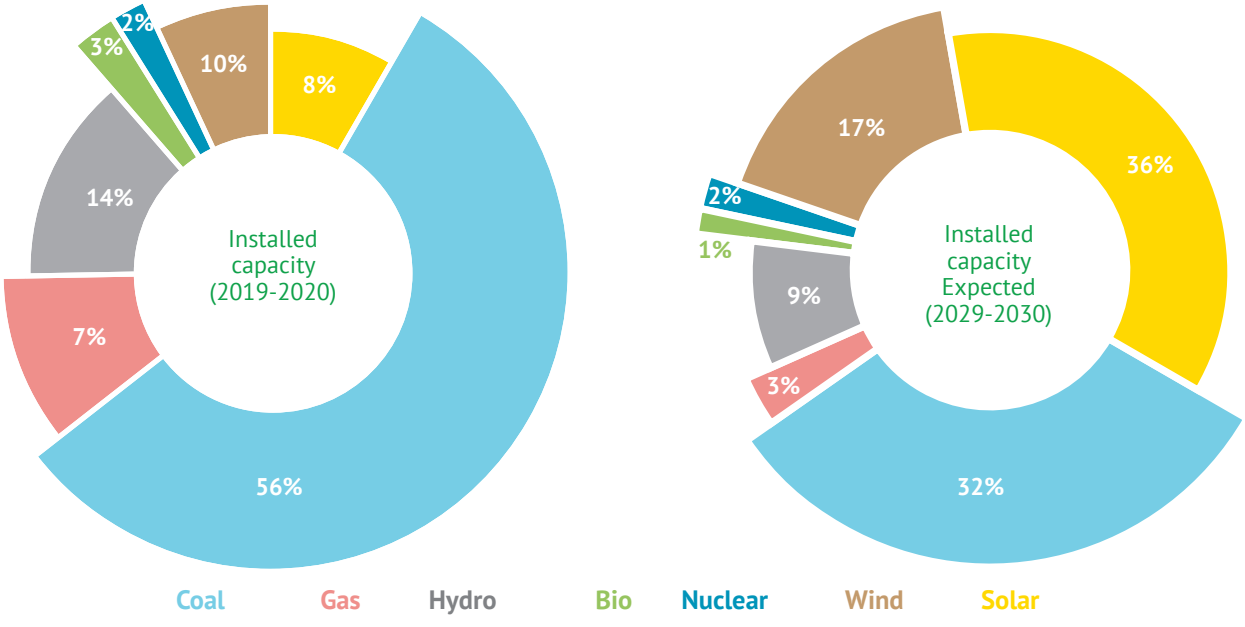
As on March 31, 2019, the total installed capacity stood at 361.5 GW which constituted 228 GW from thermal, 7 GW from nuclear, 127 GW from renewable energy (including 50 GW from hydro).

The detailed fuel wise breakup of the total installed capacity as on March 31, 2019 and the energy contribution from different sources during 2018-19 is depicted in figure 1.1 below.

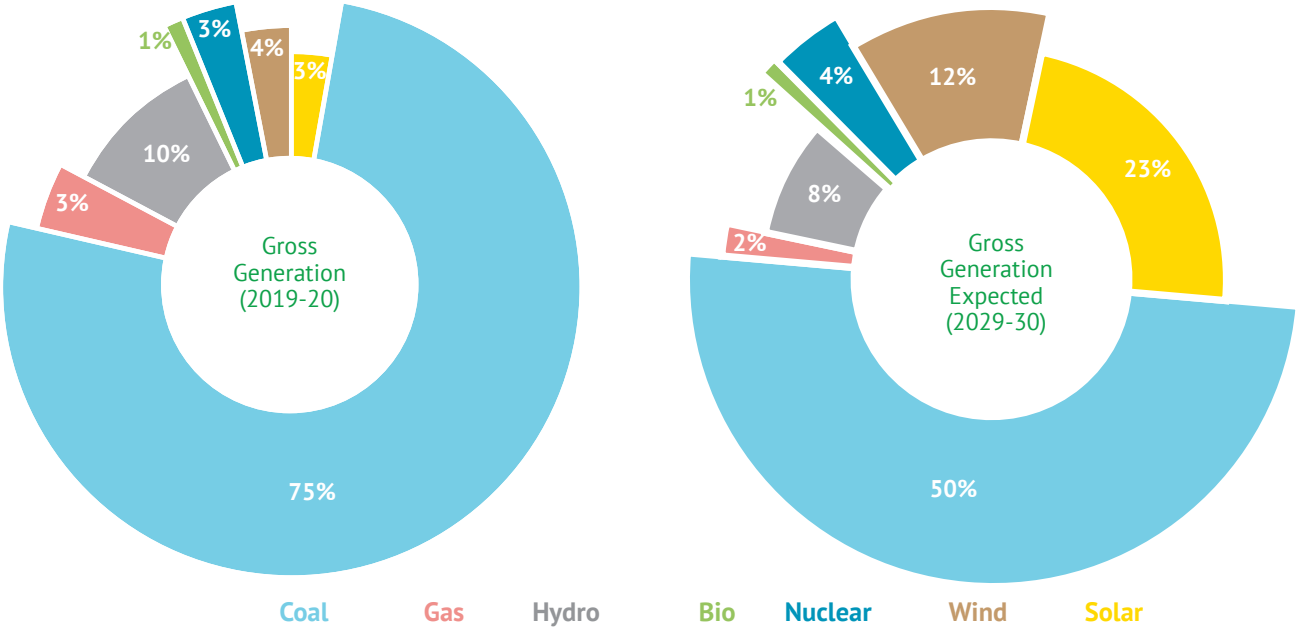
It can be observed that although the installed capacity of thermal sources is about 63% of the total installed capacity, the net generation from these sources is around 78% (75% coal and 3% gas) of the total generation mix. While, the share of renewables (including hydro) in the total installed capacity is about 35%, it's share in total generation mix is only 18%.

The next decade of the Indian electricity sector would witness a major transformation with respect to demand growth, energy mix and market operations. As per the Central Electricity Authority (CEA) estimates, by 2029-30 the share of renewable energy generation would increase from 18% to 44% while that of thermal is expected to reduce from 78% to 52%. The projected installed capacity in year 2029-30 is around 832 GW and would comprise of 291 GW from thermal, 17 GW from Nuclear, 523 GW from Renewable energy (including 73 GW from Hydro). This shift would to be driven by the falling cost of solar panels and battery storage systems.

Figure 1.1: Technology wise installed capacity Vs. gross electricity generation share in India



Source: CEA, JMK Research



Source: CEA, JMK Research

Why is Storage needed?

The rise of intermittent power sources such as solar and wind brings along the challenges in planning and operation of these power systems. The problem of intermittent power generation due to the variation in wind speed and the solar irradiation intensity throughout the day leads to inconsistent power generation throughout the day. Another constraint is the inability to 'control' the generation to match the demand, as can be done in a dispatchable fossil fuel power plant. Thus, limiting the dependency on renewable energy power in certain scenarios.

As per the Western Wind and Solar Integration Study (WWSIS) by National Renewable Energy Laboratory (NREL):

- At up to 10% renewable energy penetration, the grid is stable with very few issues.
- At 20% penetration, grid stability issues become more frequent.
- With 30% penetration, grid becomes unstable, affecting the performance of other power generating plants such as those of coal and nuclear.

It is estimated that, by 2030, the RE sources penetration in India is likely to reach 44%. This would create formidable challenges in maintaining grid stability. Effective energy storage solutions hold the key to overcome these challenges.

> Storage technologies can provide the required backup power for intermittent renewable energy capacity without threatening grid stability or the ability to meet electricity demand.

The various uses of energy storage are:

- Time shift for generated energy
- Energy scheduling
- Grid stabilization
- Peak shaving of demand
- Sale of power at peak times - arbitrage

In the next section, we will discuss how storage complements the solar technology and what are various advantages of solar+storage systems.

2. The Power of Synergy: Solar+Storage

Power cuts are very common in a power deficit country like India. This deficit has over the years created a dependency on the alternate energy, mainly from highly polluting diesel gensets. Such are the pollution levels in certain cities (especially Delhi-NCR) that the Government had to ban the use of diesel gensets and push for the environmentally friendly options. In such scenarios, rooftop solar plants have emerged as the most viable and eco-friendly solution which could reduce the dependency on power supply from DISCOMs.

Currently, solar covers around 3% of the total electricity generation in India. With the projected installed capacity of 300 GW by end of 2030, the contribution of solar would increase to 23%.

Solar plants along with battery storage add flexibility by smoothening the short term variability, eliminating production and load peaks, allowing very fast injection and absorption of electricity, and making solar fully dispatchable. Some of the benefits of solar+storage system are discussed in detail below:

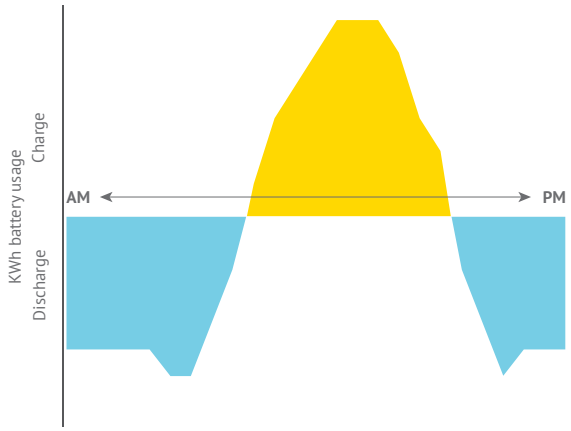
Optimize solar supply

The solar supply is variable in nature and may or may not meet the demand when required. In solar+storage system a consumer can opt for an oversized solar system and use the excess electricity to charge storage system. The stored energy can then be used either to meet the demand for a few additional hours (depending on the size of the battery) or to adjust any load–generation mismatch. This would help in providing reliable and affordable power with ready backup. The consumers can even manage the demand using storage systems and get a relief on the demand charges.

Firms the solar output

Solar generation can vary frequently and hence can cause a lot of disturbance at the load side. The addition of storage can smoothen the power output and can make the output of a solar power plant completely dispatchable.

Figure 2.1: Battery charge and discharge in a day



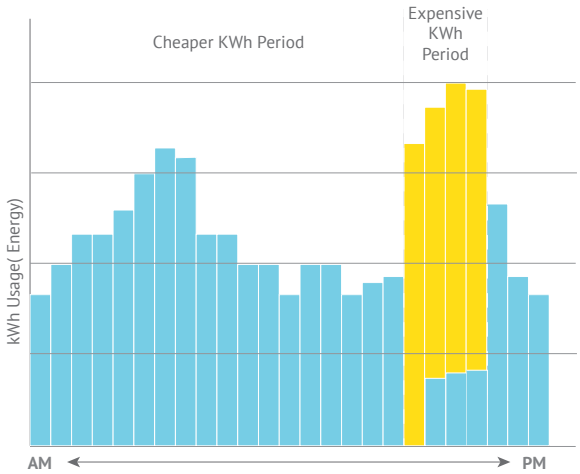
Provides ancillary services

Ancillary services are functions that maintain reliable electricity system with the proper flow and direction of electricity and addresses imbalances between supply and demand. To provide such services, generators must respond quickly to signals to help correct the frequency fluctuations. Solar+storage system has high flexibility and it provides faster and accurate services to grid operators. It is also able to provide ancillary services better than the other sources.

Provides stable energy prices

Arbitrage is storing or buying of electricity at lower rates and selling it in peak hours when the demand is high. In Solar+storage systems, arbitrage of electricity is possible by storage systems absorbing electricity from the grid at times when power prices are low and selling this electricity back into the grid when prices are high (this is applicable in the case where Time of Day

Figure 2.2: Energy usage distribution in a day.



Cheaper KWh Period: time of day when the utility rates are low and correspondingly consumption is also not high

Expensive KWh Period: time of day when utility rates as well as consumpiton is high. Storage takes care of excessive requirement.

tariffs are applicable). This also leads to lower electricity prices and helps improve the overall system operations and reliability. The figure explains the energy usage in a day along with usage in the period when energy charges are high. Consumers can avoid high energy charges by switching to storage energy during expensive power slot.

Reduces network costs

Earlier, grid were designed primarily to cater to peak demands. However, with rising RE installations, the grids are now designed for peak generation or peak demand whichever is higher (presently most of it is carried out for peak generation). Solar+storage systems help reduce peak generation significantly by integrating more electricity within the same grid, thereby, avoiding network upgrades.

Image Contribution: FLUENCE ENERGY

3. Key Drivers for Solar+Storage Systems

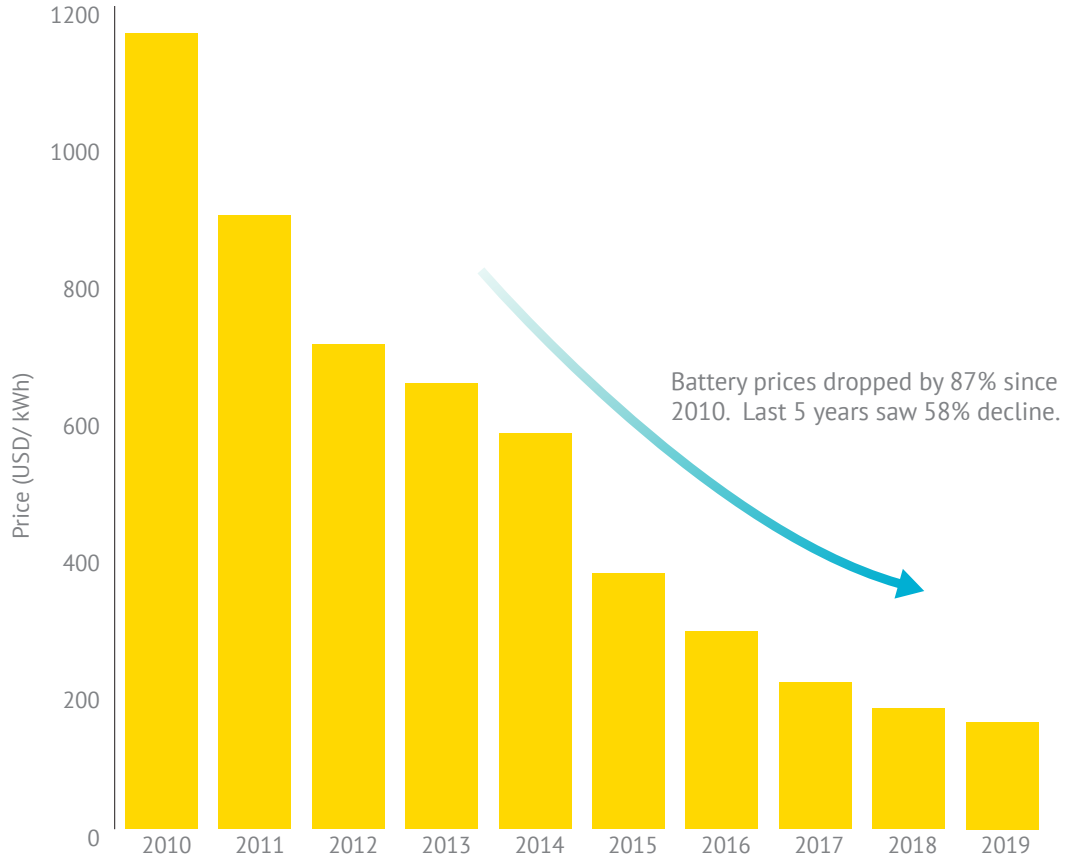
The solar+storage market in India is still in the nascent stages of development. Attributed to several factors listed below, this market is likely to grow many folds in the coming years.

Affordability and Performance

The boom in the Electric Vehicle (EV) industry has encouraged battery manufacturers to focus on Research and Development (R&D) of more efficient and affordable batteries. The updated battery technology in terms of energy density compounded with large scale production has resulted in a substantial reduction in battery pack prices (approximately 87% since 2010). The drop in battery prices from USD 1,160/ kWh in 2010 to USD 156/ kWh in 2019 have been one of the key drivers leading to reduction in overall project costs and rise of consumers' interest in storage. The prices are expected to reduce further by around 45% to USD 94/ kWh in next six years.

In addition to reduction in prices, the advancements in battery design has improved the performance of batteries in terms of lower charging time, and power to density ratio (trimmed size and weight of batteries) etc.

Figure 3.1: Average volume-weighted lithium-ion battery pack price



Source: Bloomberg New Energy Finance (BNEF)

Isolation from the regulatory uncertainty

In 2019, certain amendments to the net metering guidelines and banking regulations across key states were termed regressive by the industry. These policy changes denied the previously available benefits of solar installations to a section of customers. Below is a brief of these amendments.

Withdrawal of net-metering for corporates

Net metering allows rooftop installers to feed the excess energy generated by their plants to grid. Under net metering policy, rooftop installers are billed for the 'net' energy used each month which is the difference between the energy produced by solar power system and the energy consumed over the monthly billing period.

Net metering was introduced to make solar energy more accessible and economical for electricity consumers across the country. Although, most of the States formulated favourable regulations to boost the solar rooftop installations, a steep rise in solar rooftop capacity along with certain other factors led the State Governments to amend these regulations to reduce the benefits. Most important of the amendments is to restrain Corporate and Industrial (C&I) customers from net metering.

These issues are unlikely to be resolved in the near future. Though these policies changes were flagged regressive by industry experts, more states are expected to follow the suit with similar amendments which would eventually push-back solar installations.

Table 3.1: Key amendments to the net metering regulations

State	Provision in original net-metering regulations	Recent amendments
Uttar Pradesh	All consumers are eligible for net metering	C&I consumers are no longer eligible for net metering
Tamil Nadu	All consumers are eligible for net metering	C&I consumers except LT commercial are no longer eligible for net metering
Himachal Pradesh	All consumers of DISCOMs are eligible for net metering	Only domestic consumers with a letter of approval are eligible for net metering, while C&I consumers are not eligible anymore
Rajasthan	Banking of power is allowed for a year	Banking of power is allowed for only a month

Source: JMK Research

Withdrawal of banking facility

For third party sale projects, Haryana became the first state to withdraw banking facility while Maharashtra and Rajasthan reduced the banking period from annual to monthly basis. Several states capped the banking energy to lower percentages.

- **Maharashtra:** Unutilized banked energy limited to 10% and purchased at pooled cost.
- **Andhra Pradesh**: Unutilized banked energy is capped at 10% of total banked energy during the year that too at 50% of Average Power Purchase Cost (APPC), earlier it was 100% of APPC.
- **Rajasthan**: Only 10% banked energy at 60% of energy charges of large industrial tariff

In such scenario, the solar+storage would be an apt technology, isolating the consumers from a lot of policy and regulatory uncertainties.

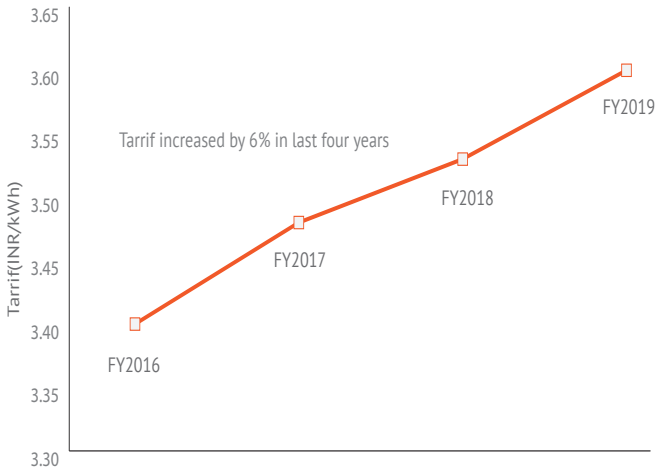
Tariff certainty for next 25 years

After the failure of UDAY scheme, it is quite evident that tariff reforms are the only way to ease the financial stress of DISCOMs. The cost of conventional power is expected to rise in the coming years with increase in prices of coal and other raw materials, mandatory adoption of environmental standards for coal power plants in India and shut-downs of old thermal power plants (low cost).

As per industry sources, the installation of emission-cutting equipment such as FGDs would also lead to an increase in power tariff by 62-93 paisa/ kWh. Also, rising manpower costs along with the O&M costs would have an impact on the grid tariffs. This can be substantiated from the graph below, which depicts that the Average power purchase cost (on all India basis) over past 4 years from non-renewable sources has increased by about 6%.

As price of grid power rises and states continue to reduce net metering benefits, consumers will see a higher gain in retaining the self-generated power for their future use. Hence, the commercial viability of a Battery Energy Storage System (BESS) is expected to improve substantially as the solar+storage tariffs are fixed for next 25 years without any escalation.

Figure 3.2: Average power purchase cost (APPC) across India



Source: JMK Research

Reliable power supply

The power transmission infrastructure in India is yet to reach the level of high reliability and quality to ensure less or no power cuts. For power backups, most of the consumers have to rely on Diesel Gensets which are very costly to operate (INR 14-16/ kWh) and puts additional financial burden on the consumers. Therefore, battery storage is an alternate economical option available to end consumers.

Environment friendly

The battery storage can store and restore power in absence of direct sunlight or power interruption from DISCOMs. Electricity from storage is both environmentally friendly and cost effective when compared to other power backup sources especially Diesel Gensets. Diesel gensets emit different kinds of harmful gaseous pollutants such as nitrogen oxide, sulfur dioxide, particulate matter, unburned hydrocarbon, carbon monoxide, and carbon dioxide. These gases are harmful not only to living matter but also contribute to global warming.

The battery storage does not have any direct adverse impact on the environment as it does not emit harmful gases. Moreover, these batteries can be recycled and most of its components can be reused in producing more batteries.

Freedom from the hidden cost of integrating variable renewable energy

As the market percentage of renewables increase, there would be hidden power system costs for integrating the Variable Renewable Energy (VRE) generation. Such costs are incurred because of the forced flexible operations of conventional power plant fleet to maintain grid stability. The hidden costs for integrating VRE amounts to about INR 1.5-2.0/ kWh, which is additional to the solar tariff. These costs can be avoided with the introduction of energy storage along with the renewable energy.

4. Challenges in Adopting Storage with Solar

Despite a variety of applications of storage along with the advantages, the adoption rate of storage with solar has been very low in India. The lower than expected growth of solar+storage market can be attributed to various factors ranging from implementation costs to lack of favourable state policies. Some of the factors are highlighted in detail below:

High upfront costs are keeping the consumers away from setting up storage systems. In past few years, the cost of Li-ion batteries has witnessed sharp decline and the trend is expected to continue for another couple of years. Most of these batteries are imported from China as India does not have any major Li-ion cell manufacturer to contribute to the affordability. India needs strong policies and investment solutions to support better energy storage usage to ultimately facilitate faster adoption rate.

Consumer awareness holds the key to success of any consumer centric technology. The lack of understanding makes the consumers perceive the storage as a complex, unwanted and expensive addition to solar implementations. There is a need to set up a mechanism to educate the consumers about the features and benefits of storage with solar.

Policies and guidelines required for scale implementation of energy storage in solar plants are yet not formalized by the Government of India. The lack of regulations and financial incentives adds to consumer scepticism about Government support to a new and expensive technology. In such a case, it would be wise for a consumer to put its high investments on hold until the regulatory clarity is achieved.

Operational and Maintenance (O&M) challenges: High ambient temperatures in most parts of India for almost half of the year can result is high O&M challenges for the battery storage. Also, as solar+storage is still in nascent stage of development we may lack the capability to operate and maintain the system to its full capability.

5. Government Initiatives

Energy Storage is a critical component of the energy infrastructure strategy of the Government of India and its support for the sustained thrust to renewables industry. In the last two years, the Central and State agencies have come up with several initiatives to encourage the adoption of energy storage in India. Some of them are:

- In the budget 2019, the Government reduced custom duties on Cobalt matter from 5% to 2.5%, a key ingredient for advanced lithium-ion batteries.
- In March 2019, the cabinet approved National Mission of Transformative Mobility and Battery Storage, which included phased manufacturing programs, valid till 2024, to support e-mobility and battery storage.
- The Government introduced a Wind-Solar hybrid policy, in May 2018, permitting the use of any kind of energy storage technology to maintain grid stability by keeping demand and supply gap as low as possible.
- On 08 April 2019, MNRE issued draft guidelines for storage battery testing in test labs under the Implementation of Quality Control Order on SPV Systems, Devices and Components Goods 2017. These guidelines are yet to be finalized.
- In January 2017, CERC introduced a staff paper on Energy Storage in India. The paper talks about grid level applications of energy storage systems, potential owners of energy storage facilities, operational framework and challenges. However, the paper does not specify any target or incentives for setting up the energy storage plants.
- In January 2020, MNRE has released a draft policy for the supply of Round-The-Clock (RTC) power to DISCOMS which would be a mix of renewable energy and electricity generated in coal-based plants. According to the draft, a generator has to supply power such that at least 51% of the annual energy supplied corresponds to renewable energy.

In contrast to the initiatives taken at the central level for promotion of the storage technologies, State Governments are yet to come up with their storage specific policies/ guidelines. Andhra Pradesh and Madhya Pradesh are the only states which have invited Expression of Interest (EOIs) for the development of battery manufacturing plants and installation of energy storage facility.

Apart from the various policy measures, the central as well as state government agencies have also floated various storage tenders which are discussed in detail in next section.

"There is an urgent need to declare economy wide goals for battery storage, similar to what has been done on the solar and wind side. Also, the regulator needs to create the right incentive structure for quick responding battery storage"

Rupam Raja
(Marketing Director, India, Fluence Energy)

6. Storage Tenders

The year 2019 saw a rise in the number of storage tenders owing to a strong push by the Government, and decline in the cost of storage technologies. In 2019 itself, India's first and biggest battery-storage system of 10 MW is commissioned in Delhi at the Rohini substation of Tata Power Delhi Distribution Ltd. (TPDDL). This project is built by AES in partnership with Mitsubishi Corporation for almost $9 million.

Request For Proposal (RFP) or Expression of Interest (EOI) is issued for another 8 new storage tenders (refer table 1) in last one year only. Most of these tenders are issued across Jammu & Kashmir, Lakshadweep, Himachal Pradesh and Andaman & Nicobar Islands mainly to reduce dependency on diesel in these remote locations.

A large wind solar hybrid project with a capacity of 160 MW and storage capacity in range of 30-40 MWh is also expected to come up in Andhra Pradesh. This project is funded by the World Bank and bids are already submitted.

In October 2019, SECI Issued 400 MW tender for Round the Clock Supply of renewable power along with Energy Storage. UHBVN also issued EOI for a 100 MW RE plant with storage.

In June 2019, Madhya Pradesh Power Management Company Ltd. (MPPMCL) invited Expressions of Interest (EoI) for setting up of 500 MW of project with 8 hours of continuous discharge (~4000 MWh) in conjunction with a storage manufacturing facility. The aim of the EOI is to invite global companies to demonstrate their technologies and share experiences.

Similarly, Transmission Corporation of Andhra Pradesh invited proposals for storage project of 400 MW with 8 hours of discharge per day (3,200 MWh) which has to be operational from October 2021. The project saw participation from Greenko and Sterlite Power but was later cancelled by the newly appointed Government in Andhra Pradesh citing high project costs.

Even though a lot of new solar/ wind+storage tenders are issued, the design of these tenders make their implementation unsustainable. In most of these tenders, the storage capacity is so high that it leads to infeasible solar+storage tariffs, and eventually to cancellations of many of these tenders. Hopefully, as the market will mature all these operational and execution level challenges would streamline.

Table 6.1: Major storage tenders issued in India, as of October, 2019

Tendering Authority	Location	Capacity	Tender Scope	Current Status	Winner	Date Issued
SECI	PAN India	Solar, Wind, Hybrid with storage - 400 MW, "Round-the-Clock" Supply to NDMC	BOO	RFS issued	N/A	Oct 2019
UHBVN/ DHBVN	PAN India	100 MW Solar & Wind/Small Hydro projects with Energy Storage System	BOO	EOI issued	N/A	Sep 2019
SECI	Lakshadweep	1.95 MW Solar + 2.15 MWh battery energy storage	EPC	RFS Issued		Sep 2019
REIL	Andaman & Nicobar Islands	1.7 MW solar, 1 MWh storage	EPC	RFS Issued		Apr 2019
SECI	Andhra Pradesh	160 MW wind solar hybrid with 30-40 MWh storage	EPC	Bids submitted		Apr 2019
SECI	Leh	3 MW solar, 3.2 MWh storage	EPC	Result announced	Sunsource	Mar 2019
SECI	Leh and Kargil	14 MW solar, 42 MWh storage	BOO	RFS Issued		Mar 2019
SECI	Lakshadweep	20 MW floating solar, 60 MWh storage	EPC	Bids submitted		Feb 2019
NLC	Andaman & Nicobar Islands	20 MW solar, 8MWh storage	EPC	Result announced	L&T	Apr 2018
SECI	Leh	3 MW solar, 5 MWh storage	EPC	Result announced		Jul 2018
NTPC*	Andaman & Nicobar Islands	17 MW solar, 24 MWh storage	EPC	Result announced	BHEL	Mar 2018
NTPC*	Andaman & Nicobar Islands	8 MW solar, 3.2 MWh storage	EPC	Result announced	BHEL	Mar 2018

Source: JMK Research

*Tenders cancelled due to high cost

7. Key Players

There are several players who are providing solar + storage solution on OPEX as well as CAPEX model in India.
These players can be divided into three broad categories:

- Project developers providing solutions for on Built Own Operate (BOO) basis
- Players providing EPC solutions
- Key storage solution providers

Table 7.1: Key project developers providing Solar+ Storage solutions

AMPLUS SOLAR	Amplus is one of the biggest distributed solar energy company in India. The Company has already installed 3 solar + storage systems for C&I consumers on OPEX model. They are rooftop solar systems with battery size ranging from 14 kWh to 96 kWh.
HERO FUTURE ENERGIES	Hero Future Energies provides battery energy storage solution for applications in utility-scale solar, behind the meter and micro-grids. It provides solutions on both CAPEX and OPEX models.
SunSource ENERGY	SunSource has been active in solar + storage space for a long time. In 2013, company installed a 100 kW project along with 300 kWh battery storage system for a resort-cum-residential complex. Recently, it won one of India's largest solar projects with storage in Leh. The company is setting up two other solar storage-based projects in Jammu & Kashmir and Himachal Pradesh.
Sterlite Power	Sterlite power is a transmission solution provider which is very keen to foray in storage solutions. They have already bid for two storage projects in the US.
RAYS POWER INFRA	Company is exploring the feasibility of Solar + Storage solutions to provide 24 hours uninterrupted power supply. It aims to become a leader in battery technology and establish a self-owned manufacturing plant.

Table 7.2: EPC players providing Solar+ Storage solutions

BHEL	BHEL is one of the largest EPC players in the power sector. They are actively bidding for solar + storage projects on EPC model and have already won few projects by SECI. However, these projects were cancelled due to high costs.
L&T	L&T is also a big EPC player in the power sector. One of its solar+ storage project from SECI is expected to be commissioned by next year.
GE	GE is very actively bidding for solar+ storage projects in India. It is one of the few players who have in-house technology for wind, solar and storage.
Sterling & Wilson	Sterling & Wilson is a leading third party EPC player active in Indian solar sector. They are also now focussing on providing EPC services for solar+ storage projects and are actively bidding for these projects.
Suzlon	Mahindra Susten is another leading third party EPC service provider who is now actively participating in solar+storage tenders in India.

Table 7.3: Key storage solution providers

Fluence	Fluence (JV between Siemens and AES) is a global leader in Energy Storage solutions. It is the technology provider for the 10MW/ 10MWh Battery Energy Storage System (BESS) at Tata Power Delhi Distribution Limited (TPDDL) (erstwhile NDPL) in Rohini, Delhi
Wärtsilä	Wartsila is one of the leading MNC having more than 50 storage sites operational across the world.
Exicom	Exicom is a leading Indian company with focus on Telecom, Energy Storage and E-mobility. The company has its own battery pack manufacturing facility in India.
Okaya	Okaya is a leading Indian battery manufacturing company specializing in storage solutions for small applications. Okaya is a sister concern of Microtek, a leading supplier of UPS solutions in India.

8. Project Economics of Solar+Storage Systems

The rapid growth of solar deployments and a fast decline in the costs of energy storage technologies have stimulated the interest in combining solar with energy storage.

The combination of solar+storage provides dispatchable energy (i.e. energy on demand), reliable capacity (i.e. grid stability) and would overcome the twin challenges of variability and the diurnal nature of solar generation.

To understand the current cost dynamics of battery storage, JMK Research & Analytics did a detailed analysis of technical and financial parameters of the solar+storage system for three different scenarios for Commercial and Industrial (C&I) segment:

Case A

Grid connected 25 MW (AC) Solar with 10 MW / 4 hour battery back-up (DC coupled co-located solar and storage systems)

Case B

Decentralized 10 MW (AC) Solar with 2 MW /10 hour battery back-up (DC coupled co-located solar and storage systems

Case C

1 MW rooftop solar with 250 kW / 4-hour battery back-up storage system

What is Battery capacity?

Battery capacity is measured in terms of power output and energy capacity ratio that is the duration for which the battery can supply power. Power rating specifies the power that battery is able to supply at one particular moment.
Energy capacity specifies total amount of energy that can be stored in a battery and can be discharged (this is total amount of power stored multiplied by total duration of hours the power can be supplied). Hence battery capacity is measured in terms of both kW of power and kWh of energy capacity.

The **battery cost** depends on both power rating and energy capacity ratio. The battery cost rises as duration of battery increases as it would have more battery packs to supply power for longer durations.

Balance of systems and **EPC costs** are directly proportional to the cost of lithium-ion power capacity.
As per various industry sources, the current EPC prices of battery storage are in the range of USD 300-320/ kWh. As per the BNEF, learning rate for lithium-ion battery is 18% i.e, for every doubling of cumulative volume, there is 18% reduction in the battery price.

> We expect that by 2021, the costs of battery storage would reduce by almost 15 -20%.

Battery specific assumptions for the Financial Model

- EPC prices for storage: USD 270/ kWh
- Depth of discharge: 80%
- Round trip efficiency: 90%
- Charge discharge per day: 1 cycle

Table 8.1: Assumptions for financial model

Assumption	Solar	Battery
Debt Equity	70:30	
Loan Tenor	10 years	
Interest Rate	9.50%	
Return on Equity (Post Tax)	14.00%	
Life Cycle	25 years	10 years (Replacement considered after 10 years) 15 years for 2nd Battery (considering technological advancements)
Depreciation	3.6% for 25 years	9% for first battery life, 6% for second battery life
O&M charges	INR 0.3 million per MW (with 3% escalation per year)	INR 0.05 million per MW (with 3% escalation per year)
Product Specifications	Mono Crystalline modules	Lithium-Ion battery

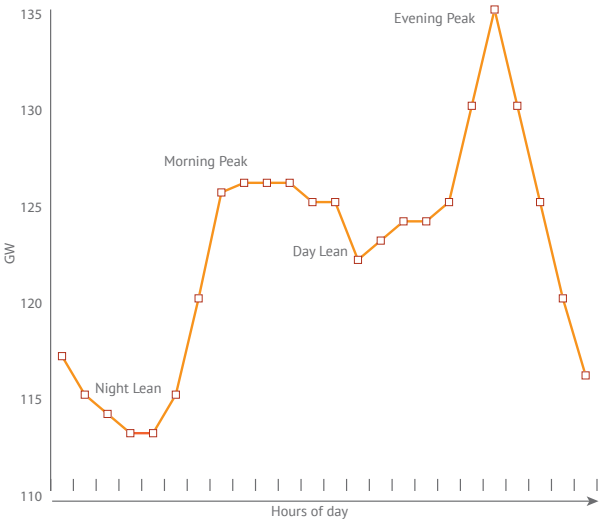
Source: JMK Research

Rationale behind the 4-hour battery back-up

A typical load curve illustrating the national variation in demand (aggregated electrical load of the different states in India) over a specific time is provided in Figure 8.1 below.

As can be seen, the peak comes from 18:00 hours to 22:00 hours (6 p.m. to 8 p.m.) in the evening. As more and more states opt for the time-of-day tariff, the battery back-up of 4 hours would help consumers avoid the high cost of tariff applicable in these peak hours.

Fig 8.1: Average national demand variation in a day



Source: NLDC, IEEFA

Case A: Grid connected 25 MW (AC) solar with 10 MW / 4-hour battery back-up

At present, in India, the commercial and industrial (C&I) consumers face steep electricity costs with frequent disruptions in the power supply. Installing a storage system with solar can address both these issues and significantly reduce electricity bills of corporates.

The cost of a co-located, DC-coupled system is 7-8% lower than the cost of a system with solar and storage sited separately[1]. Co-locating the solar and storage subsystems produces cost savings by reducing costs related to site preparation, land acquisition, interconnection, hardware (via sharing of hardware such as switchgears, transformers, and controls) and other installation overheads.

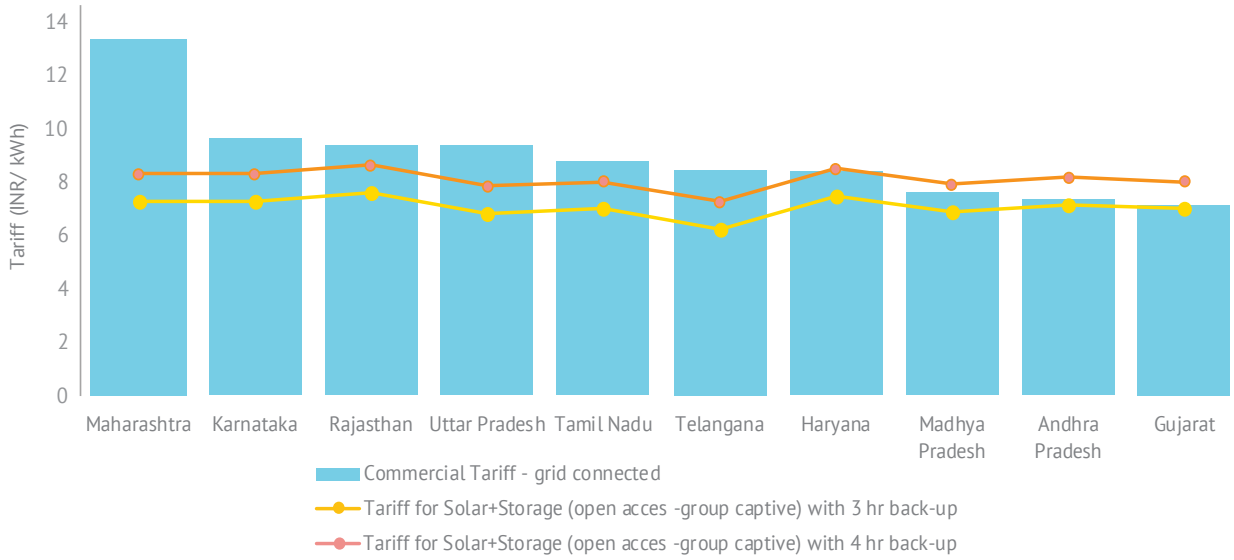
Considering various technical and financial assumptions, by 2021, the tariff of solar+storage system in this scenario comes to about INR 7/ kWh (at the base-case scenario).

The final tariff for C&I consumers for top 10 states is calculated after considering all the charges- transmission and distribution (T&D) losses, T&D charges, cross subsidy charge (CSS) and additional surcharges (wherever applicable).

Commercial Consumers

For commercial consumers, as can be seen from the graph below, solar system with a 3 hour storage backup is economically viable in all the states while with a 4-hour storage backup is viable in all states except for Andhra Pradesh, Madhya Pradesh and Gujarat.

Figure 8.2: Comparison of grid connected commercial tariff vis-a-vis solar+storage tariff



Source: JMK Research,
Note:

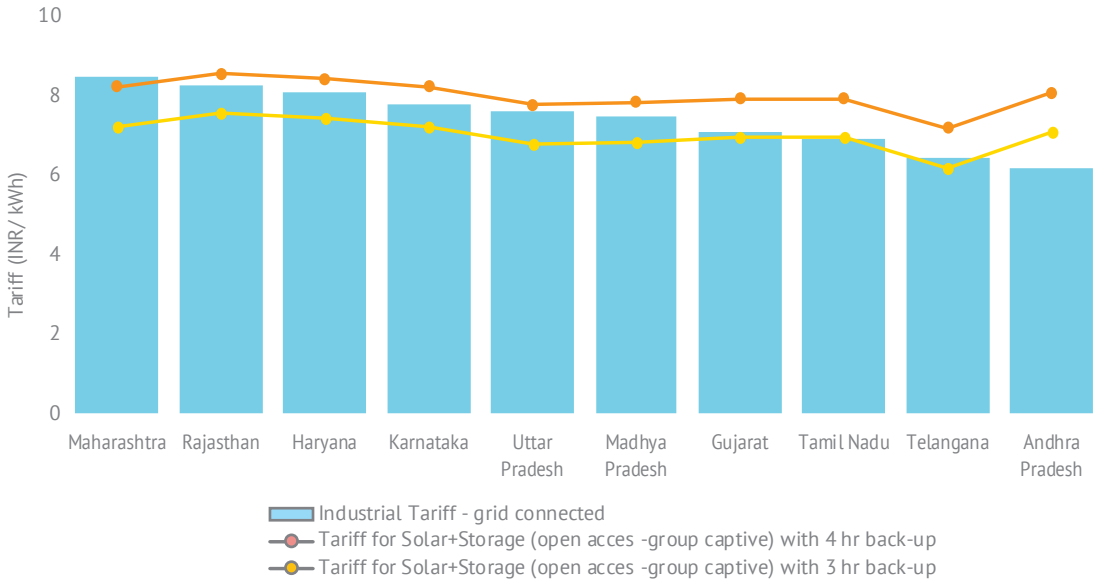
- Grid tariffs considered for the 33 kV HT category.
- Grid tariffs include variable energy charges, fuel surcharge and electricity duty and does not include fixed (demand) charges
- Open access waivers are calculated for group captive model

[1] Source: NREL report on "2018 US utility scale Photovoltaics-Plus-Energy Storage System Costs Benchmark"

Industrial consumers

For industrial consumers, as can be seen from the graph below, solar+storage system is still not economically viable across most states. However, the price reduction in coming years coupled with increase in tariff for the industrial consumers would drastically improve the viability of the solar+storage system.

Figure 8.3 : Comparison of grid connected industrial tariff vis-a-vis solar+storage tariff



Source: JMK Research
Note:

- Grid tariffs considered for the 33 kV HT category.
- Grid tariffs include variable energy charges, fuel surcharge and electricity duty. Do not include fixed (demand) charges
- Open access waivers are calculated for group captive model

Case B: Decentralized/ off-grid 10 MW (AC) solar with 2 MW/ 10-hour battery back-up

A decentralized 10 MW (AC) solar system with 2 MW/ 10-hour storage backup (DC coupled solar and storage system) are preferred in places with limited or no grid connectivity. Most of such places have high dependence on costly diesel gensets.

> In Andaman & Nicobar, and Lakshadweep Islands, the diesel gensets cater to 70% and 90% of the power, respectively.

Of the total installed capacity of 57.45 MW in the Andaman & Nicobar Islands, 40 MW is generated by diesel gensets while the remaining is catered by renewable energy. Similarly, Lakshadweep has 23 MW generation comprising of 21 MW from diesel gensets and 2 MW from solar.

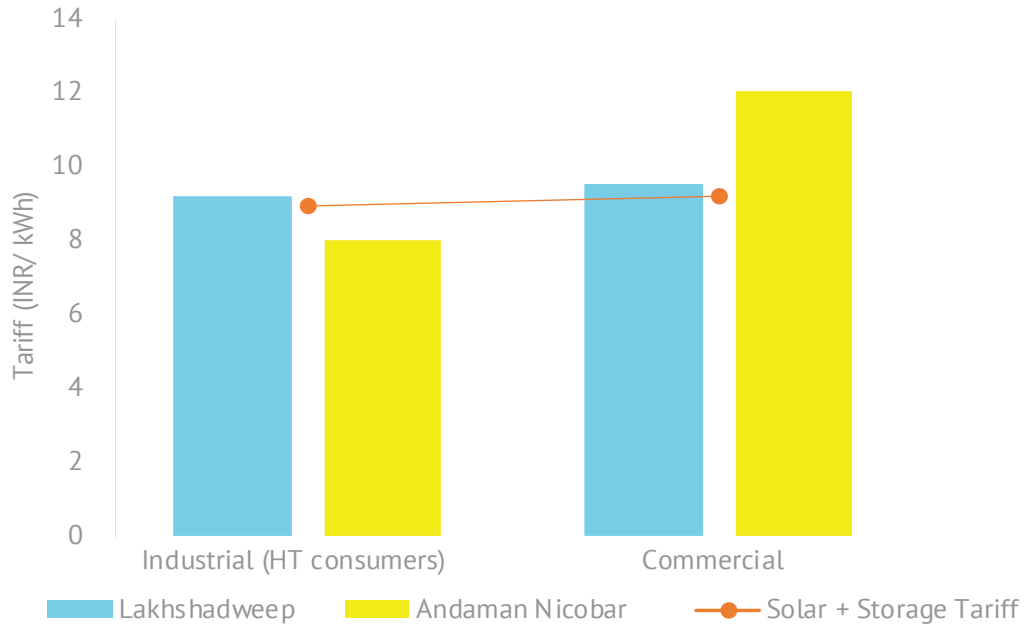
In last few years, the Average Power Procurement Cost (APPC) for Andaman & Nicobar and Lakshadweep islands has been in the range of INR 10 -12 per kWh. This is mainly due to the dependency on diesel gensets for generation of electricity.

The operating cost of diesel generation sets is extremely high and varies in the range of INR 13-17/ kWh, based on the several factors including size and make of the DG set, how old the DG set, O&M practices for the DG, load at DG set during operations and the most importantly the fuel cost.

Solar+storage can provide standalone-grid solutions to such remote areas thereby completely replacing diesel generators. Considering all the technical and financial parameters, by 2021, for this scenario, the tariff for the solar+ storage system including wheeling and transmission charges and losses would be in the range of ~ INR 8.5-9/ kWh.

As seen from the Figure 8.4, the cost of solar+storage is much lower (~ INR 9/ kWh) in comparison to the energy charges for commercial consumers in Andaman & Nicobar

Figure 8.4: Energy charges for 2019-20 vis-a-vis solar+storage tariff



Source: JMK Research

and Lakshadweep islands. For industrial (HT consumers) solar+storage tariff is feasible in Lakshadweep islands but not in Andaman & Nicobar Islands. However, the average increase in grid tariff in Andaman & Nicobar and Lakshadweep islands has been 30-48% in last one year for various categories of consumers. Therefore, going forward, this tariff would be feasible in next few years.

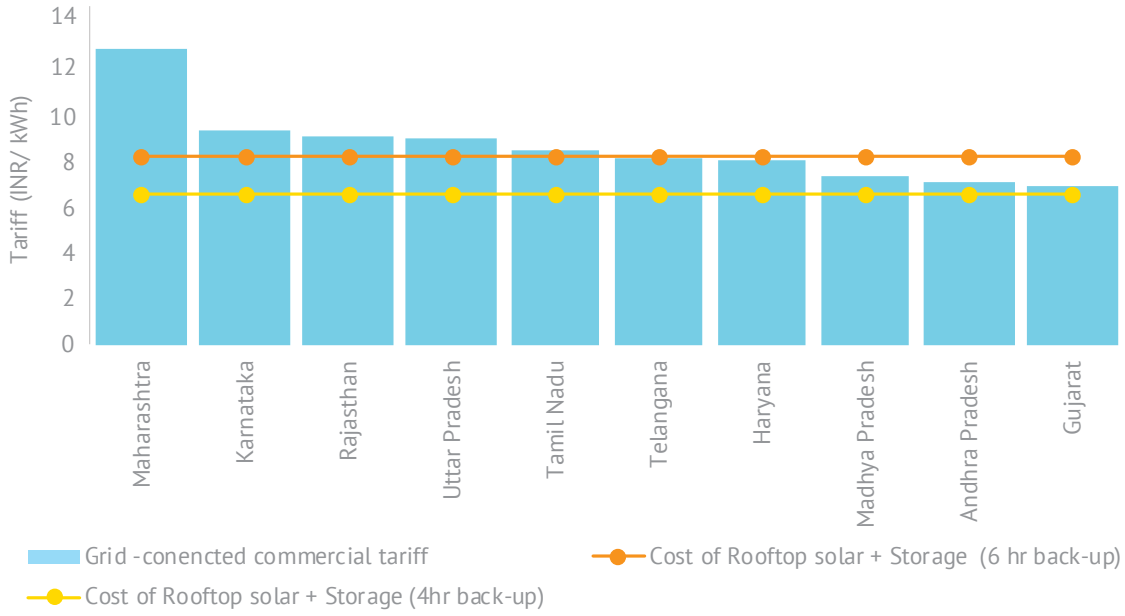
Considering all these facts it makes a strong business case for the standalone solar+storage which operates itself as mini grid and tariff is fixed for the next 25 years.

Case C: 1 MW rooftop solar system with 250 kW/ 4-hour battery back-up

Rooftop solar with storage system is a win-win solution for both the end consumers and the DISCOMS. As per our analysis, the Levelized Cost of Energy (LCOE) for a 1 MW rooftop system attached to a 250 kW of energy storage with a back-up of 4 hours comes in the range of INR 6.6–6.8/ kWh. This is lesser than the grid tariffs for most of the commercial consumers across key states and far lesser than the power produced from Diesel gensets.

For commercial consumers, the rooftop installations with a backup system of 4 hours would be economically feasible across all the states whereas a 6-hours backup system would

Figure 8.5 : Comparison of grid connected commercial tariff vis-a-vis solar+storage tariff



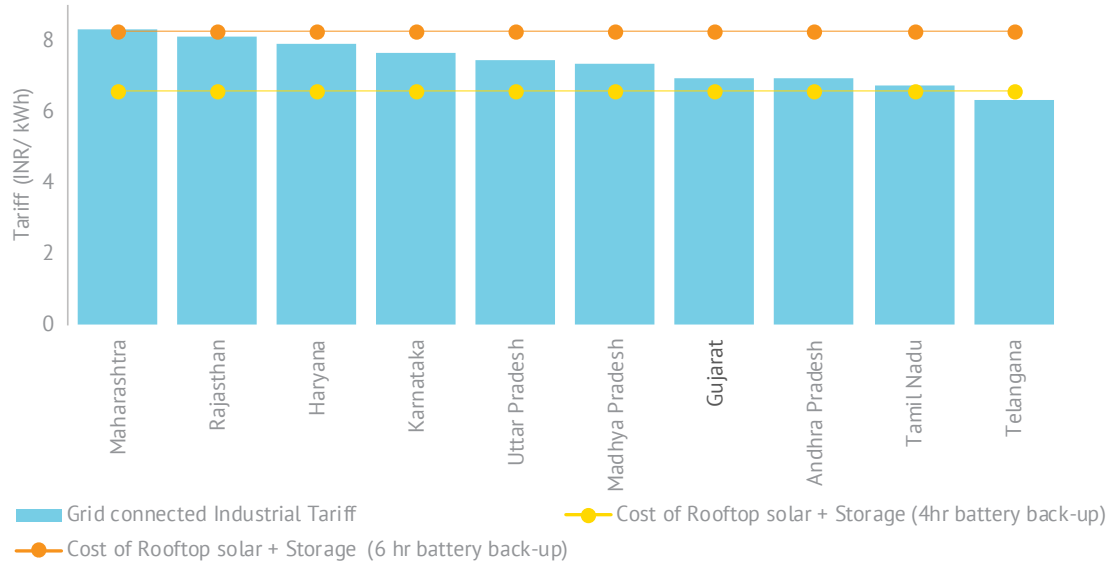
Source: JMK Research
Note:
- Grid tariffs considered for the 33 kV HT category.
- Grid tariffs include variable energy charges, fuel surcharge and electricity duty. Do not include fixed (demand) charges

not be viable in some states such as Haryana, Andhra Pradesh, Madhya Pradesh and Gujarat. For industrial consumers, rooftop installations with a backup system of 4-hours would be feasible across all the states except Telangana whereas a 6-hours backup system would not be viable in most of the states.

The conclusion derived from the above case studies is that the LCOE of solar + storage is already economical for commercial and industrial category in majority of the states for both open access (group-captive model) and rooftop projects. Solar+storage is also a viable option for the standalone system where there is no Grid connectivity and the electricity is generated using Diesel gensets.

Furthermore, with the proposed battery manufacturing facilities along with associated incentives, the cost of storage system are likely to fall further. Thus, improving the financial viability of solar+storage systems. As per JMk Research estimates, by 2021-22, we are hoping the adoption of solar+storage is likely to pick pace in India.

Figure 8.6: Comparison of grid connected industrial tariff vis-a-vis solar+storage tariffs



Source: JMK Research

Note:

- Grid tariffs considered for the 33 kV HT category.
- Grid tariffs include variable energy charges, fuel surcharge and electricity duty. Do not include fixed (demand) charges

9. Way Forward

Solar energy by itself is not interchangeable with the base-load sources of fossil fuel energy such as coal and diesel. Yet, by pairing with energy storage solar firms its generation, and may be able to displace fossil fuel generators. Clearly, going forward, the energy storage is poised to be a shot in the arm for India's ambitious 2030 renewable energy target of 460 GW. As per CEA, about 34 GW/ 136 GWh of battery storage is expected to be installed by 2030. This capacity would be used for RE integration, ancillary services, demand side and peak load management services.

To further give impetus to storage market, policy makers should also devise policies to benefit all the stake holders. Presently, there is a lack of clarity about functional classification of energy storage as it is both a generator and a consumer of electricity. Changes to existing regulatory framework are required to provide an Identity to Energy Storage. Energy storage is yet to find a mention in the Electricity Act 2003.

Government should introduce definition of "Electricity Storage" in the Electricity Act, 2003.

This definition should:

- Establish storage as a new type of asset on the grid that can provide multiple services– alongside the traditional generation, transmission and distribution assets.
- Acknowledge that electricity storage provides value as it can both absorb and release electricity from and into the grid respectively.

The current efforts by the Government of India to effect changes in the Electricity Act 2003, as part of the Indian Electricity Amendment Bill 2018, which is yet to be submitted for passing in Indian Parliament, presents the best opportunity to include Energy Storage.

Also, energy storage should be allowed as an essential regulatory asset for DISCOMS which would help them recover costs from its customers.

Table 9.1: Tweaking required in the proposed Electricity (Amendment) Bill 2018

Clause No.	Particulars	Suggestions
2 (vi)	'(15A)"decentralized distributed generation" definition	Clause should include deployment of appropriate energy storage devices when clubbed with variable renewable energy (VRE)
2 (xi)	'(23 A) "Electricity Distribution Code" means the Electricity Distribution Code specified in section 50	Should include Energy Storage devices to support carriage& content model adoption
2 (xix)	'(57A) "renewable energy sources" definition	Renewable energy sources to be differentiated between firm & non-firm sources
6	In section 7(1), and clause (b) of section 73 definition of spinning reserve	Non-generating capacities like energy storage devices should be included as part of the spinning reserves definition
45	In section 79 of the Act, in sub-section (1), for clause (C)...to regulate inter-state transmission...smart grid, ancillary services...	Energy Storage devices also need to be considered

Source: JMK Research

In the table above, JMK Research recommends section wise additions to the Electricity Amendment Bill 2018.

Provide financial Incentives

Government of India needs to come up with financial incentives or VGF schemes to promote storage technologies till the time they achieve grid parity as was earlier done for solar projects. Financial incentives would reduce burden on consumers/utilities and help in faster adoption.

A separate fund can also be created to support solar+ storage systems.

Availability of low-cost financing

Finances plays a key role in supporting and promoting any upcoming technologies. Hence, Government should direct the financial institutions and banks to provide low-cost financing to upcoming solar+storage projects. This would further help in reduction in tariff and improve projects' viability.

Image Contribution: FLUENCE ENERGY

JMK Research & Analytics

REPORTS CALENDAR 2020

RENEWABLE ENERGY

ELECTRIC VEHICLES

RENEWABLE ENERGY		ELECTRIC VEHICLES
Monthly RE Update Q4 2019 RE Update Solar+BatteryStorage:Assessing Viability	JAN	Monthly EV Update
Monthly RE Update Solar: 2019 Report Card	FEB	Monthly EV Update
Monthly RE Update	MAR	Monthly EV Update Future of 2-wheeler EVs in India
Monthly RE Update Q1 2020 RE Update	APR	Monthly EV Update
Monthly RE Update **Annual series**: PV modules Technology Trends	MAY	Monthly EV Update
Monthly RE Update **Annual series**: Solar Inverter Technology Trends	JUN	Monthly EV Update Future of 3-wheeler EVs in India
Monthly RE Update Q2 2020 RE Update	JUL	Monthly EV Update
Monthly RE Update	AUG	Monthly EV Update
Monthly RE Update Solar: Annual Report Card	SEP	Monthly EV Update Future of 4-wheeler EVs in India
Monthly RE Update Q3 2020 RE Update	OCT	Monthly EV Update
Monthly RE Update **Annual series:** Solar+storage adoption in **India**	NOV	Monthly EV Update
Monthly RE Update	DEC	Monthly EV Update Evolving Charging Infrastructure Lanscape in India

In 2020, JMK plans to roll out atleast 36 reports on RE (20) and EV(16) segments combined with an aim to provide indepth market analyses and industry updates to a large number of readers from both RE and EV industry.

We also provide our subscribers access to extensive online **Databases**

- **Solar** Project Guidebook (2,100+ projects)
- **Wind** Project Guidebook (10,000+ projects)
- **RE Tender** Guidebook (300+ tenders)

To **Advertise** in our reports and get online demo/ subscribe to our **Databases** write/call us at

JMK Research & Analytics

E: contact@jmkresearch.com
M: +91-7428306655
A: 27/2C, Palam Vihar, Gurgaon
W: www.jmkresearch.com

GRID CONNECTED
SOLAR ROOFTOP
SOLUTIONS

RESIDENTIAL > COMMERCIAL > INDUSTRIAL

Delhi (Corporate Office):
F213/A, 1st & 2nd Floor,
Ols Mehrauli Badarpur Road,
Lado Sarai, New Delhi 110030
Tel.: +91 11 4057 1616
rooftop@claroenergy.in

Sales Office:
504, Chitrankshi Apartments,
A V Road, Anand 388001,
Gujarat

CLARO®

JMK Research & Analytics

A: 27/ 2C, Palam Vihar,
Gurugram, Haryana, India - 122017
M: +91 - 742 830 6655
W: www.jmkresearch.com