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Firming up solar energy with energy storage systems

Rooftop solar to add 10 GW by FY2023

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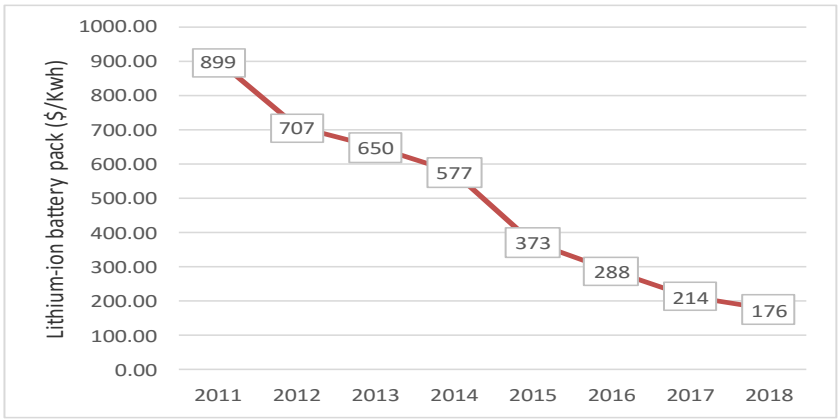
As the cost of solar power and lithium-ion battery prices are declining at a much faster than anticipated pace to new lows, battery energy storage systems (BESS) are likely to disrupt the power sector. Solar power with lithium-ion battery storage can harness a variable solar energy and provide firm solar energy. Hence, ESS is a key technological disruptor of the new eco system and is poised for rapid growth stimulated by tougher environmental policies and regulatory reforms. Simultaneously, declining prices of lithium-ion batteries make it economical for commercial & industrial buildings and high-end residential consumers. Rooftop solar plus storage helps in reduction of transmission and distribution losses for state distribution companies (discoms) and defers investments in transmission infrastructure.
CARE Ratings expects addition of 10 GW of rooftop photovoltaic installations by fiscal 2023 driven by commercial & industrial buildings and phase II of grid-connected RTS programme.

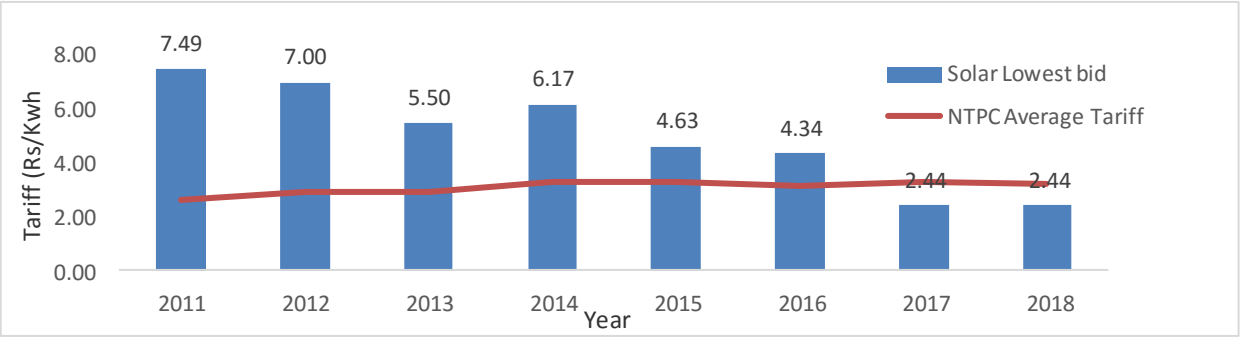
Due to cost barriers, tenders announced in co-located storage segment so far are facing delays. However, with declining cost of Solar Photovoltaic (SPV) Systems and battery storage, electricity generation from rooftop solar (RTS) installation is already economically viable for some consumers in the commercial and industrial segment. Furthermore, Central Finance assistance (CFA) of 40% for residential rooftop solar (RTS) projects (1-3 Kw) under phase II of grid-connected RTS programme will improve project economics of RTS for low-end residential consumers. Out of total solar installation of 28.20 GW as on 31 March 2019, rooftop solar installation stood at a mere 1.80 GW. Artificial caps in net metering, huge upfront costs are key impediments to the rooftop segment. Battery energy storage systems (BESS) will provide a much needed fillip to rooftop segment. Growth in RTP can be achieved by incentivising utilities, providing viability gap funding/subsidies to storage solutions, policy enforcement, providing flexible financing and creating awareness among consumers.

Graph 1. Lithium-ion battery pack average prices (Annual)



Source: Bloomberg New Energy Finance (BNEF), CARE Ratings

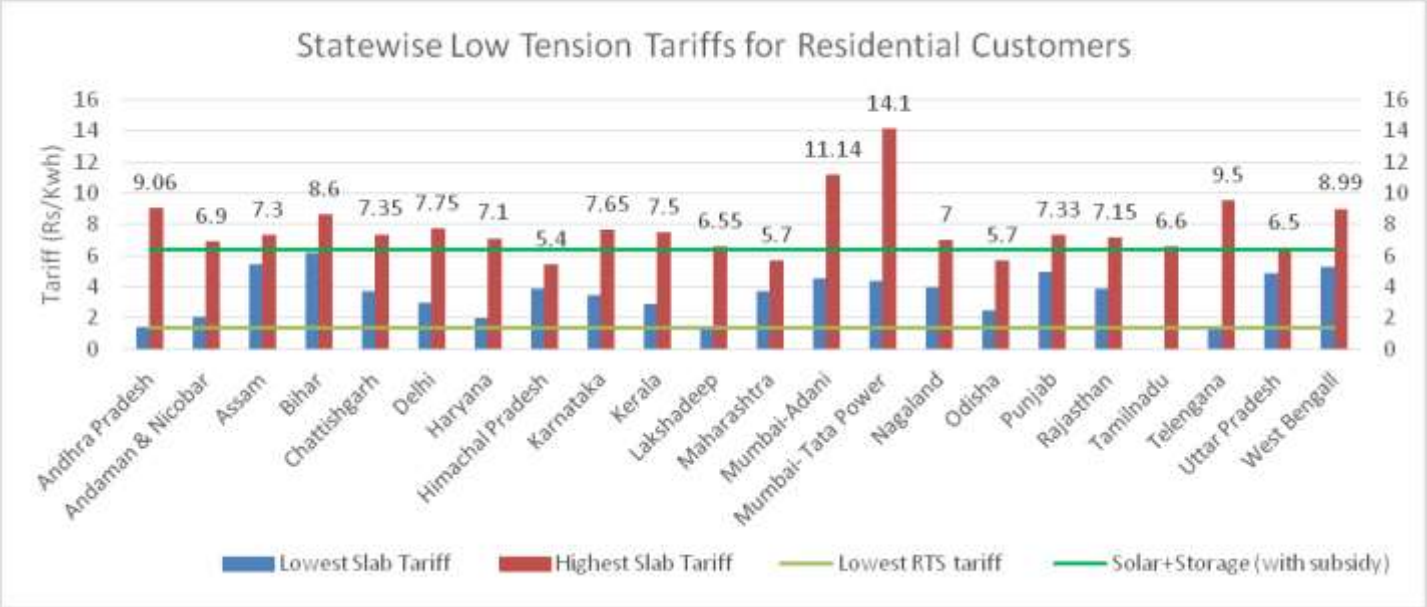
Graph 2. Large scale solar projects Tariffs Vs NTPC average Tariff (Annual)



Source: MNRE, NTPC Annual Reports, CARE Ratings

In the past seven years, lithium-ion battery prices have plummeted by 80% from $800 per Kwh in 2010 to $176 per Kwh in 2018. For the past two years, decline in battery pack prices was driven by technology improvement in terms of energy density and economies of scale. As per the BNEF, learning rate for lithium-ion battery is 18 per cent i e for every doubling of cumulative volume, 18% reduction in price. Meanwhile, solar tariff has fallen from INR 7.49/Kwh in 2011 to INR 2.44/Kwh in 2018. Solar tariffs discovered in auction during 2017 and 2018 were lower than NTPC's average tariff of INR 3.23 during FY18. In India, electricity for the residential sector is highly subsidised and price of grid power is lower than solar power for residential buildings with low consumption. As per the tariff orders of states, grid tariff is in the range of INR1.35-14.1/kwh per unit depending on monthly consumption and state and average tariff of NTPC was INR 3.23 /KWh. The difference between grid and levelized cost of energy of RTS with storage back up is impeding the large scale adoption of RTS. However, these two are converging very fast and will provide a fillip to energy storage systems. Business models, which can provide value proposition to customers by taking the advantage of falling prices of modules, battery packs and subsidies may disrupt the market.

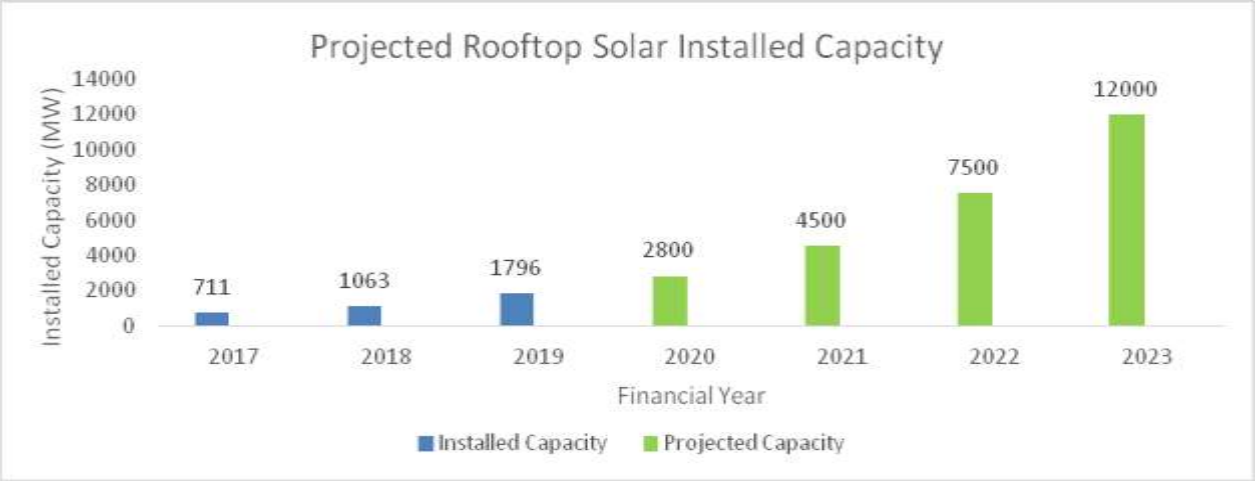
Graph 3. Comparison of State-wise Grid Tariffs and LCOE Solar PV plus Battery storage



Source: Tariff Orders of states, CARE ratings

Government of India's target of 40GW of solar-power through roof-top installations by the year 2022 would provide fillip to growth of energy storage sector. The 40GW target is to be achieved through solar installations on rooftop space of residential, commercial, industrial, government, academic institute buildings. As per the MNRE, grid connected roof-top solar installations stands at around 1.85 GW as on 30th April 2019. Gujarat has the highest installed rooftop solar capacity in India of 346 MW followed by Maharashtra at 186 MW, Maharashtra at 184 MW, Rajasthan at 154 MW and Tamil Nadu at 143 MW. Out of total installed capacity, Industrial and commercial consumers account for 70% whereas residential customers account for less than 10% largely on account of upfront costs and lack of awareness. Speedy sanction of subsidies and availability of financing to residential consumers will provide much needed impetus to growth of rooftop solar in the untapped residential segment. Recently, government has approved CFA of Rs.11,814 crore in the form of subsidies to residential customers and incentives to state power distribution companies (implementing agency) for development of 38 GW under phase II of rooptop solar programme by 2022. CARE believes that these measures will kick start growth in RTS. CARE expects that RTS will add approximately 9-10 GW by 2022 and out of it, at least 5 to 10% will have back up with batteries.

Graph 4. RTS installed capacity and projected installed capacity



Source: MNRE, CARE Ratings

Business models of energy storage sector can be broadly classified as front-of-the-meter (utility side) and behind-the-meter (consumer side).

1. **Consumer side business models:**

a) Residential: In most of the states, grid tariff for residential customers is much lower than Rooftop Solar PV levelized costs. Thus, further innovation and cost reductions will tap this segment. RTS market is currently dominated by capex model but strong growth is expected from renewable energy service company (RESCO) model wherein RESCO funds, installs and operates and enters into long term power purchase agreement with customers.

b) Industrial and Commercial: Industrial consumers could more readily find economic benefit from investment in solar as grid tariffs are higher than levelized cost of energy for industrial consumers and tax incentive in the form of accelerated depreciation of forty per cent is available for them. Commercial entities who are highly dependent on diesel generators or in remote areas without grid access are potential consumers for the energy storage sector. Telecom towers, petrol pumps, academic institutes, medical centres and rural banks are predominantly using solar systems with battery storage facilities. Rooftop solar power with energy storage provides relief from outages and control over generation and usage.

C) Solar micro/mini-grids: Micro/mini grids are a promising alternative to grid to supply reliable and uninterrupted electricity. Ministry of New and Renewable Energy (MNRE) targets to deploy at least 10,000 renewable energy based micro and mini grids across the country with a minimum installed renewable energy capacity of 500 MW by 2022 (taking average size as 50 kW). Since the electricity to rural households needs to be supplied during evening hours primarily, micro/mini-grids require a large battery bank to store the entire energy generated from solar PV system during day hours. This will go a long way in accelerating the energy storage market. Recently, NTPC floated two tenders for 8MW at Chidiyatapu and 17MW at Manglutan (South Andaman) with energy storage in both the projects.

2. Utility side business model:

Utility side business models depend on ownership i.e whether energy storage system (ESS) is owned by generator or transmission licensees. In India, first grid-scale lithium-ion battery energy storage system was commissioned in February, 2019. It is located at a substation owned by Tata Power Delhi Distribution Ltd. The facility is owned and operated by AES Corporation and Mitsubishi Corporation, who have jointly constructed the project. This project will pave the path for wider adoption of grid-scale energy storage technology across India. Storage would address key issues like peak load management, frequency regulation, system flexibility and reliability of the network. Battery storage can help reduce the ramping capacity needed to start thermal plants, integrate variable renewables by smoothing their output to the grid and in general provide critical flexibility to the grid as storage can be located anywhere in the network and it would provide flexibility to set up battery storage at outskirts of cities. Recently, The Madhya Pradesh Power Management Company (MPPMCL) has issued Expression of Interest (EoI) for executing energy storage projects (500 MW) in the state of MP. The EoI also allows participants to install micro-grid projects with batteries for grid stabilisation.

3. Aggregator business model:

In this model, third party owns solar and storage system and sells power to home owners. Homeowner pays as per the power purchase agreement (PPA) terms and conditions. Aggregator takes up the role of aggregating thousands of energy storage systems and provides service. Recently, Andhra Pradesh Eastern Distribution Company Ltd (APEDCL) has launched a scheme which involves installation of customer owned grid connected solar rooftop systems with EMI partly shared by state discom on NPV neutral basis. Utility will act as a demand aggregator and furthermore finance these projects. Consumer will have to pay EMI equivalent to their present utility bills during the tenor of loan and discom will pay remaining amount of EMI. In case, discom pays some amount during loan tenor, it will continue to collect EMI from consumer post loan tenor till the time it collects equivalent amount on NPV neutral basis. This model addresses risks such as upfront capital cost, higher perceived default risk of loan etc. Successful implementation of this scheme will reduce subsidy burden as target customers are subsidized low-end residential customers.

Table 1. Key drivers of energy storage models

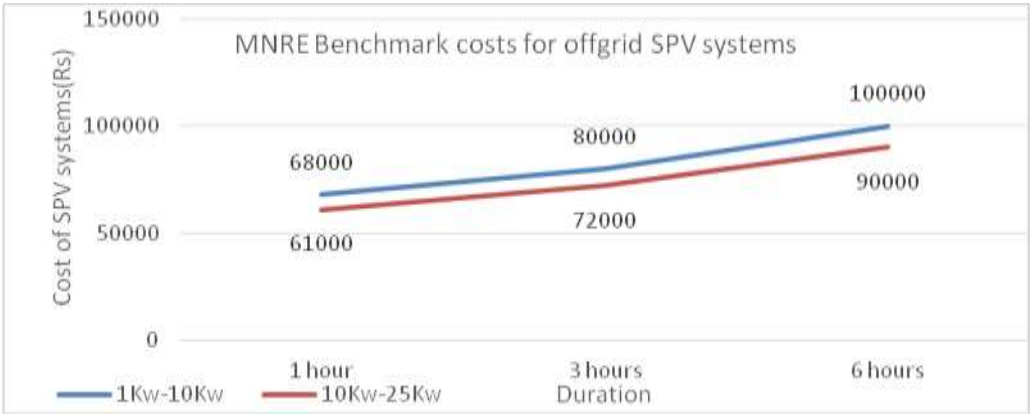
	Standalone	Residential (PV+Storage)	Commercial (PV+Storage)	Utility (PV+Storage)	Transmission & Distribution
Energy arbitrage	✔			✔	✔
Frequency regulation	✔			✔	✔
Spinning reserve				✔	✔
Transmission & Distribution deferral					✔
Bill management		✔	✔		
Backup power		✔	✔		

Source: CARE Ratings

Project Economics of Solar PV plus battery storage:

Decline in battery prices were driven largely by smartphones and followed by the automotive sector. Further reduction in costs would be driven by improvements in storage technologies like increase in energy density, economies of scale and cost innovations. Cost of the battery depends on power output and energy capacity ratio. Battery capacity is measured in terms of Kw of power and Kwh of energy capacity. Power rating specifies the instantaneous demand requirement that it is able to supply whereas energy capacity specifies total amount of energy that the battery is able to store. The battery cost per Kw will increase as duration of battery increases. Inverter cost remains constant per constant power size irrespective of battery duration. Similarly, transmission line costs are constant per constant power size. Balance of systems, EPC costs and margins are directly proportional to cost of lithium-ion power capacity.

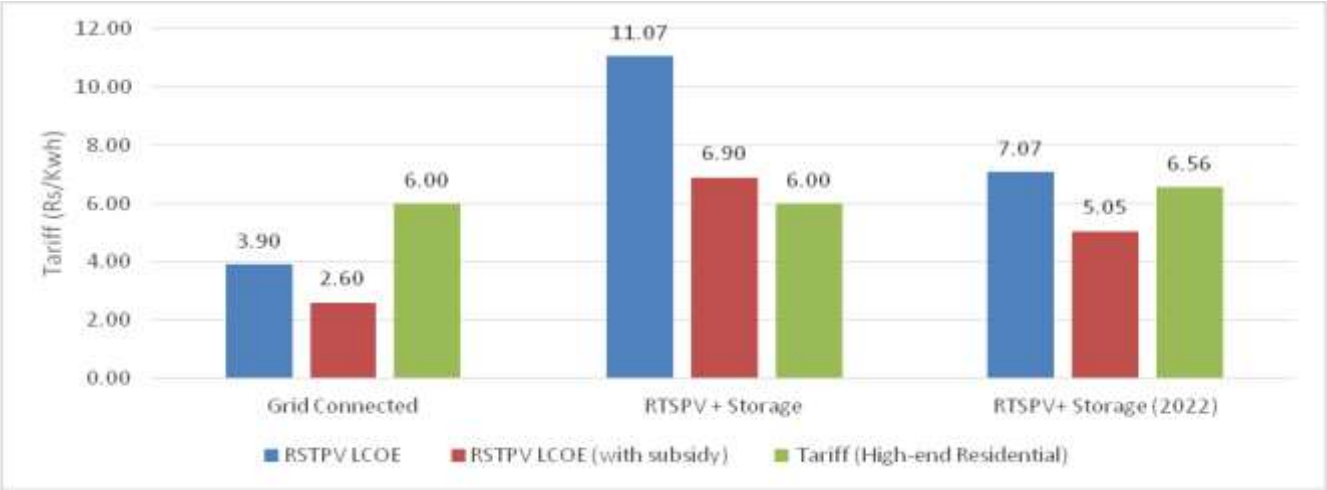
Graph 5. MNRE benchmark costs (FY19) for off-grid SPV systems Vs Duration of battery



Source: MNRE, CARE Ratings

MNRE benchmark price of on grid systems is at 60 Rs/Wp for capacities in the range 1kw-10kw and off-grid solar systems is at 100 Rs/w whereas benchmark costs of CERC/SERCs for on grid Solar PV system are in the range of 35 to 40 Rs/Wp for capacities above 1 MW. Higher capacities will have economies of scale and thus prices are much lower compared to capacities in the range of 1 kw-10 kw. An off-grid solar system is best suitable for residential customers who witness frequent outages. Off-grid solar systems provide energy self-sufficiency with the help of ESS. Off grid solar systems are cost-effective depending upon consumption of power, location, outages and subsides. If residential customer consumes 10 to 15 units per day, then tariff would be in the range of INR6 to INR10 per unit depending upon the state in which he resides. On an average, 1 Kw solar panel can produce 4 to 6 units (assuming 19% CUF) depending upon irradiation and quality of panels. Solar modules of 3kw will be cost-effective for consumption rate of more than 10 to 15 units per day. Furthermore, sizing of inverter and battery will play a crucial role in achieving optimum cost levels. Battery storage capacity is equivalent to watts-hours (volts X Ah). Currently available, a 12 volt battery rated 150 Ah stores 1.80 Kwh of energy. However, battery loses some energy during charging or discharging and batteries can't be fully discharged. Assuming, 80% of depth of discharge and inverter efficiency of 95%, battery can store 1.368 Kwh. For an average load of 2000 watts (peak load is 3000 watts for 3 kw) and 6 hours of back up, battery should have a capacity to store 12 Kwh of energy. Battery capacity required for storing 12 Kwh is equivalent to 12/1.368 (rounding off to 9) number of 150 Ah size batteries. Inverter efficiency is typically 85 to 95% and one can opt for 3.5 Kw invertor.

Graph 6. Comparison of LCOE of business models



Source: CARE Ratings

Table 2: Assumptions

Particulars	Solar PV capex	Battery Capex
Life Cycle	25 years	5 years
Debt equity	70:30	70:30
Loan tenor	12 years	5 years
Interest	10%	10%
Return on equity (Post-tax)	14%	14%
Degradation	0.7%	
Product specifications	Multi-Crystalline module	Lithium-ion, battery backup 6 hrs
Depreciation	5.28% for first 12 years and 2.04% for next 13 years	10% per year
O&M	INR 600 Per Kw	

Table 3: Battery specifications

Battery Sizing (2000 units of consumption)	
Solar panel	3kw
Batteries for 6 hrs backup	9X 150 Ah
Invertor	~3.5 Kw
Depth of discharge	80%
Invertor efficiency	95%
Guarantee	5 years (5X365 cycles)

Source: CARE Ratings

Table 4. Cost of storage for different durations based on existing MNRE benchmarks

Subsidy/Decline in costs	Duration		
(LOCE in INR/Kwh)	**6 Hours**	**4.5 Hours**	**3 Hours**
0%	7.17	5.37	3.58
20%	5.73	4.30	2.87
30%	5.02	3.76	2.51
40%	4.30	3.22	2.15
50%	3.58	2.69	1.79

Source: CARE Ratings

Based on latest CERC/SERCs benchmarks of RTSPV levelised cost of energy for RTSPV plus storage with back up of 6 hours **is approximately INR 11 per unit**. And the same would come down to INR 7.50 per unit with a backup of 3 hours. At present, LOCE of solar plus storage is already economical for commercial and industrial category. Furthermore, proposed manufacturing facilities of batteries along with incentives, would bring down cost of storage.

Electricity Storage in other countries: Germany had pushed solar storage by providing subsidies during the period 2013 to 2018. One out of every two orders for rooftop solar panels in Germany is sold with a battery storage system. Battery prices have plummeted so dramatically that Germany has now removed subsidies. In the U.S, California has been among the fastest adopters of energy storage in the world. California became the first U.S. state to mandate solar rooftop panels on new homes. California will add about 1.3 gigawatts of energy storage to the grid by 2020 to help renewable integration.

Table 5. Key drivers of RTS in successful implementation (International)

Country	Ownership	Implementation model	Incentive
Germany	Customer Owned	Gross metering	Feed-in-Tariff/Subsidies
California	Customer Owned	Net metering	Net Metering/ Self Generation Incentive Program
Japan	Customer Owned	Net metering	Net metering/Subsidies

Source: CARE Ratings

Utility scale storage projects in India: Recently, AES Corporation and Mitsubishi Corporation commissioned first grid large scale lithium-ion battery storage facility of 10MW / 10MWh in Delhi. Furthermore, Solar Energy Corporation of India (SECI) announced a tender for 1.2GW of Inter State Transmission System (ISTS)-connected solar to be combined with 3,600MWh of energy storage. In another tender for 1.2GW of ISTS-connected wind-solar hybrid projects, the government has included energy storage capacities in hybrid projects. Central government subsidies to residential customers coupled with recent fall in module prices has made renewable energy competitive compared to grid power for commercial & industrial customers and high-end residential customers. Central government plans to set up around 50 GW of battery manufacturing capacity with fiscal incentives which would further reduce cost of storage. CARE expects traction in utility scale storage projects in the current financial year.

Table 6. Energy storage projects pipeline

Company	**Capacity**	Location	**Current status**
PGCIL	1 Kw SPV, 250 Kwh	Puducherry	Commissioned
AES (Tata Power)	10 MWh	Delhi	Commissioned
NTPC	2 MWh	Port Blair	Under implementation
NTPC	17 MW SPV, 6.8 MW/6.8 MWh	South Andaman	Under implementation
NTPC	8 MW SPV, 3.2 MW/3.2 MWh	South Andaman	Under implementation
SECI	160 MW (120 MW Solar + 40 MW Wind) 10 MW/20 MWh	Andhra Pradesh	Under implementation
SECI	2 MW SPV, 1 MWh	Kaza	Tender stage
SECI	2X1.5 MW SPV, 2 X 0.75MW/2.5 MWh	Leh	Tender stage
SECI	14 MW SPV, 42 MWh	Ladakh and Kargil	Tender stage
SECI	1.2 GW SPV, 3.6 GWh	Across India	Tender stage

SECI	100 MW SPV, 150 MWh	Ananthapuram	Tender stage
SECI	100 MW SPV, 150 MWh	Talaricheruvu	Tender stage
SECI	20 MW SPV, 60 MWh	Lakshadweep	Tender stage
MPPCL	500 MW SPV, 8 hrs back up	MP	Tender stage

Source: CARE Ratings

Conclusion: Energy Storage is reaching an inflection point and is poised to give a big boost to India's ambitious solar energy target of 100 GW by 2022. Due to cost barriers, tenders announced so far are facing delays. However, with declining cost of Solar PV systems and battery storage, electricity generation from rooftop solar installation/utility scale projects is already economically viable for some consumers. Going forward, policy makers should devise business models which will benefit all stake holders. Initial growth in RTP can be achieved by incentivising utilities, providing viability gap funding/subsidies to storage solutions, policy enforcement, providing flexible financing and creating awareness among consumers.

In this new solar ecosystem, consumers will have more direct control over power generation, leading to a big difference in our perception about renewable energy. Energy storage technologies like solar batteries provide utilities and energy users more flexibility in the way that they generate and use electricity. This new solar ecosystem assures self-sufficiency in addition to ecological benefits.

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