2020

SOLAR PLUS ENERGY STORAGE

Feasibility of Behind-the-Meter systems for LT consumers in Tamil Nadu

AurovilleConsulting

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FOREWORD

The electricity grid is a complex system in which supply and demand must be equal at any given moment. The intermittency of renewable energy sources, such as solar and wind, and variability of demand creates a substantial mismatch between energy produced and required. A transition towards a decarbonized and sustainable energy future will be incomplete without energy storage solutions. Energy storage plays an important role in balancing supply and demand, and helps to create a more flexible and reliable electricity grid. If we want to source 100% of our electrical energy from renewables by 2050, significant investment in energy storage is necessary. This report focuses on the financial feasibility of investing in solar plus energy storage (lithium-ion) on the consumer side of the service connection (behind-the-meter) for selected LT consumer categories in Tamil Nadu.

- **TRANSITION TOWARDS GRID-INTERACTIVE ENERGY STORAGE**

Consumers have been installing behind-the-meter (BtM) energy storage systems for several decades. This is driven by frequent power outages across the country. These energy storage systems, typically uninterrupted power supply (UPS) systems, operate in a grid-passive mode to ensure the continuous availability of power in the event of service interruption. In India, annually over 5 GWh of lead-acid batteries are sold predominantly for residential power back-up applications (KPMG, CES 2018).

Many buildings have two electrical circuits for their internal electricity load. One circuit for the essential load, such as fans and lights, that can be supplied from a battery storage system in the case of a power outage. And a second circuit for non-essential load for which, in case of grid interruptions, no back-up supply is available.

The presence of grid passive BtM battery storage systems along with the existing electrical circuits at the building level and the declining cost of solar PV and battery storage solutions are expected to propel a distributed solar plus energy storage revolution in the near future.

There are opportunities for the utilities to leverage on these developments and prepare for the grid-integration of these distributed energy sources with appropriate feed-in tariffs, market design and aggregation mechanisms.

- **INCREASING AFFORDABILITY AS DRIVER**

The cost of lithium-ion (Li-ion) battery has seen a steady decline over the past years, this trend is expected to continue for the foreseeable time. A 78% reduction in the cost of Li-ion battery pack over the 2015 cost is expected by 2030 (Schmidt et al. 2017). Consumers, in India particularly, are highly cost-sensitive. With the increasing affordability, solar plus energy storage could become a viable investment option while providing a certain degree of energy security and independence for the consumers.

- **STORAGE READY**

In March 2019, the Ministry of New and Renewable Energy (MNRE) launched its Phase II of the Grid-Connected Rooftop Solar Programme (MNRE 2019). The program aims nationwide at installing a cumulative capacity of 4 GW rooftop solar energy for domestic consumers by the year 2022. Capital subsidy of up to 40% on the benchmark cost is provided. As part of Phase II of the national program on rooftop solar, TANGEDCO plans to add 5 MW of rooftop solar capacity for domestic consumers.

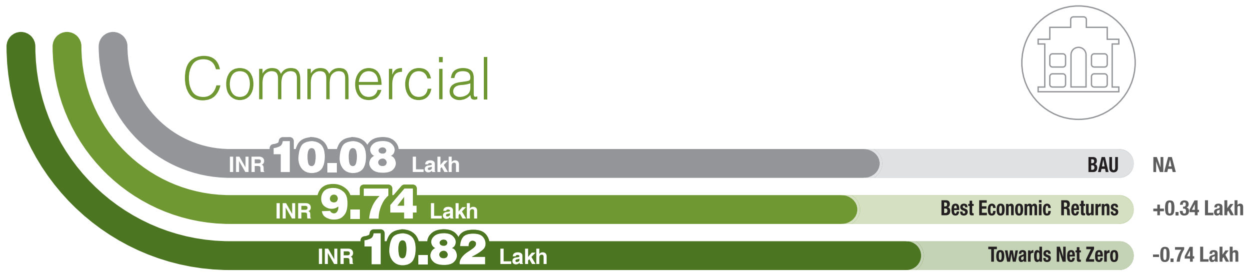
There is a unique potential to make this or subsequent schemes 'energy storage ready' by accommodating hybrid solar inverters in the benchmark cost. This will provide the consumers with the possibility to add energy storage capacity to their existing BtM solar energy system without the requirement to change the solar inverter or to invest into a separate inverter for the energy storage system.

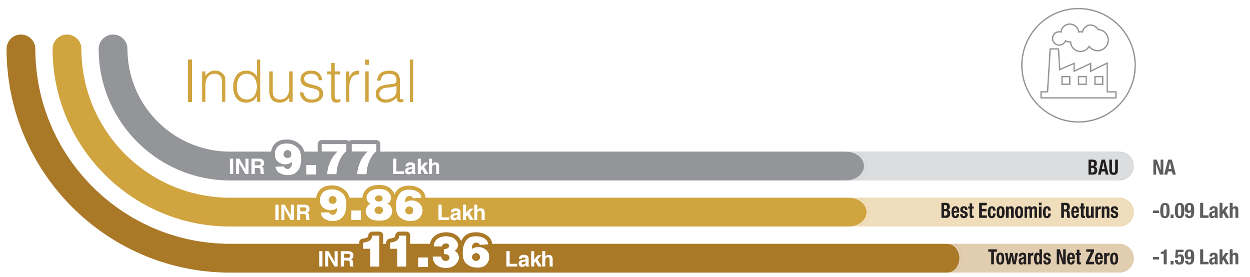
KEY FINDINGS

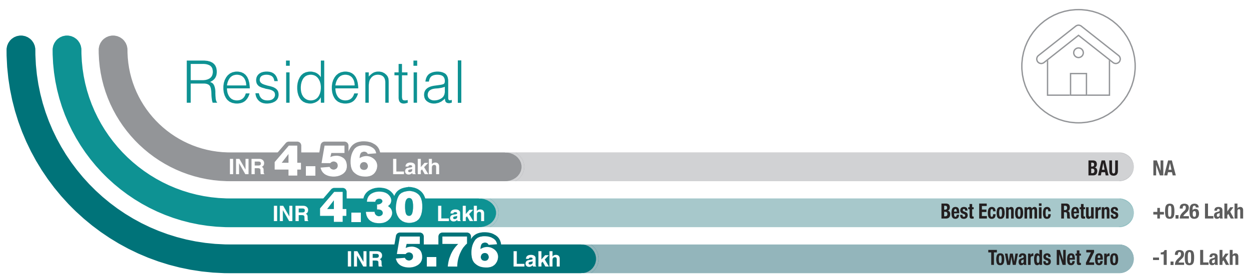
• SOLAR PLUS ENERGY STORAGE IS ALREADY A FINANCIALLY VIABLE OPTION

The 'Best Economic Returns' case for BtM solar plus energy storage, in which the solar and energy storage capacities have been sized to achieve maximum savings through bill management, results in lower electricity costs for both the residential slab IV consumer category and the commercial consumer category. For the industrial consumer category, the cost under the 'Best Economic Returns' case for BtM solar plus energy storage is marginally higher than the cost of supply from grid only. The 'Towards Net Zero' case is resulting in a higher 10-year supply costs for all 3 selected LT consumer categories, when compared to supply from grid only (Business as Usual - BAU).

Discounted cost of electricity supply over 10 years

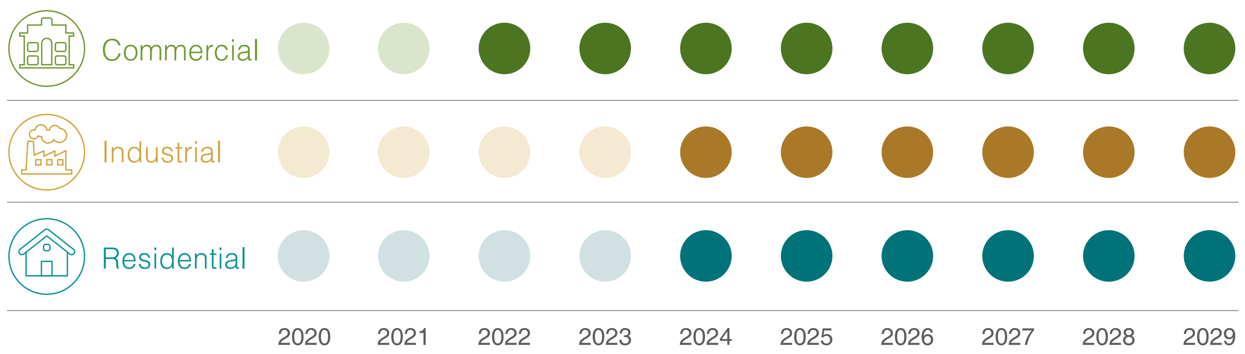






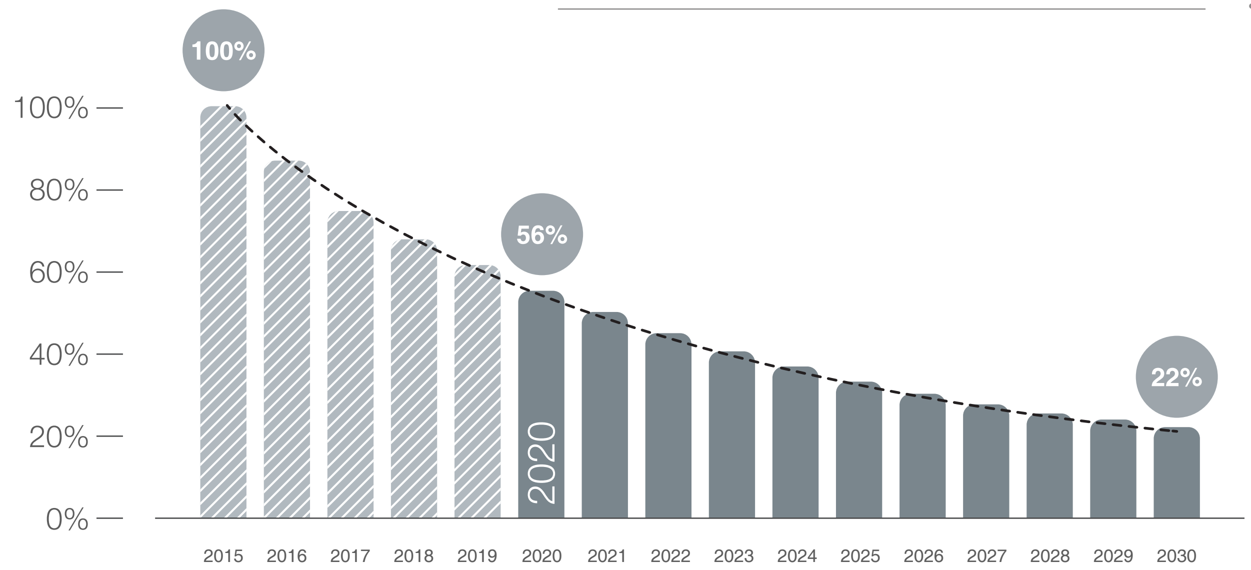
• 'TOWARDS NET ZERO' WILL BE FINANCIALLY VIABLE FOR THE COMMERCIAL CONSUMER CATEGORY FROM 2022 ONWARDS

Financial viability of BtM solar plus energy storage by year of investment for the 'Towards Net Zero' case[1]



• COST OF LI-ION BATTERY STORAGE TO REDUCE BY 78% IN 2030 OVER THE 2015 VALUE

Battery Pack Cost Reduction (%) 2015 to 2030



Li-ion battery pack cost has reduced significantly over the last five years. As of 2020, it is at 56% of the 2015 cost. By 2030 the battery pack cost is further expected to drop to 22% of the 2015 cost (Schmidt et al. 2017).

[1] *For residential consumer category, MNRE subsidy is considered.*

01 ASSUMPTIONS

- **Consumer category**

Are defined as per the existing schedule of tariffs in Tamil Nadu. For the domestic consumer category only the slab IV tariff (above 500 units bi-monthly), the highest domestic tariff slab, is simulated for the financial feasibility analysis (TNERC 2017).

- **Bill management**

Bill management has been considered as the only revenue stream for BtM solar plus energy storage. Considering the current low net feed-in tariff (INR 2.28 per kWh) (TNERC 2019a) for consumer category solar energy, and the absence of a dedicated feed-in tariff for solar plus energy storage systems, the BtM solar plus energy storage capacity sizing and dispatch strategy is focused around maximizing the self-consumption and reducing grid export. As fixed/demand charges for all LT consumer categories in Tamil Nadu are billed as a fixed amount per kW/month of sanctioned load, no financial savings on load reduction occur through BtM systems. As of 2019, no time of day (ToD) tariffs are available for LT consumers categories in Tamil Nadu.

- **Best Economic Case**

Under the 'Best Economic' case BtM solar and energy storage system for the respective consumer categories are sized to achieve maximum financial gains through bill management over a 10-year time period. Solar capacity has been sized to meet the instantaneous load, during sunshine hours. Any surplus solar energy is being stored and dispatched whenever required. Capital subsidy available by MNRE for domestic rooftop solar is considered and assumed to be constant for the financial feasibility analysis for the residential sumer category.

- **Toward Net Zero**

Under the 'Towards Net Zero' case the BtM solar plus energy storage system is sized to achieve a Net Zero energy balance of the selected LT consumer categories in year 1.

- **Electricity consumption year 1**

The year 1 electricity consumption is calculated based on the state's average annual consumption per service connection point of each selected LT consumer category using 2019 consumption data (TNERC 2017, TNERC 2019b, Energy Department of Tamil Nadu 2020).

- **Average annual increase in electricity consumption**

This has been derived by calculating the average annual growth rate for the respective consumer categories from 2011 to 2019 (TNERC 2017, Energy Department of Tamil Nadu 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, 2019 & 2020).

- **Solar energy penetration**

The percentage of gross solar energy generation on total electricity consumption in year 1.

- **Battery dispatch strategy**

Li-ion battery (lithium iron phosphate) is used for energy storage in the analysis. One discharging cycle per day was assumed. The objective was to optimize solar energy self-consumption and minimize grid import. The battery is charged from the surplus solar energy only. Export from the battery storage system to the grid has not been considered.

- **Levelised cost of solar and storage (LCOSS)**

The LCOSS value has been calculated using the tool 'Levelised Cost Calculator for Distributed Energy Resources V1.0' (Auroville Consulting 2020). LCOSS values are used for financial analysis.

- **Net feed-in tariff**

Surplus solar energy exported to the grid is being compensated at a net feed-in tariff of INR 2.28 per kWh (TNERC 2019a). For future years the same solar net feed-in tariff as per TNERC (2019a) has been assumed.

- **Tariff escalation**

An annual consumer tariff escalation of 5% has been assumed.

- **Time period**

The cost-benefit analysis was undertaken for a 10-year time period.

- **Discount factor**

For the net present value calculations a discount factor of 9.53% has been used.

- **Breakeven investment year**

It indicates the year in which investing into BtM solar plus energy storage results in lower electricity costs over 10 years as compared to grid supply only (BAU case). In the analysis for the breakeven investment year an annual tariff escalation, consumer load growth, resizing of solar PV (to match the base year electricity consumption), resizing energy storage capacity (to match the ratio) and a reduction in the capital cost of BtM solar plus energy storage are considered.

02 COMMERCIAL CONSUMER

Electricity consumption 2020:	Average annual electricity increase:	Tariff:	Annual tariff escalation:
9,523 kWh	11.88%	8.05 INR/kWh	5%

A Best Economic Returns

63% SOLAR ENERGY PENETRATION

LCOSS 7.52 INR/kWh

System Capacities

Technology	Capacity	Ratio
Solar PV	4.00 kW	1.00
Battery energy	2.50 kWh	0.62
Battery power	1.25 kW	0.31

B Towards Net Zero

100% SOLAR ENERGY PENETRATION

LCOSS 8.42 INR/kWh

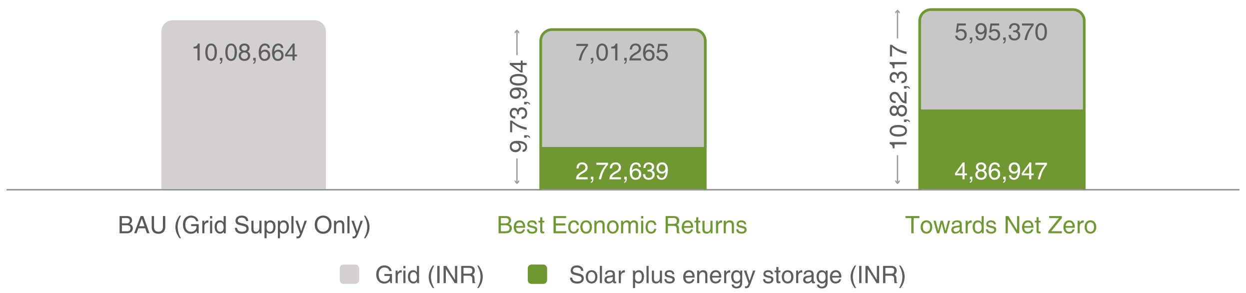
System Capacities

Technology	Capacity	Ratio
Solar PV	6.40 kW	1.00
Battery energy	5.00 kWh	0.78
Battery power	2.50 kW	0.39

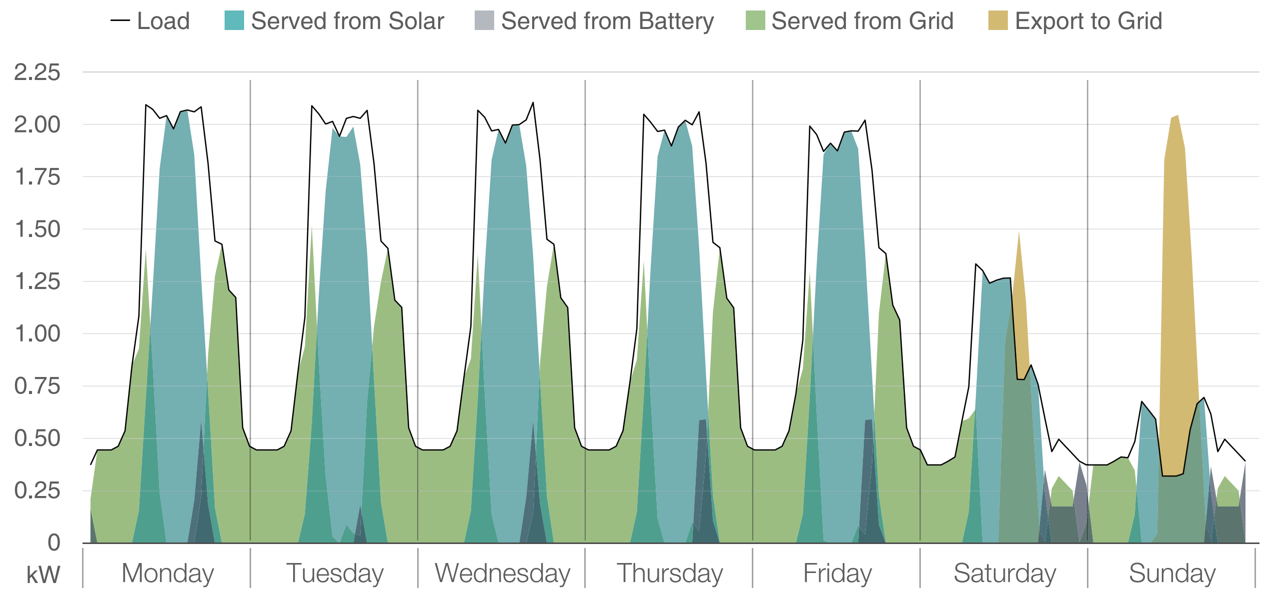
- **Solar Plus Energy Storage A Winning Proposition**

Discounted cost savings for the ‘Best Economic Returns’ case over a 10-year time period are expected to be INR 34,760. An investment into BtM solar plus energy storage in 2020 under the ‘Best Economic Returns’ case therefore presents a financially viable energy sourcing option for the commercial consumer category. Whereas for the ‘Towards Net Zero’ case the results show an increase in electricity cost over 10 years as compared to grid supply only by INR 73,653.

10-year discounted cost of electricity



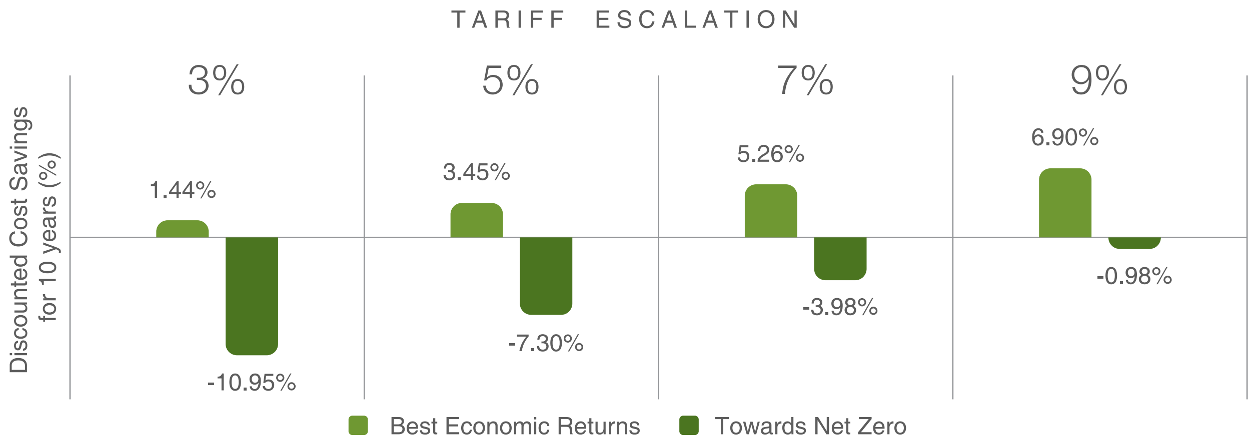
Example of a weekly dispatch in May 2020 for the ‘Best Economic Returns’ case



- ## Future tariff escalation as key variable

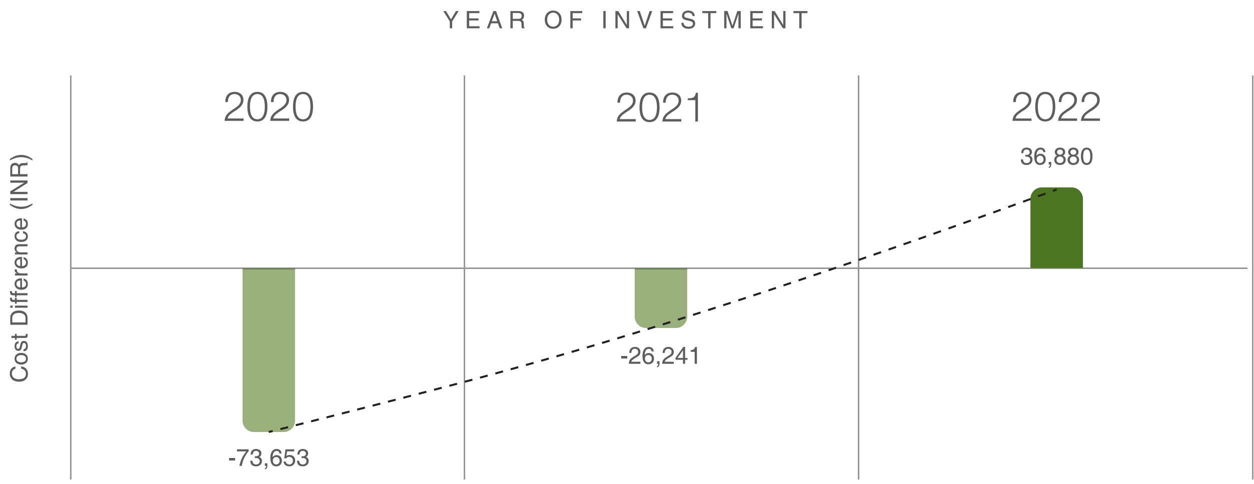
With bill management as the currently single available value stream for BtM solar plus energy storage system, future consumer tariff escalation is a key variable for its financial feasibility. As Tamil Nadu has not seen a consumer tariff revision since 2016, a steeper tariff escalation can be expected in the near future. With an average annual tariff escalation of 9% for the commercial consumer tariff the 'Best Economic Returns' case is expected to result in 10-year cost savings of 6.90% over the BAU case and the cost for the 'Towards Net Zero' case is just marginally higher than the supply from grid only.

Sensitivity analysis for different tariff escalation rates



- ## Investing into the 'Towards Net Zero' case is viable from 2022 onwards

10-year cost difference between BAU and 'Towards Net Zero' case by the year of investment



03 INDUSTRIAL CONSUMER

Electricity consumption 2020:	Average annual electricity increase:	Tariff:	Annual tariff escalation:
13,109 kWh	9.59%	6.35 INR/kWh	5%

A — Best Economic Returns

55% SOLAR ENERGY PENETRATION

LCOSS 7.23 INR/kWh

System Capacities

Technology	Capacity	Ratio
Solar PV	4.80 kW	1.00
Battery energy	3.00 kWh	0.63
Battery power	1.00 kW	0.21

B — Towards Net Zero

100% SOLAR ENERGY PENETRATION

LCOSS 8.02 INR/kWh

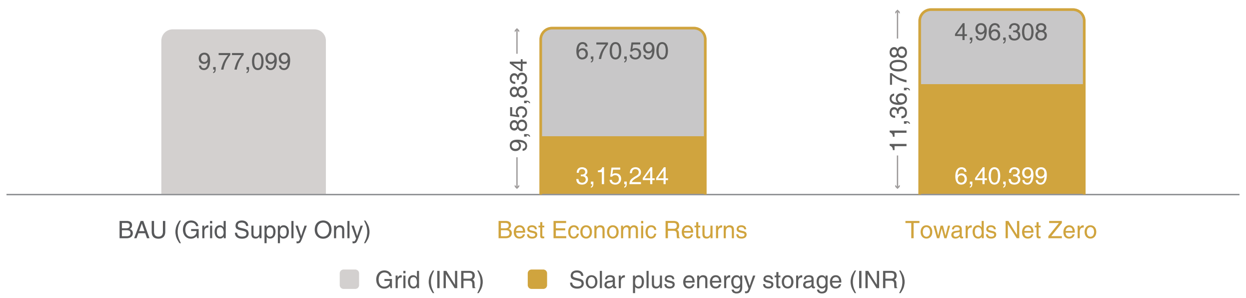
System Capacities

Technology	Capacity	Ratio
Solar PV	8.80 kW	1.00
Battery energy	7.00 kWh	0.80
Battery power	3.50 kW	0.40

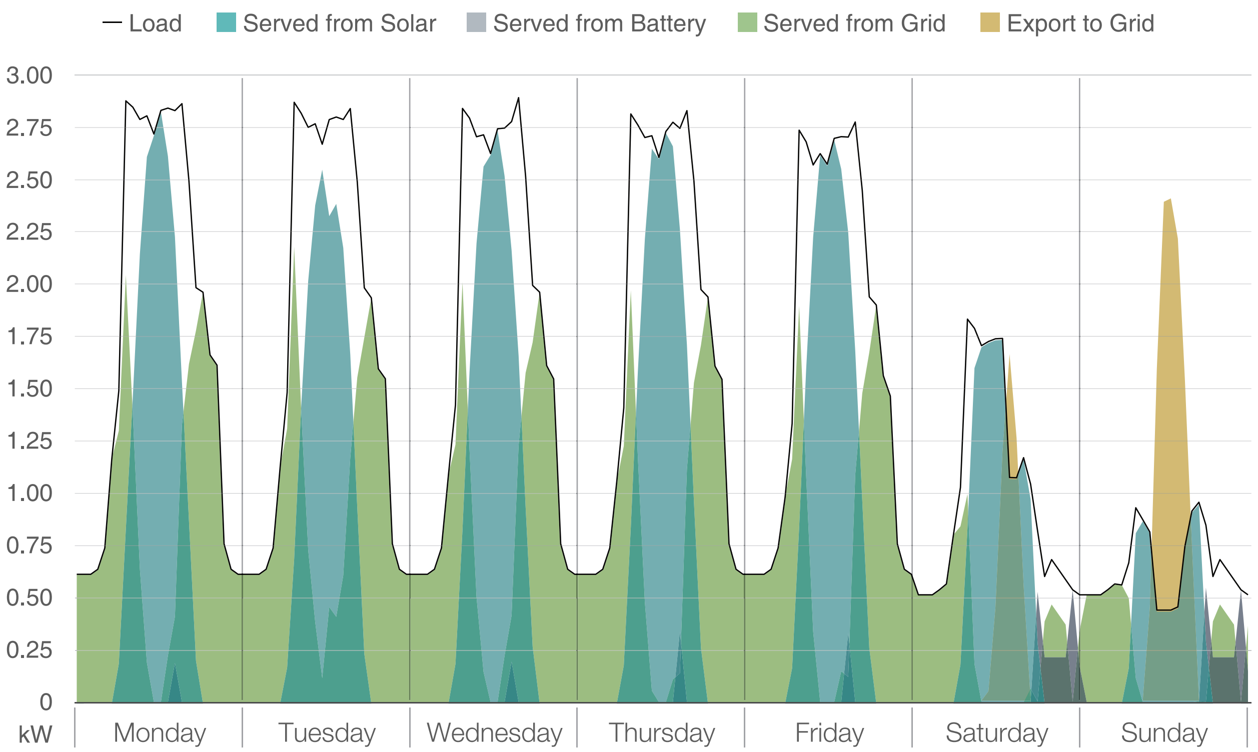
• Not yet a Winning Proposition

For the industrial consumer category, an investment into BtM solar plus energy storage in the year 2020 under the “Best Economic Returns’ case result in a marginally higher cost of supply (by INR 8,735) over a 10-year time period as compared to supply from grid only. For the ‘Towards Net Zero’ case, the results show an increase in electricity cost over 10 years by INR 1,59,608.

10-year discounted cost of electricity



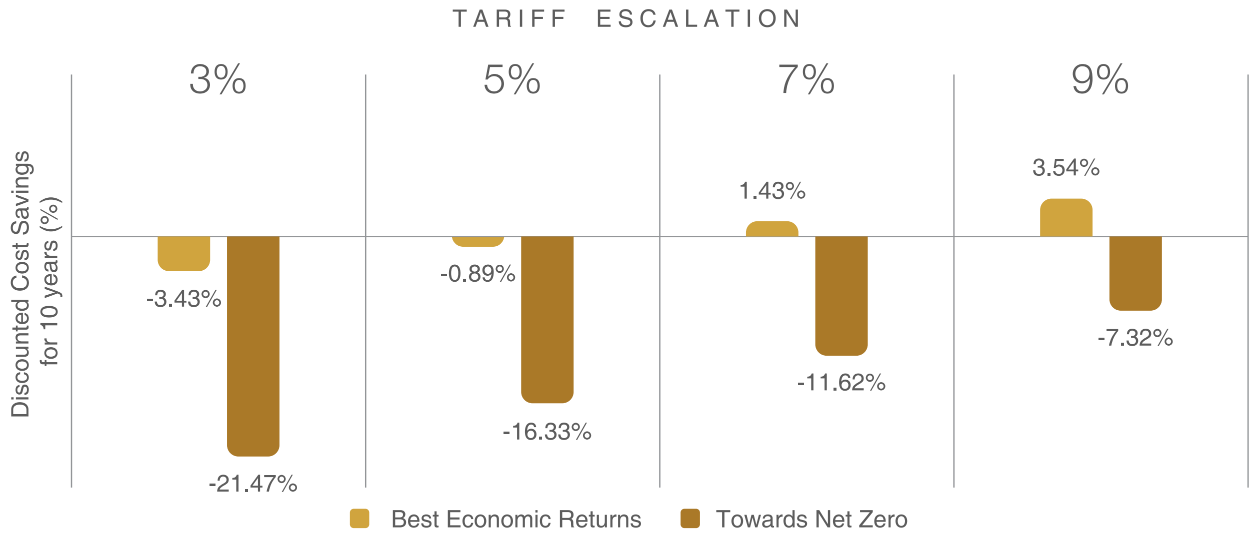
Example of a weekly dispatch in May 2020 for the ‘Best Economic Returns’ case



• Tariff escalation of 7% results in financial viability

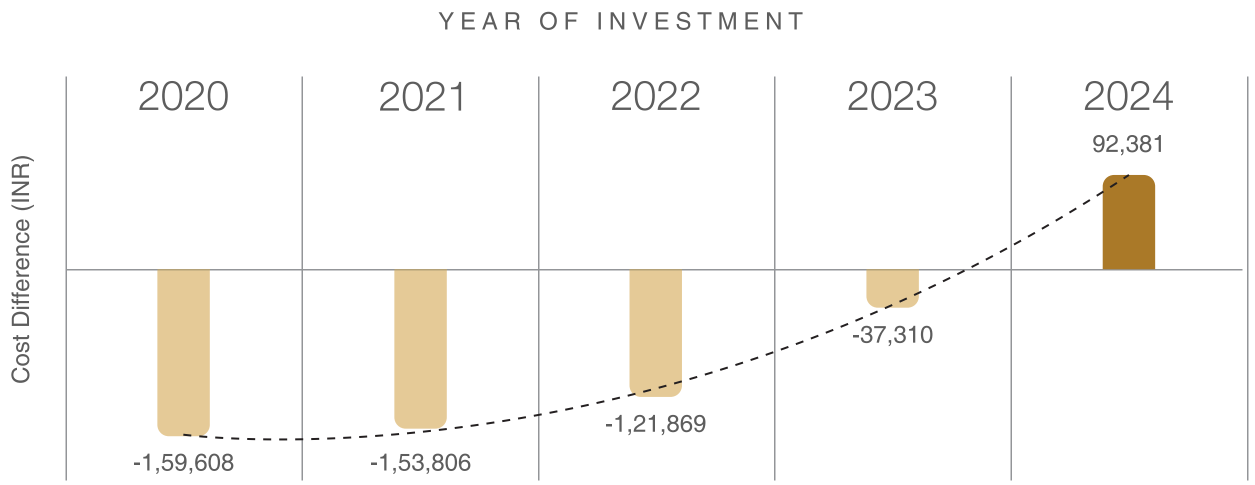
With an average annual tariff escalation of 7% or higher deploying BtM solar plus energy storage under the ‘best economic returns’ case results in a lower 10-year electricity supply costs for the industrial consumer category as compared to the cost of supply from grid only (BAU case).

Sensitivity analysis for different tariff escalation rates



• Investing into the ‘Towards Net Zero’ case is viable from 2024 onwards

10-year cost difference between BAU and ‘Towards Net Zero’ case by the year of investment



04 RESIDENTIAL CONSUMER

Electricity consumption 2020:	Average annual electricity increase:	Tariff:	Annual tariff escalation:
9,523 kWh	2.25%	5.61 INR/kWh	5%

A

Best Economic Returns

44% SOLAR ENERGY PENETRATION

LCOSS **5.72** INR/kWh

System Capacities

Technology	Capacity	Ratio
Solar PV	2.80 kW	1.00
Battery energy	1.50 kWh	0.63
Battery power	0.75 kW	0.21

B

Towards Net Zero

100% SOLAR ENERGY PENETRATION

LCOSS **7.43** INR/kWh

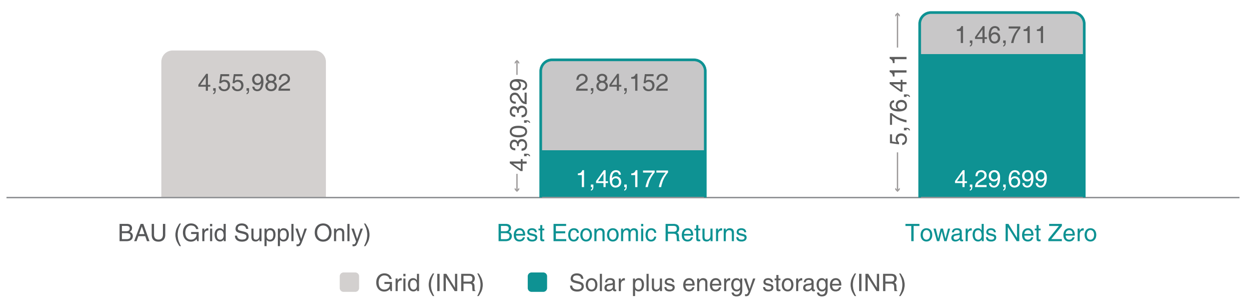
System Capacities

Technology	Capacity	Ratio
Solar PV	6.40 kW	1.00
Battery energy	5.00 kWh	0.78
Battery power	2.50 kW	0.39

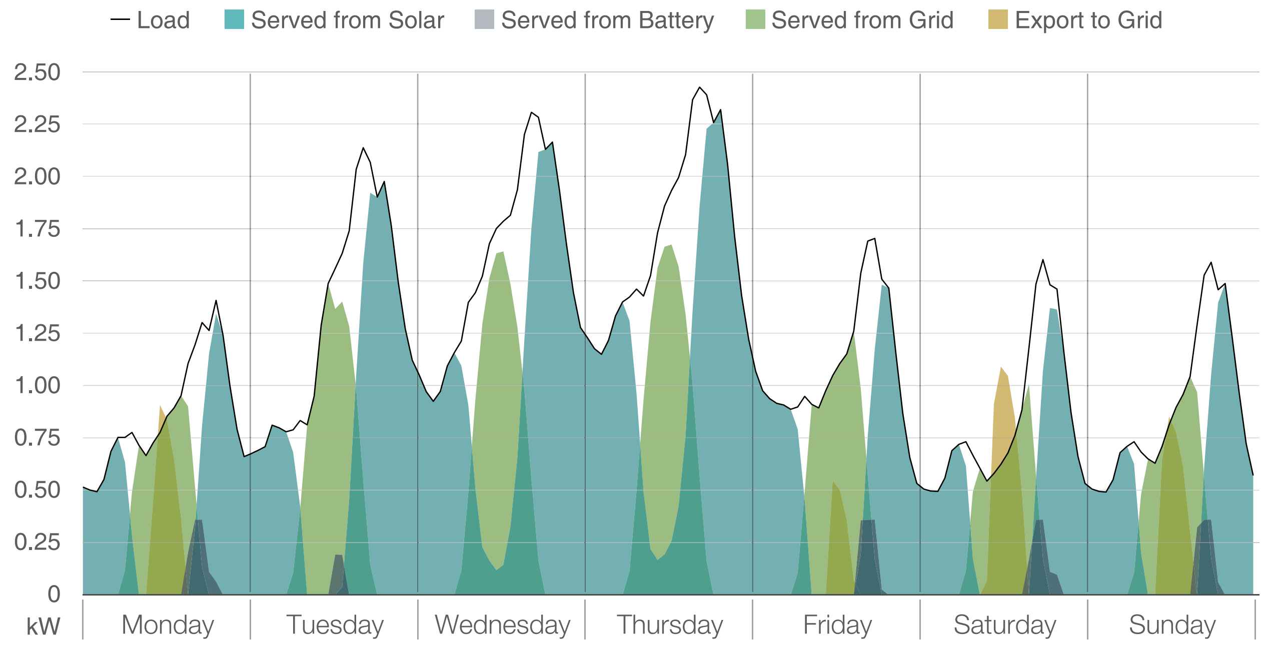
• Solar Plus Storage a Winning Proposition

Under the 'Best Economic Returns' case, an investment into BtM solar plus energy storage in 2020 is expected to result in discounted cost savings over a 10-year time period of INR 25,653. Whereas for the 'Towards Net Zero' case the results show an electricity cost increase over 10 years by INR 1,20,429. The analysis for the domestic consumer category assumes that existing capital subsidy for rooftop solar can be availed for the solar component of a BtM solar plus energy storage system.

10-year discounted cost of electricity



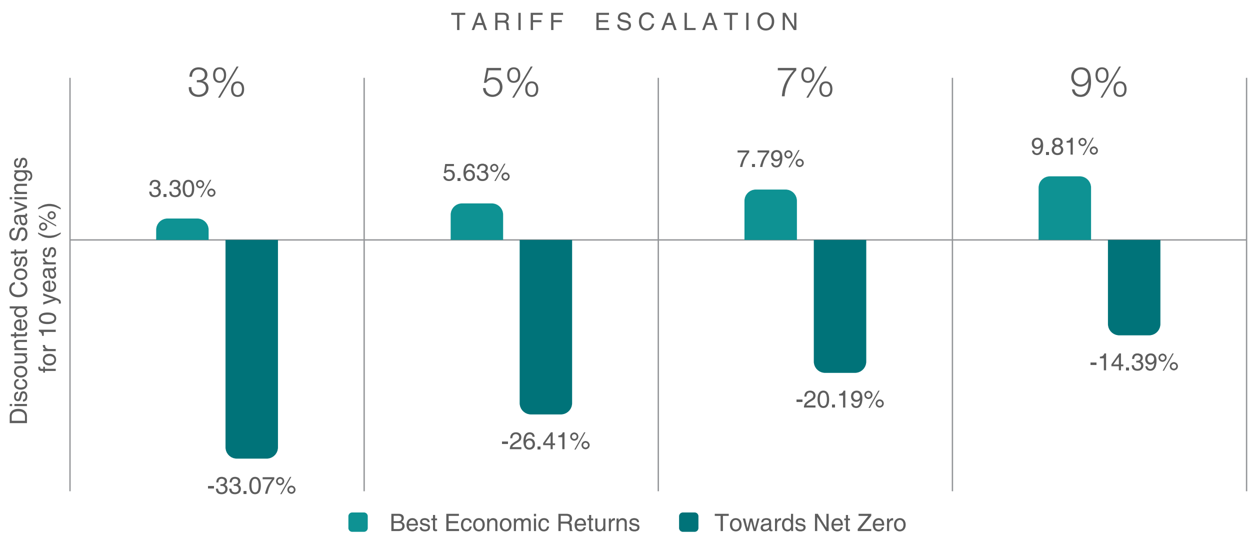
Example of a weekly dispatch in May 2020 for the 'Best Economic Returns' case



- **Future tariff escalation scenarios**

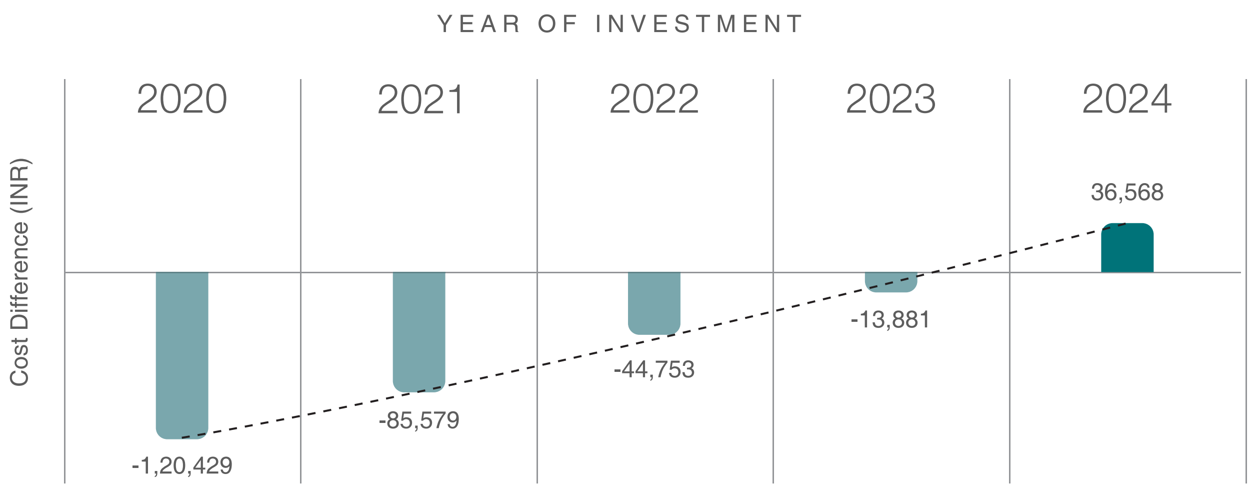
The 'Best Economic Returns' case is already a financially viable option for domestic slab 4 consumers. Higher tariff escalation will further increase the consumers' cost savings. Investing into the 'Towards Net Zero 'case in the year 2020 is not expected to result in cost savings to the domestic consumer, even with a higher tariff escalation rate of 9%.

Sensitivity analysis for different tariff escalation rates



- **Investing into the 'Towards Net Zero' case is viable from 2024 onwards**

10-year cost difference between BAU and 'Towards Net Zero' case by the year of investment



05 THE DRIVERS

- **Lack of quality power supply**

An average Indian household receives 20.6 hours of power supply from the grid (CEEW 2020). Unreliable grid supply and power quality issues (voltage, frequency and harmonics) drive consumers towards deploying power back-up solutions such as diesel generators and UPS systems.

- **High cost of existing back-up solutions**

BtM solar plus energy storage becomes an increasingly attractive alternative to these more conventional back-up systems. The kWh of electricity from diesel generators comes at a cost range of INR 16-40 per kWh (Powerline 2018). Diesel generators, though reliable and tested, are not only expensive but can be noisy, take up space, emit pollutants and have a longer response time compared to battery storage. The recent decrease in the cost of both, solar PV and Li-ion battery storage and an increasing commitment by a larger share of the population to shift towards sustainable solutions is expected to result in an increased uptake of BtM solar and energy storage systems.

- **Possibility for customization**

BtM solar and energy storage systems can be customized to meet each consumers priorities and requirements, such as bill management or reliable supply.

• CASE STUDY 1

Self-Generation Incentive Program, California

Photo credit: (ARENA 2020)

• Drivers: Reliability of supply, bill management and resiliency

The California energy storage rebate program, technically referred to as the Self-Generation Incentive Program (SGIP), was established back in 2001. Originally designed to help subsidize the costs of distributed generation, the program was updated in 2017 to encourage the deployment of energy storage (Zinaman, Bowen, & Aznar, 2020). SGIP provides an incentive as high as USD 250 per kWh for battery installation, covering the majority of the battery costs (Energy Sage 2019). SGIP funds have fueled a substantial share of the more than 400 megawatts of residential and commercial behind-the-meter batteries installed in California as of 2020 (Green Tech Media 2020).

California contributes nearly 70% of the US' installed Commercial & Industrial (C&I) storage. The C&I user's demand charges and ToD rates can make up more than 50% of the total energy bill in specific cases. Storing energy in batteries and discharging them to mitigate demand peaks and peak hours is a lucrative way of bill management (Energy Storage News 2018a).

The recent massive wildfires in California have caused rolling blackouts. In order to tackle this situation, California is shifting more than USD 100 million from the SGIP budget to help low-income communities install about 100 megawatts of behind-the-meter battery projects. This established a reliable supply of power during the crisis and contributed to a more resilient grid (Green Tech Media 2020).

06 THE BARRIERS

• Cost-Economics

The current low solar energy net feed-in tariff of INR 2.28 per kWh for behind the meter systems paired with strongly subsidized electricity tariff rates for many LT consumer categories in Tamil Nadu results in a low or negative return on investment for a substantial share of the state's electricity consumers. The economic slow-down due to Covid-19 is also expected to result in lesser investments in BtM solar plus energy storage systems.

• Regulations

The current regulations for BtM solar energy systems limit the permissible solar energy capacity at 100% of the sanctioned load of the consumers' service connection. With the integration of solar and energy storage, this limitation could become a deterrent in terms of potential BtM capacity that can be deployed by consumers.

• Tax rates

Li-ion battery systems are currently taxed by the Indian Government at 18% under its Goods and Services Tax (GST) (GST Council 2018). Solar energy systems are taxed at a GST rate of 5%. A reduction of GST from 18% to 5% for energy storage system may contribute to accelerating the deployment of BtM energy storage solutions.

07 WAY FORWARD

• Integration with Government Schemes

The inclusion of hybrid inverters in current and future rooftop solar schemes by MNRE has the potential to act as a catalyst to accelerate BtM solar and energy storage systems. All newly installed rooftop solar system under Phase II of MNRE's rooftop solar program can be made 'energy storage ready'.

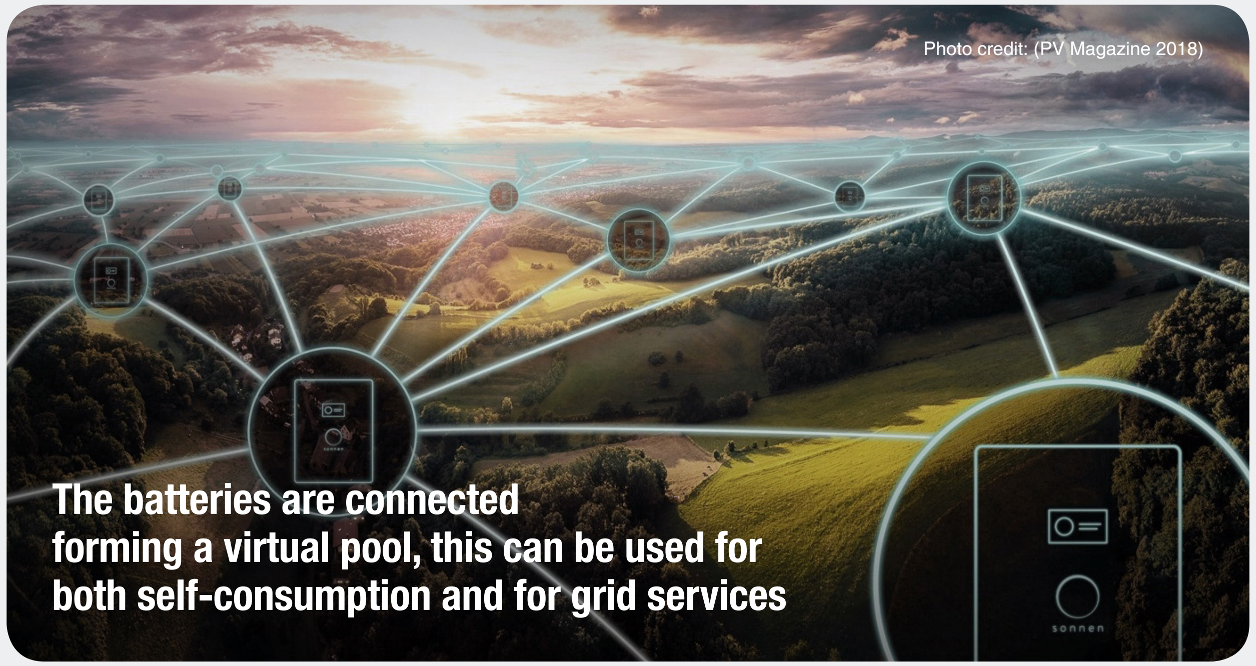
• Market Design

ToD tariffs for import and export (ideally short and high and with critical peak pricing) appear to be a low-hanging fruit in order to propel BtM solar plus energy storage systems. The design of the feed-in tariff rates will need to be fair, for both the consumers and the utilities, and reflect the actual cost of generation. The Tamil Nadu Solar Energy Policy 2019 already suggests the introduction of ToD tariffs for BtM solar and energy storage systems (TEDA 2019). The inclusion of all consumer tariff categories (HT and LT) under the net feed-in mechanisms will be required. Market design for ancillary services and aggregation of BtM solar energy and storage systems will have to be developed by the regulators. The limitation of solar energy capacity not exceeding the sanctioned load can be relaxed with the addition of battery storage system, which can propel a Net Zero scenario.

• Forward-looking regulations

Existing BtM solar and storage systems in India, are neither expected nor required to meaningfully interact with the electricity grid. Forward-looking regulations and standardized communication and control protocols will be required to leverage grid-services that can be provided by such systems. Developing such regulations proactively will create a much-needed enabling environment for BtM solar plus energy storage systems to take off.

• CASE STUDY 2
Community Based Model, Germany



• Driver - Reliability of supply, low net feed-in tariff and grid stability incentive

By the end of 2019, there were about 2,06,000 energy storage systems in homes throughout Germany, about 65,000 new residential battery solutions were installed in 2019 alone.

Sonnen GmbH contributed 20% of all residential battery systems deployed in 2019. (Renewable Energy World 2020). They have introduced a new community energy exchange program which comes with a EUR 19.90 monthly service fee and allows Sonnen customers across the country to share energy and thus potentially cut electricity costs by around 25 percent compared to standard utility rates.

During sunny days, when there is surplus solar energy generation, instead of selling solar energy to the utility, the surplus solar energy supplied a virtual energy pool that serves other Sonnen customers. For every kWh that is shared with this energy community, the consumer receives a financial compensation that is higher than the compensation offered by the utility. The price paid by the consumer when the community power is used is far less than the market price (Sonnen 2020).

This community-based model not only allows about 75% self-consumption by the customer, but it also offers 100% independence from conventional suppliers. The batteries are connected forming a virtual battery pool. Having a big virtual storage, they can offer services to the grid operators. The combined usage of storage for both self-consumption and grid services increases the value for the customer as it creates multiple revenue streams (Energy Storage News 2017).

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ANNEXURE 1: Assumptions

- **Commercial Consumer (Best Economic Returns and Towards Net Zero)**

Solar PV System capital cost (w/o solar PCU cost)	INR/kW	41,500
Hybrid inverter capital in base year	INR/kW	24,000
Battery pack capital cost in base year	INR/kWh	17,000
Cost for storage container and others	INR/kW	5,500
EPC cost	INR/kW	1,200
No. of full battery discharge cycles		4,000
No. of partial battery cycles (Best Economic Return)		5,000
No. of full/partial battery cycles (Towards Net Zero)		4,000
Service connection fixed charge (Bi-monthly)	INR/kW	140

- **Industrial Consumer (Best Economic Returns and Towards Net Zero)**

Solar PV System capital cost (w/o solar PCU cost)	INR/kW	41,500
Hybrid inverter capital cost in base year	INR/kW	24,000
Battery pack capital cost in base year	INR/kWh	17,000
Cost for storage container and others	INR/kW	5,500
EPC cost	INR/kW	1,200
No. of full battery discharge cycles		4,000
No. of partial battery cycles (Best Economic Return)		5,300
No. of full/partial battery cycles (Towards Net Zero)		4,000
Service connection fixed charge (Bi-monthly)	INR/kW	70

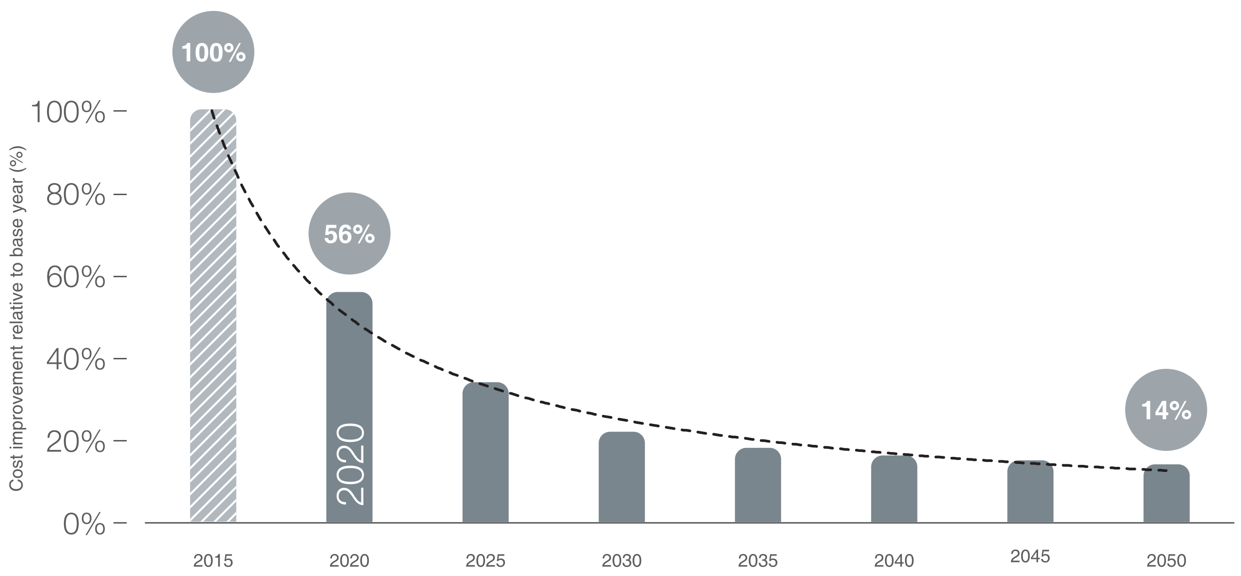
- **Residential Consumer (Best Economic Returns – Capital subsidy of 40% for capacity up to 3 kWp)**

Solar PV System capital cost (w/o solar PCU cost)	INR/kW	25,200
Hybrid inverter capital cost in base year	INR/kW	24,000
Battery pack capital cost in base year	INR/kWh	20,000
Cost for storage container and others	INR/kW	5,500
EPC cost	INR/kW	1,200
No. of full battery discharge cycles		4,000
No. of partial battery cycles (Best Economic Return)		5,300
Service connection fixed charge (Bi-monthly)	INR/Service	50

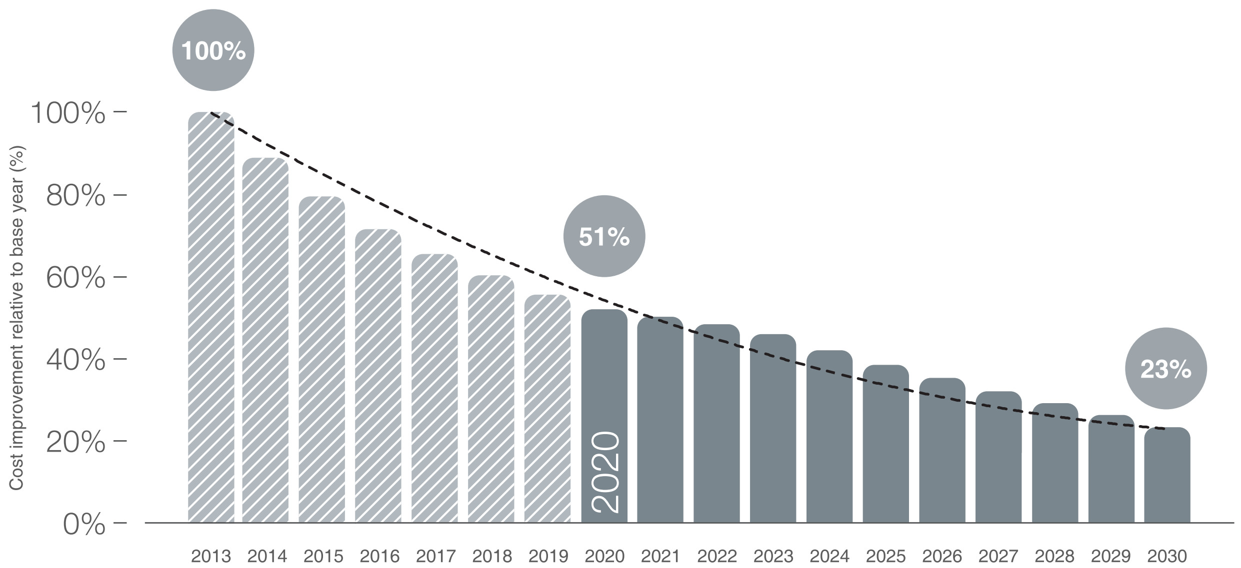
- **Residential (Towards Net Zero – Capital subsidy of 40% for capacity up to 3 kWp and 20% for capacity beyond 3 kWp and up to 10 kWp)**

Solar PV System capital cost (w/o solar PCU cost)	INR/kW	29,238
Hybrid inverter capital cost in base year	INR/kW	24,000
Battery pack capital cost in base year	INR/kWh	20,000
Cost for storage container and others	INR/kW	5,300
EPC cost	INR/kW	1,200
No. of full battery discharge cycles		4,000
No. of full/partial battery cycles (Towards Net Zero)		3,600
Service connection fixed charge (Bi-monthly)	INR/Service	50

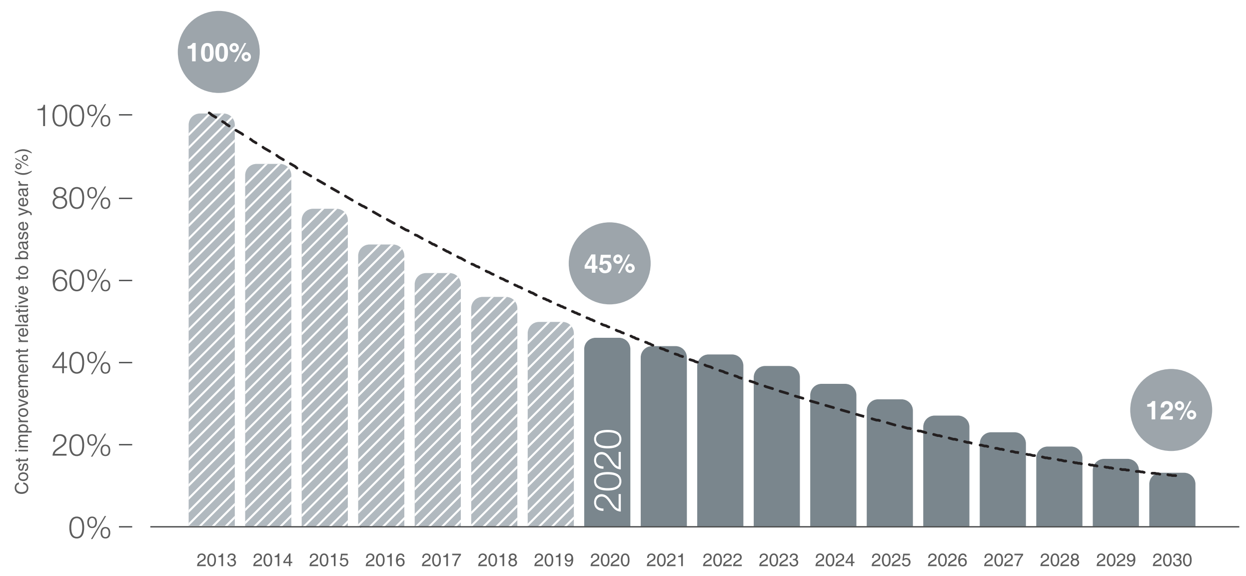
Li-ion cost improvement curve (%)

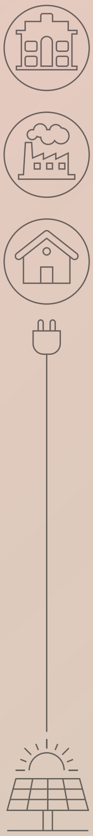


Solar PV Cost Improvement Curve(%)



Inverter Cost Improvement Curve (%)





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