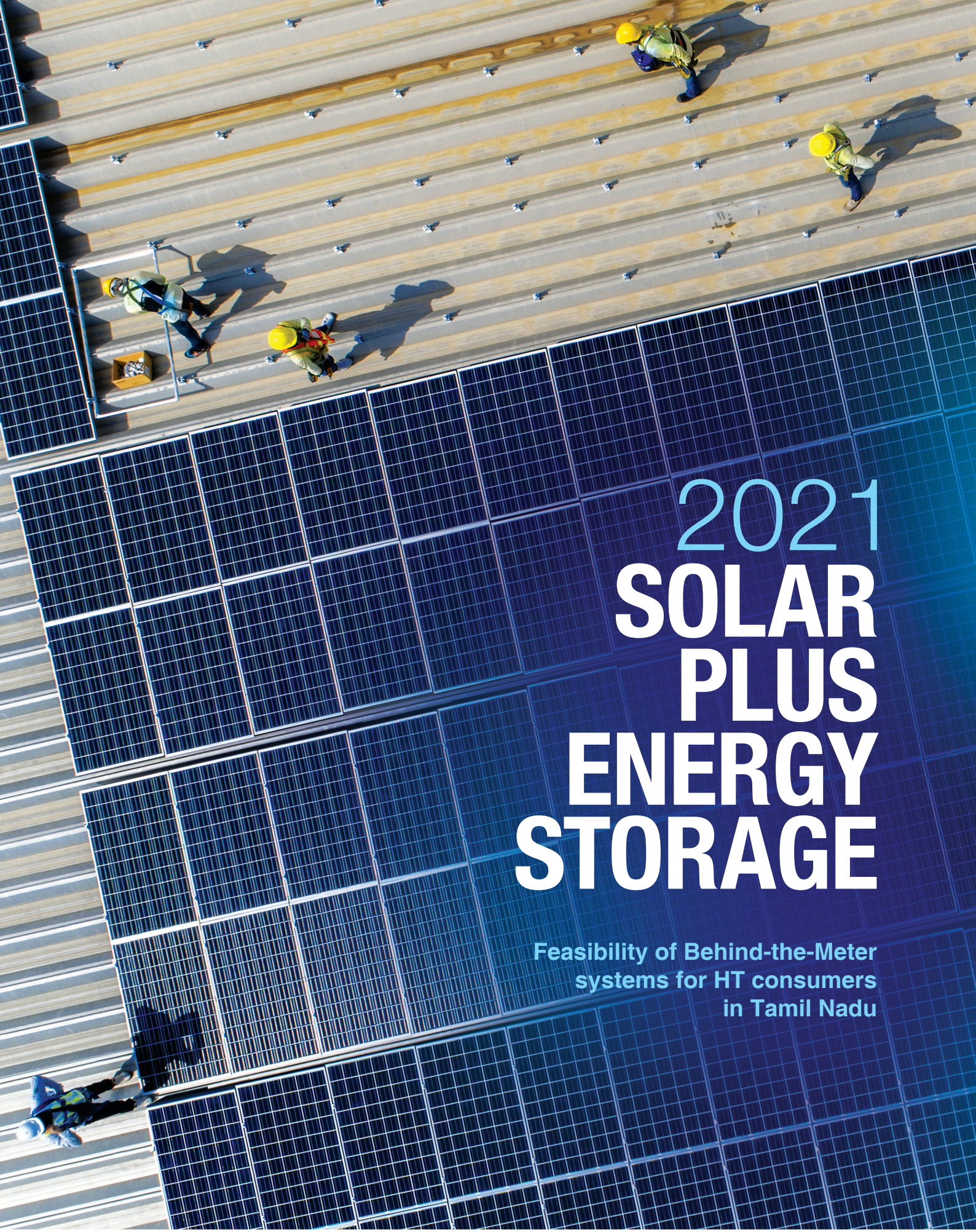

# 2021 SOLAR PLUS ENERGY STORAGE

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

AurovilleConsulting

2021

# SOLAR PLUS ENERGY STORAGE

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

# ACKNOWLEDGEMENT

This publication forms part of the Sustainable Energy Transformation, Tamil Nadu (SET-TN) series of documents and activities. SET-TN aims to facilitate higher clean energy deployment in the State by working with all stakeholders in order to find sustainable and equitable solutions. SET-TN is a collaborative initiative by Auroville Consulting (AVC), Citizen consumer and civic Action Group (CAG) and the World Resources Institute India (WRI).

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# FOREWORD

Energy storage is expected to play an increasingly important role in the future electricity grid systems due to its potential to balance power supply and demand. Coupled with solar energy generation, behind-the-meter (BtM) solar plus energy storage offer the potential to create economic value to consumers through bill management strategies such as demand charge reduction and maximising on-site self-consumption. Widespread adoption of BtM solar plus energy storage systems depend on the value consumers can derive from such systems. This report compares the cost of supply from the grid, partial supply from solar and partial supply from solar plus energy storage (lithium-ion) on the consumer side of the service connection (behind-the-meter) for selected HT consumer types in Tamil Nadu.

- **BENEFITS FOR THE CONSUMERS**

Behind-the-meter energy storage combined with solar energy offers a solution for both bill management and power back up.

Solar plus energy storage lessens the dependence upon grid supply, enhances reliability and resilience, and supports organizations in meeting their environmental goals and emission reduction targets.

- **BENEFITS FOR THE UTILITY**

BtM solar plus energy storage can also provide critical balancing and ancillary services to the grid operator.

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.

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.

- **INCREASING AFFORDABILITY AS DRIVER**

The cost of lithium-ion (Li-ion) batteries has seen a steady decline over the past years, and this trend is expected to continue for the foreseeable time. By 2030, a 78% reduction in the cost of Li-ion battery pack over the 2015 cost is expected (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**

BtM solar energy systems are an effective option for HT consumers in Tamil Nadu to reduce electricity costs and emissions. An increase in the energy tariffs for electricity sourced from the grid and a decreasing price of energy storage systems are expected in the near future.

HT consumers installing BtM solar energy systems without energy storage may consider deploying a solar hybrid inverter at the outset. This will provide the consumers with the possibility to add energy storage capacity to their existing BtM solar energy system without the requirement to invest into a separate inverter for the energy storage system as soon as they consider energy storage as an attractive investment option.

# KEY FINDINGS

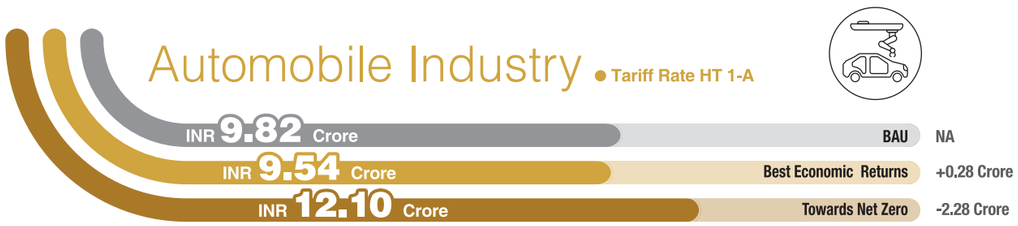
## • SOLAR PLUS ENERGY STORAGE IS ALREADY A FINANCIALLY VIABLE OPTION

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 all three selected HT consumer types, each with its respective tariff rates and load profiles. The results show that BtM solar plus energy storage is more attractive for an ‘Office’, as compared to an Industrial or an Educational institute. This is primarily on account of the higher tariff rate at 8.00 INR/kWh (HT- III) and load profile.

The ‘Towards Net Zero’ case is resulting in a higher 10-year supply costs for all 3 selected HT consumer types, when compared to supply from the grid only (Business as Usual - BAU).

**Discounted cost of electricity supply over 10 years**



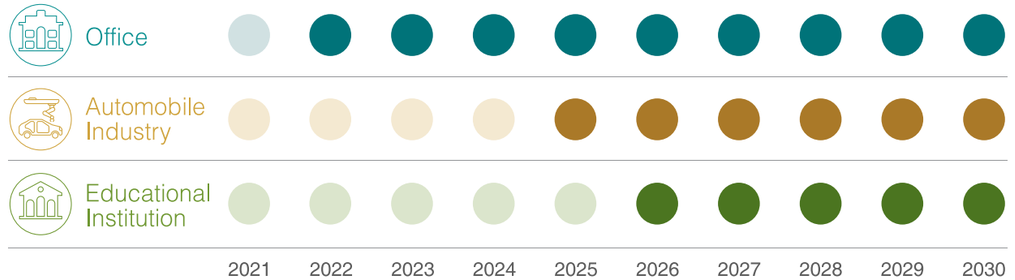







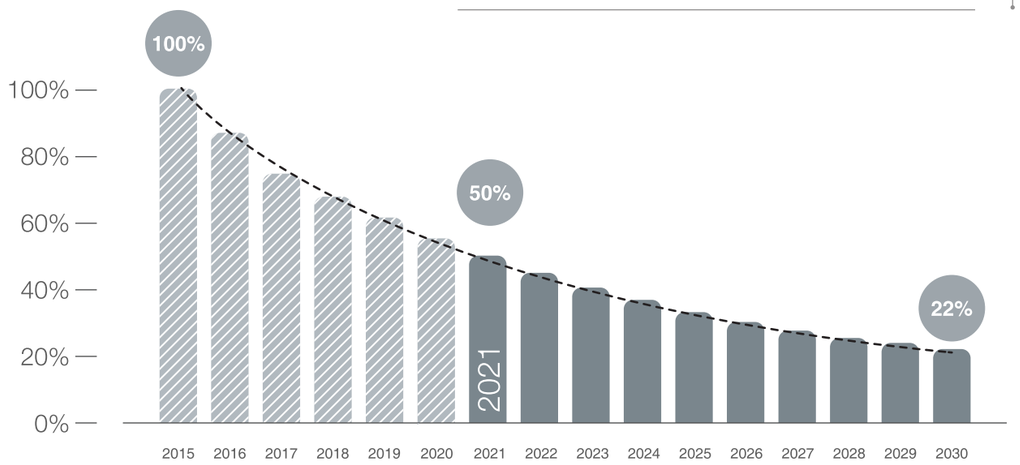
## • INVESTMENT INTO THE ‘TOWARDS NET ZERO’ WILL BE FINANCIALLY VIABLE FOR THE HT OFFICE CONSUMER TYPE FROM 2022 ONWARDS

**Financial viability of BtM solar plus energy storage by year of investment for the ‘Towards Net Zero’ case**




## • 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 2021, it is at 50% 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).

# 01 ASSUMPTIONS

- **Consumer types**

Are defined as per the existing schedule of tariffs in Tamil Nadu (TNERC 2017) and their typical load profiles (IESO 2021, REopt 2021).

- **Bill management**

Bill management has been considered as the only revenue stream for BtM solar plus energy storage. In the context of Tamil Nadu net feed-in metering mechanism bill management translates into maximizing solar self-consumption and reducing grid export.

- **Time of day (ToD)**

ToD tariffs are available only for the consumer category HT industrial (HT- IA). The ToD tariff offers a 5% rebate on energy charges during off-peak hours (10:00 PM to 5:00 AM) and a 20% increase in energy charges during peak hours (6:00 AM to 9:00 AM and 6:00 PM to 9:00 PM) (TNERC 2017).

- **Demand Charge**

The demand charge for HT consumers is INR 350/kVA/month. In this assessment, the monthly demand charge is calculated based on the maximum recorded peak for each month. Currently demand charges are calculated on either the monthly recorded peak demand or as 90% of the sanctioned demand, whichever is higher (TNERC 2017). Financial savings through peak load reduction on account of BtM solar plus energy storage are added to the overall savings under bill management.

- **Paralleling**

HT consumers in Tamil Nadu are currently excluded from availing the net feed-in mechanisms. The only option available to an HT consumer for BtM solar energy system is through 'paralleling' operation, in which any excess generation has to be curtailed. For generation capacities larger than 1 MW with paralleling, the consumer requires a dedicated feeder. Further, the parallel operation of a rooftop solar plant attracts a monthly parallel operation charge of INR 15,000 per month for each MW (TNERC 2018a, 2020a).

- **Electricity tax**

Tax of 5% applies to the electricity charges which include energy charges and demand charges.

- **Best Economic Return**

For the solar plus energy storage system the Solar capacity has been sized to meet the instantaneous load, during sunshine hours and maximum financial gains through bill management over a 10-year time period. Any surplus solar energy is being stored and dispatched whenever required.

- **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 for the selected HT consumer type and the battery is sized at providing two hours of back up for peak load in year 1. Energy efficiency improvements has not been considered for calculation.

- **Electricity consumption year 1**

The year 1 electricity consumption is calculated based on the state's average annual consumption per service connection point of the total HT consumer-type using 2019 consumption data (TNERC 2017, 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 2015 to 2019 (TNERC 2017, Energy Department of Tamil Nadu 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**

A DC-coupled 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 (LCOS)**

The LCOS value has been calculated using the tool 'Levelised Cost Calculator for Distributed Energy Resources V2.0 (Auroville Consulting 2021).

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

The LCOSS value has been calculated using the tool 'Levelised Cost Calculator for Distributed Energy Resources V2.0 (Auroville Consulting 2021). LCOSS values are used for financial analysis.

- **Net feed-in tariff**

Currently HT consumers are excluded from net feed-in. For calculation of futurist scenarios, net feed-in for HT consumer with a tariff of INR 2.08/ kWh is considered. This is at par with the current solar net feed-in tariff for LT consumers (CAG 2020).

- **Tariff escalation**

An average 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 8.67% has been used (TNERC 2020).

- **Power factor**

A common power factor of 0.9 is considered. Power factor incentive and penalty has not been considered for financial analysis (TNERC 2017).

- **Break-even investment year**

It indicates the year in which investing in 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 peak demand of year 1 with two hours of backup) and a reduction in the capital cost of BtM solar plus energy storage are considered

- **ToD Solar Export**

Currently there isn't any ToD for the excess solar export to the grid. In the calculation for various tariff designs, a feed-in tariff of INR 2.08/kWh (CAG 2020) (TNERC 2019a) along with a 5% rebate during off-peak hours and 20% increase in tariff during peak hours is considered.

# 02
# OFFICE

| Electricity consumption 2021: | Average annual electricity increase: | Tariff: | Annual tariff escalation: |
|---|---|---|---|
| 1,225 MWh | 6.51% | 8.00 INR/kWh | 5% |

## A
## Best Economic Returns

**57.3%** SOLAR ENERGY PENETRATION

LCOSS **6.87** INR/kWh

**System Capacities**

| Technology | Capacity | Ratio[1] |
|---|---|---|
| Solar PV | 425.04 kW | 1.000 |
| Battery Energy | 4.00 kWh | 0.009 |
| Battery Power | 1.00 kW | 0.002 |

## B
## Towards Net Zero

**100%** SOLAR ENERGY PENETRATION

LCOSS **9.52** INR/kWh

**System Capacities**

| Technology | Capacity | Ratio |
|---|---|---|
| Solar PV | 750.19 kW | 1.000 |
| Battery Energy | 740.00 kWh | 0.986 |
| Battery Power | 370.00 kW | 0.493 |

*[1] The ratio can be used to determine the solar and energy storage capacities for diverging electricity consumption, provided the load profile remains similar.*

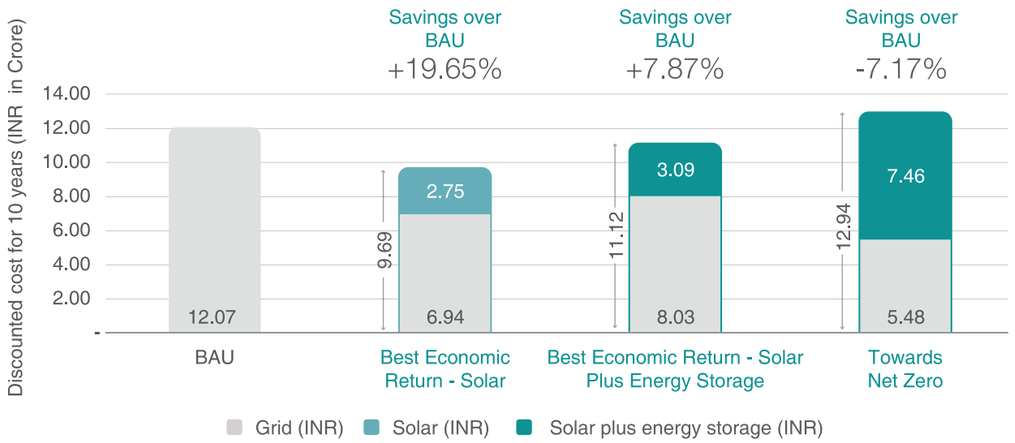


## • Solar Plus Energy Storage A Winning Proposition

Discounted cost savings for the 'Best Economic Returns' for BtM solar plus energy storage cases over a 10-year time period is expected to be INR 0.95 Crore (7.87%). An investment into solar plus energy storage in 2021 is, therefore, a financially viable investment proposition.

Whereas the 'Towards Net Zero' case shows a higher electricity cost over 10 years as compared to BAU by INR 0.87 Crore. In terms of bill management, the best investment option, however, is an investment in a BtM solar energy system only this has an expected saving of INR 2.38 Crore (19.65%).

**10-year discounted cost of electricity[2]**



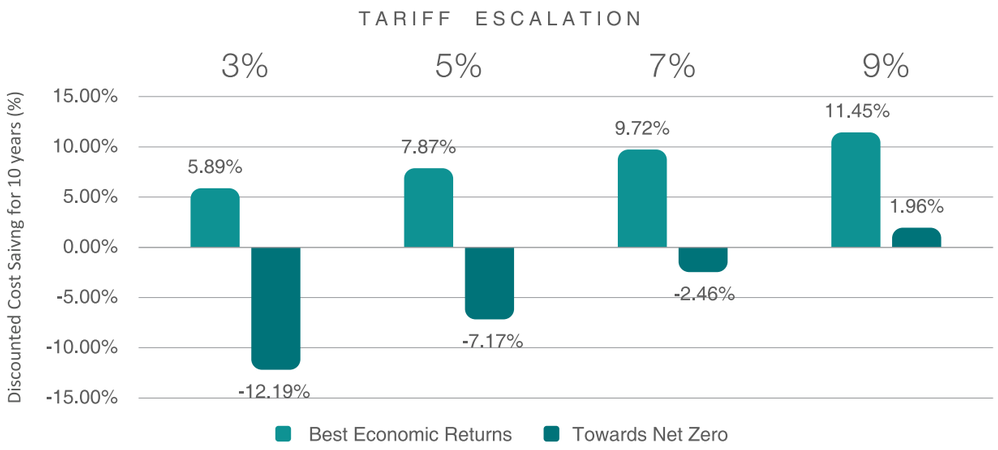

## • Future tariff escalation as a key variable

With bill management as the current single available value stream for BtM solar plus energy storage system, future consumer tariff and demand charge 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.

The figure below indicates the cost savings for 10 years for tariff escalations of 3%, 5%, 7% and 9%. With an average annual tariff escalation of 9% for the HT III tariff the 'Best Economic Returns' case is expected to result in 10-year cost savings of 11.45% over the BAU case and the 'Towards Net Zero' will result in marginal savings over the BAU case of 1.96%.

*[2] For 'Best Economic Returns' – Solar case, Solar PV size is 625 kW and LCOS is 4.13 INR/kWh*

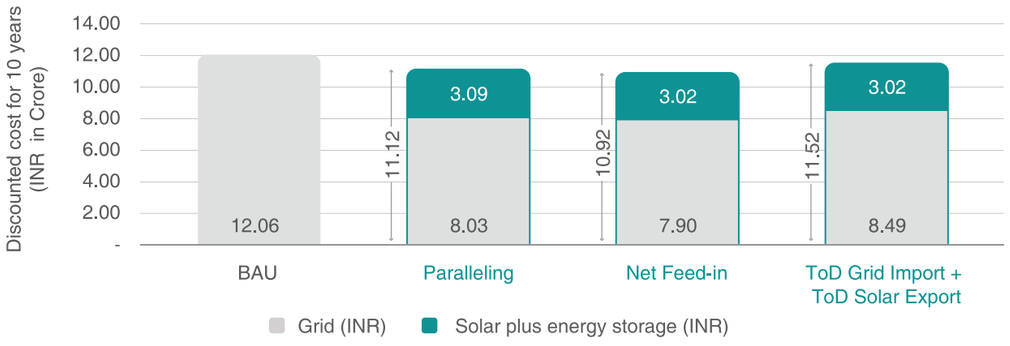
**Sensitivity analysis for different tariff escalation rates**




- **Metering mechanisms and tariff designs**

Different metering mechanisms such as a paralleling, net feed-in and a ToD tariff for solar export and a ToD tariff for grid import were analyzed for the 'Best Economic Return' case. The scenario with a net feed-in results in the lowest cost, with discounted savings of INR 1.14 Crore (9.49%) over the BAU scenario and a saving on INR 0.19 Crore (1.75%) over the paralleling scenario.

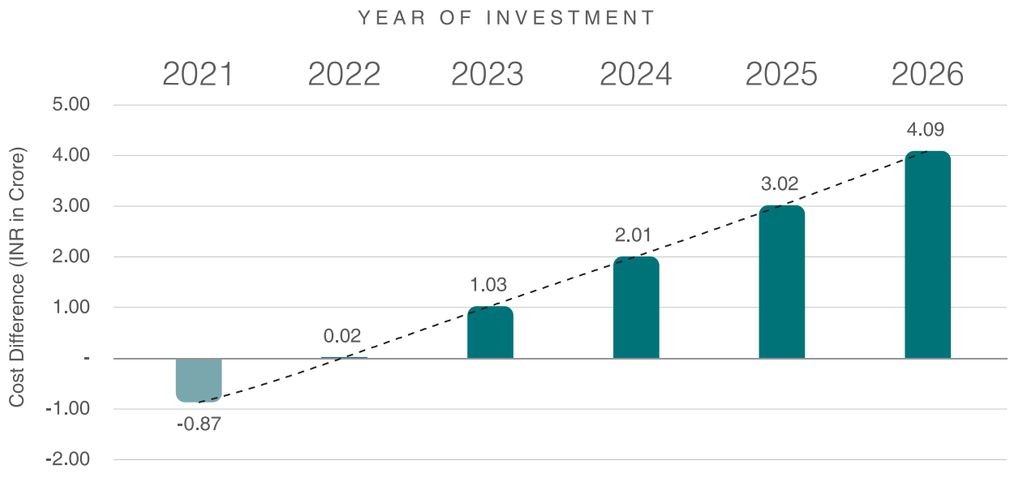
**Comparison of metering mechanisms and tariff designs**



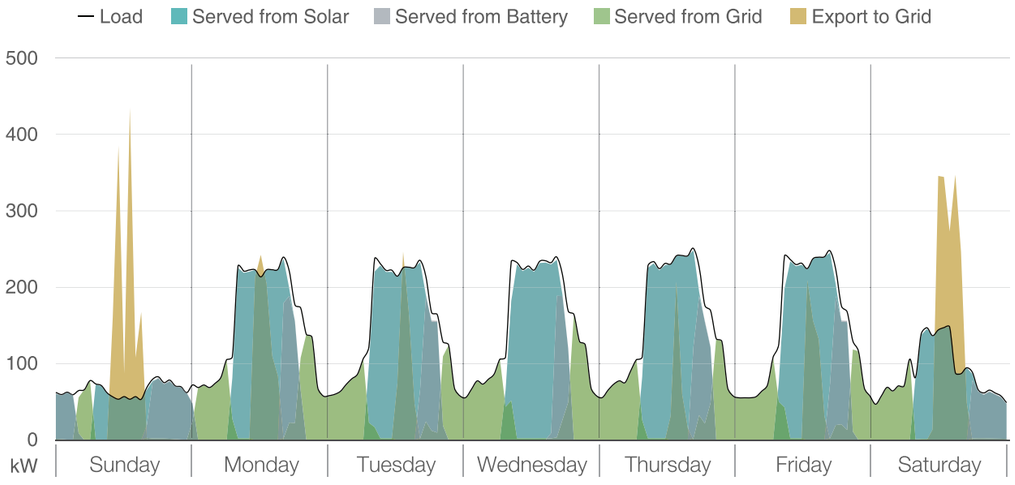



- **Investing in the 'Towards Net Zero' case is viable from 2022 onwards**

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




**Example of a weekly dispatch in January 2021 for the 'Towards Net Zero' case**



# 03
# AUTOMOBILE INDUSTRY

| Electricity consumption 2021: | Average annual electricity increase: | Tariff: | Annual tariff escalation: |
|---|---|---|---|
| 1,225 MWh | 6.51% | 6.35 INR/kWh (with ToD) | 5% |

## A
### Best Economic Returns

**33.5%** SOLAR ENERGY PENETRATION

LCOSS **6.89** INR/kWh

**System Capacities**

| Technology | Capacity | Ratio |
|---|---|---|
| Solar PV | 250.06 kW | 1.000 |
| Battery Energy | 4.00 kWh | 0.016 |
| Battery Power | 1.00 kW | 0.004 |

## B
### Towards Net Zero

**100%** SOLAR ENERGY PENETRATION

LCOSS **8.35** INR/kWh

**System Capacities**

| Technology | Capacity | Ratio |
|---|---|---|
| Solar PV | 750.19 kW | 1.000 |
| Battery Energy | 420.00 kWh | 0.056 |
| Battery Power | 210.00 kW | 0.280 |

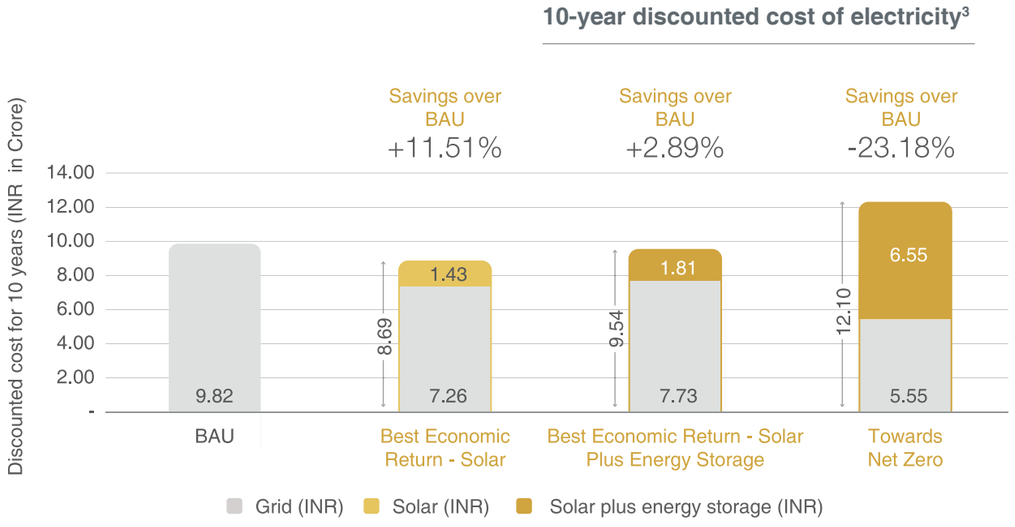


## • Solar Plus Energy Storage A Winning Proposition

For the automobile industrial consumer-type with ToD tariff, an investment into BtM solar plus energy storage in the year 2021 under the 'Best Economic Returns' case results in a discounted saving of INR 0.28 Crore (2.89%) over a 10-year time period.

Whereas 'Towards Net Zero' case show an increase in electricity cost over 10 years by INR 2.28 Crore. The investment in a BtM solar energy system only has an expected saving of INR 1.13 Crore (11.51%).

**10-year discounted cost of electricity[3]**

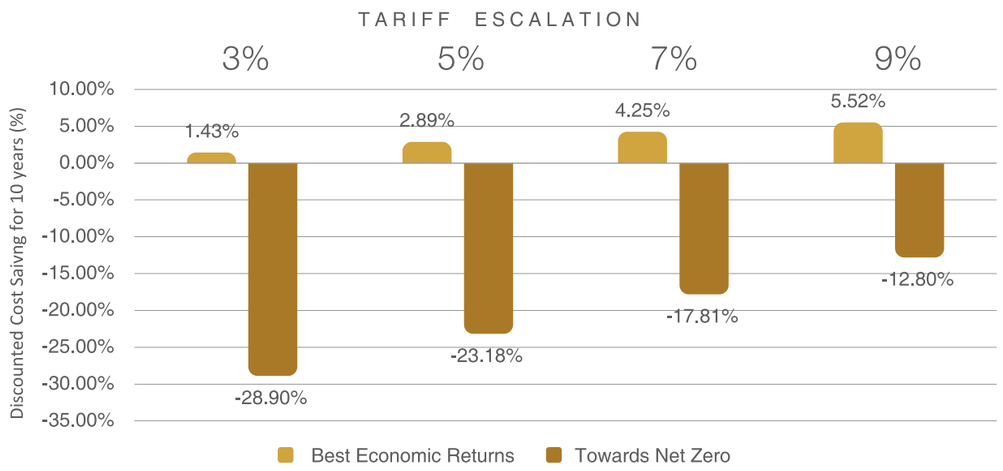



## • Future tariff escalation scenarios

The 'Best Economic Returns' case is already a financially viable option for automobile industrial consumer type. Higher tariff escalation will further increase the consumers' cost savings.Investing in the 'Towards Net Zero 'case in the year 2021 is not expected to result in cost savings to the industrial consumer, even with a higher tariff escalation rate of 9%.

*[3] For 'Best Economic Returns' – Solar case, Solar PV size is 325kW and LCOS is 4.13 INR/kWh*

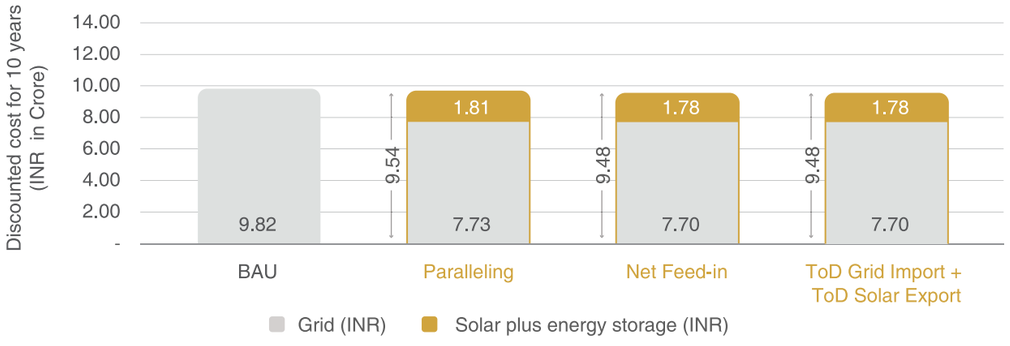
**Sensitivity analysis for different tariff escalation rates**




## • Metering mechanisms and tariff designs

A comparison of different metering mechanisms indicates that both the scenarios Net feed-in and ToD solar export with a ToD grid import results in the lowest cost, with discounted savings of INR 0.34 Crore (3.50%) over the BAU scenario and a savings of INR 0.06 Crore (0.63%) over the paralleling scenario.

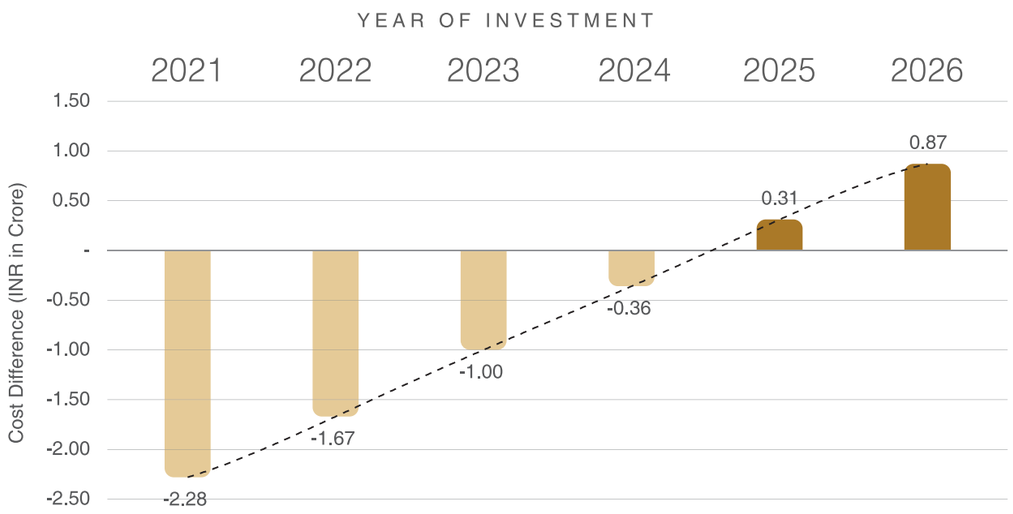
**Comparison of metering mechanisms and tariff designs**



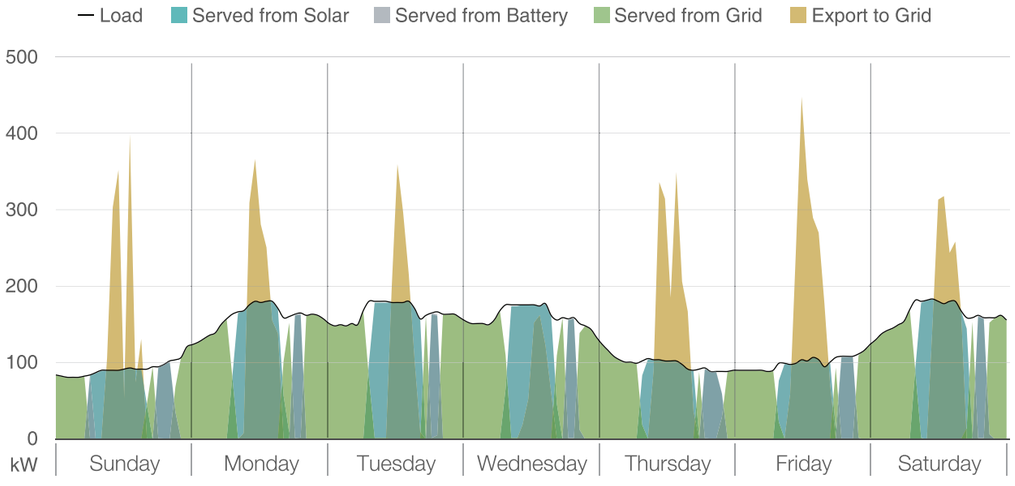



## • Investing in the 'Towards Net Zero' case is viable from 2025 onwards

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




**Example of a weekly dispatch in January 2021 for the 'Towards Net Zero' case**



# 04
# EDUCATIONAL INSTITUTION

| Electricity consumption 2021: | Average annual electricity increase: | Tariff: | Annual tariff escalation: |
|---|---|---|---|
| 1,225 MWh | 6.51% | 6.35 INR/kWh | 5% |

**A**

## Best Economic Returns

**25.5%** SOLAR ENERGY PENETRATION

LCOSS **6.90** INR/kWh

**System Capacities**

| Technology | Capacity | Ratio |
|---|---|---|
| Solar PV | 200.12 kW | 1.000 |
| Battery Energy | 4.00 kWh | 0.020 |
| Battery Power | 1.00 kW | 0.005 |

**B**

## Towards Net Zero

**100%** SOLAR ENERGY PENETRATION

LCOSS **8.72** INR/kWh

**System Capacities**

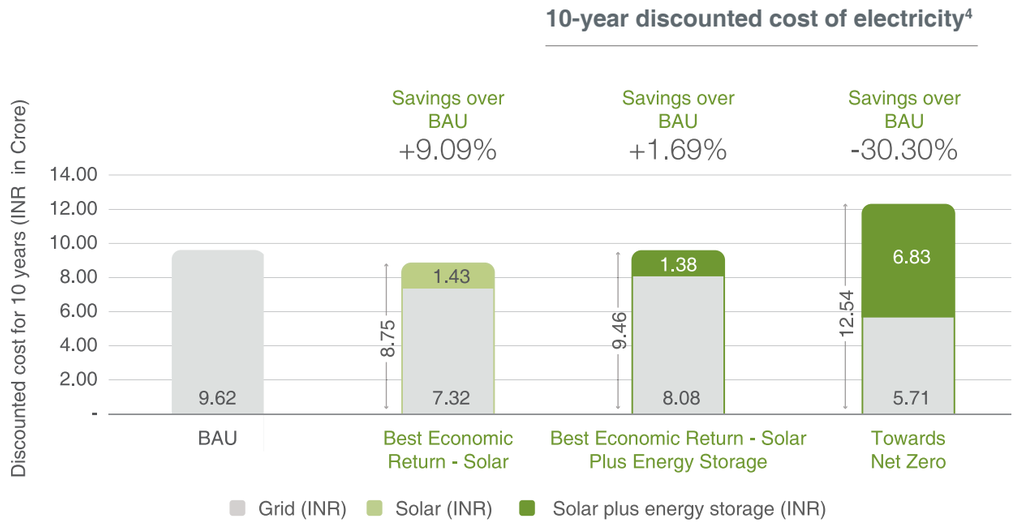
| Technology | Capacity | Ratio |
|---|---|---|
| Solar PV | 750.19 kW | 1.000 |
| Battery Energy | 520.00 kWh | 0.694 |
| Battery Power | 260.00 kW | 0.347 |



## • Solar Plus Energy Storage A Winning Proposition

For an educational institution, Discounted cost savings for the 'Best Economic Returns' for BtM solar plus energy storage cases over a 10-year time period is expected to be INR 0.16 Crore (1.69%).

Whereas for the 'Towards Net Zero' case the results show an electricity cost increase over 10 years by INR 2.92 Crore. To achieve energy cost reduction the best investment option, however, is an investment in a BtM solar energy system only. This has an expected saving of INR 0.87 Crore (9.09%).

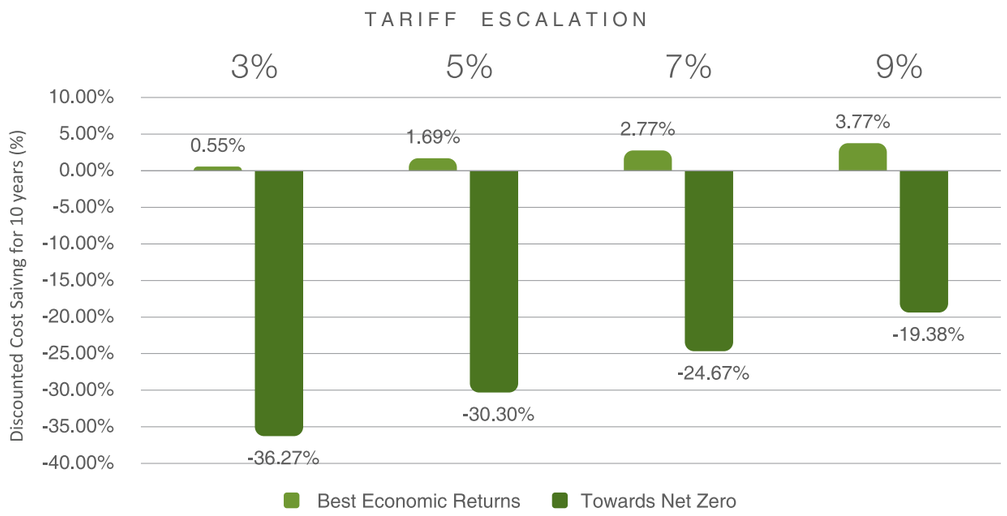



## • Future tariff escalation scenarios

The 'Best Economic Returns' solar plus energy storage case is financially viable at a lower tariff escalation. Higher tariff escalation will further increase the consumers' cost savings. Investing in the 'Towards Net Zero 'case in the year 2021 is not expected to result in cost savings to the domestic consumer, even with a higher tariff escalation rate of 9%.

*[4] For 'Best Economic Returns' – Solar case, Solar PV size is 325 kW and LCOS is 4.13 INR/kWh*

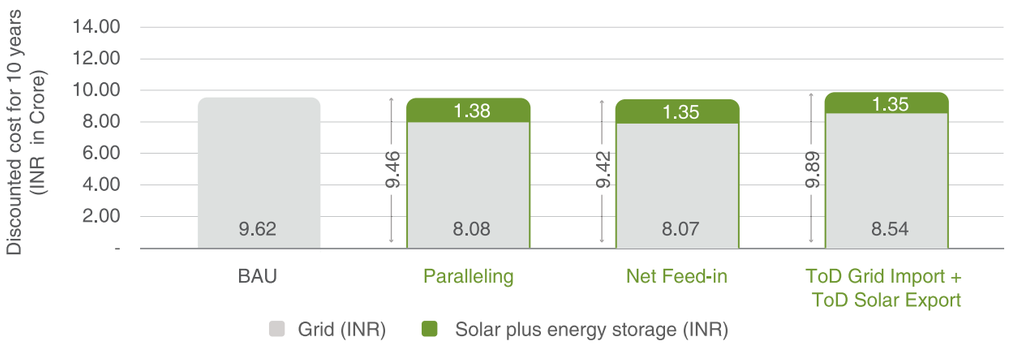
**Sensitivity analysis for different tariff escalation rates**




## • Metering mechanisms and tariff designs

Comparing the best 'Best Economic' Case with alternative metering mechanisms it is found that the scenario with a solar net feed-mechanisms results in the lowest cost. Discounted savings of INR 0.21 Crore (2.15%) over the BAU scenario and a savings of INR 0.04 Crore (0.46%) over the paralleling scenario are expected.

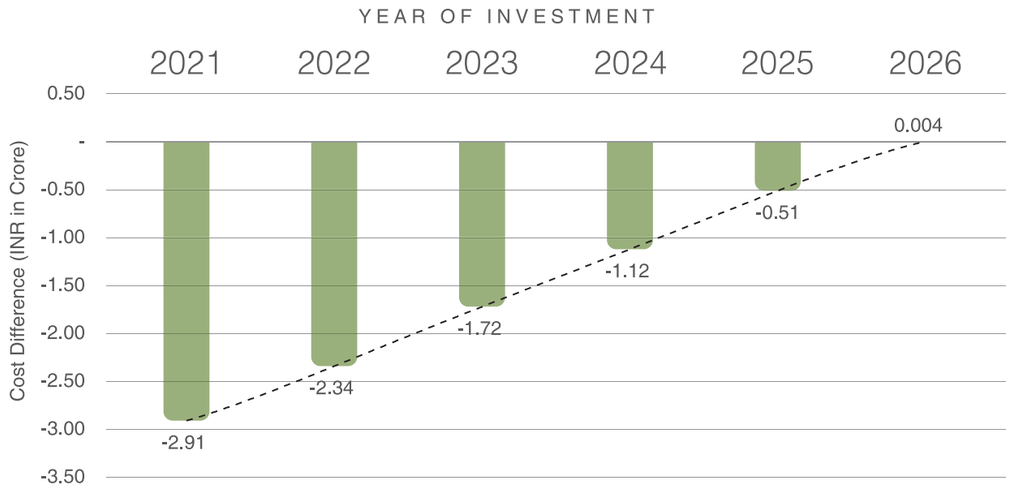
**Comparison of metering mechanisms and tariff designs**



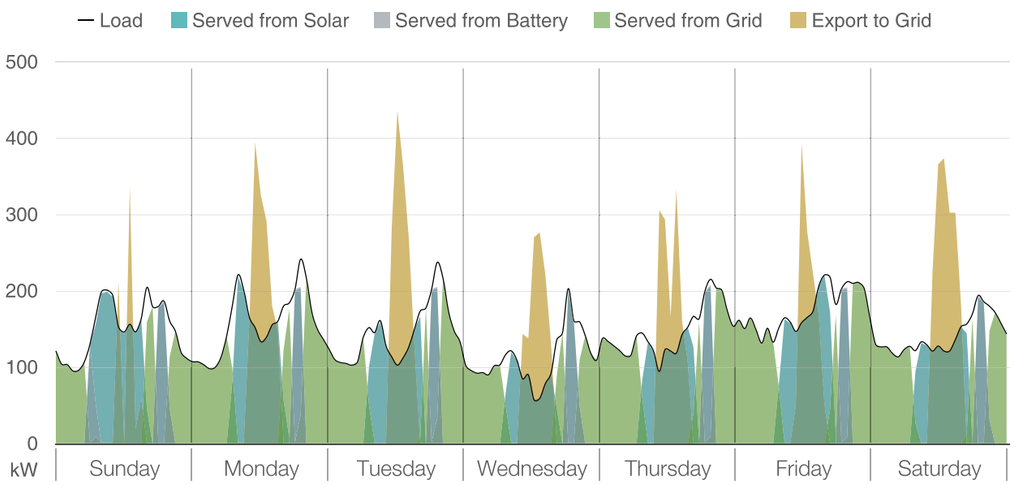



## • Investing in the 'Towards Net Zero' case is viable from 2025 onwards

**10-year cost difference between BAU and 'Towards Net Zero' case by the year of investment[5]**




**Example of a weekly dispatch in January 2021 for the 'Towards Net Zero' case**




[5] *Under the paralleling mechanisms generation capacities of 1 MW or higher required a separate feeder (TNERC 2018b).*

# 05 THE DRIVERS

## • Urge for energy self-sufficiency

Unreliable grid supply drives consumers towards deploying power back-up solutions such as uninterrupted power systems and diesel generators. Solar plus energy storage becomes an increasingly attractive alternative, it can provide a degree of energy security and independence to the consumers.

## • Higher electricity tariff

Currently, HT consumer categories are paying comparatively higher electricity tariff rates and demand charges to the utility as compared to LT consumers. Higher tariff rates incentivize consumers to explore alternative options such as BtM solar plus energy storage.

## • Non-availability of feed-in tariffs

HT consumers in Tamil Nadu are excluded from the net feed-in mechanisms. Any BtM surplus generation injected into the grid will not be compensated for. This regulation may emerge as a driver of BtM solar plus energy storage deployments, as consumers and businesses seek ways to obtain greater returns from their investments.

## • More stringent open access regulations

The concessions for renewable energy generators in regards to open access charges [e.g., wheeling charges (50% of conventional power) cross-subsidy surcharges (70% of conventional power) etc.] are expected to gradually reduce and eventually phase out in the near future (TNERC 2019b). This is likely to bring the cost of renewable energy sourced from BtM systems at par or below the cost of renewable energy sourced via the open-access mechanisms. HT consumers are therefore expected to accelerate the deployment of BtM solar plus energy systems and to optimize their energy costs.

## • Incentives on manufacturing Li-ion

In 2019-20 India imported batteries worth USD 1.2 billion making this sector heavily dependent on foreign manufacturing capacities. Niti Aayog, a Government of India think tank proposed setting up Giga capacity battery factories aggregating a capacity of 50 GWh over the next ten years at a projected cost of USD 5 billion in order to reduce India's dependence on imports. The Indian Government has proposed to offer subsidies to the tune of INR 700 Crore a year and also provide incentives such as the benefit of entire depreciation in one go and zero import duty on lithium, iron and cobalt to battery manufacturing industries (ORF 2020).



## • CASE STUDY 1

### World's Largest Behind the meter Solar plus Energy Storage by Capital Dynamics, Nevada, US


Photo credit: (Greentech Media 2020a)

## • BtM Solar Plus Storage, grid independence, self-generation

Capital Dynamics is currently building the world's largest BtM Solar and Energy Storage system. A 127 MW solar energy system coupled with a 60 MW/240 MWh Tesla energy storage system will provide round the clock energy supply (Capital Dynamics 2020).

The system will be located on the campus of a data centre operated in Nevada. Data centres have a generally flat demand profile, which influenced the choice to add a battery to the solar facility. The battery sizing turns the 127 MW of solar capacity into an evenly distributed baseload that can dispatch deep into the night. There are no transmission losses or charges and distribution losses as the public grid is not used, this is a major advantage for the behind-the-meter project. This provides cost savings on energy procurement.

This project is made possible by the large availability of land and laws in Nevada that allows a large industrial consumer to generate their power. The major challenge in replicating this would find the ideal consumer with sufficient space and laws permitting the customer to source their power (Greentech Media 2020a, 2020b).

## • CASE STUDY 2

### BtM Solar Plus Energy Storage project for Zimbabwe's leading cold store and packhouse facilities

Photo credit: (Disrupt Africa 2020)

### • Bill management, reliability of supply and crowdfunding and lease-based business model

Agriculture accounts for approximately 23% of sub-Saharan Africa's GDP, this sector is challenged by an unreliable power supply, the rising cost of electricity, climate-induced drought and limited access to finance for clean energy. Zimbabwe's leading fruit and vegetable exporter, Nhimbe Fresh, struck a deal with South African solar leasing platform Sun Exchange to install 500 kW solar plant with 1MWh of battery storage for its cold store and packhouse facilities (Sun Exchange 2020).

Sun Exchange runs a solar crowdfunding model that enables people around the world (who can earn a rental income in cryptocurrency) to purchase solar cells (built into modules) and then lease them for 20 years to power schools, businesses, and other organizations. Energy consumers at the solar projects benefit from affordable electricity for no upfront cost and pay for the solar power consumed (Mercom India 2020b).

The introduction of BtM Solar Plus Energy Storage delivers a continuous, reliable power, mitigation of frequent grid power outages and cheaper operating cost compared to diesel generators. The BtM system not only provides bill management which would result in 60% annual energy cost reduction for Nhimbe Fresh's facilities' but also reduce grid carbon emissions by more than 1,000 kilograms per year.

This project also contributes to Zimbabwe's renewable energy policy to generate at least 1.5 GW of solar power by 2030 (Mercom India 2020a).



# 06 THE BARRIERS

### • Perception of a high price

There is a general perception that energy storage is expensive. Despite the recent trend in cost reduction for solar PV and batteries, components such as hybrid inverters are still in the higher price range. Inverters have a major impact on a storage project as they significantly influence capital cost, system performance and financial returns. For a DC-coupled BtM solar plus energy system – hybrid inverters are required, which are costlier than on-grid solar inverters. With a maturing market, however, the prices for hybrid inverters are expected to fall over the next few years.

### • Absence of metering mechanism and rate design for surplus energy

Currently, HT consumers in Tamil Nadu are excluded from the solar net feed-in mechanism. This result either in curtailment of excess solar energy or feed-in of the excess into the grid free of cost, thereby reducing the cost savings to the consumers. Additionally, it prevents utilities to benefit from the values BtM solar plus energy storage systems can provide for grid management.

### • Capacity limitations

Limitations under the paralleling mechanism may prevent the realization of the 'Towards Net Zero' scenario. Under the paralleling mechanisms, solar PV systems greater than 1 MW are not permitted without a dedicated feeder.

Moreover, BtM solar plus energy storage system are limited to the sanctioned load of the service connection. A regulatory process that permits consumers to exceed this generation capacity limit along with energy storage will be required in order to make the 'Towards Net Zero Case' a reality.

### • Higher Import Duty

Import duty for solar inverter has been increased from 5% to 20% (w.e.f. 2nd February 2021) and inputs, parts and sub-parts for manufacture of lithium-ion battery and battery pack has been increased from 0% to 2.5% (w.e.f.1st April 2021) (Budget 2021).

Ministry of New and Renewable Energy (MNRE) has proposed to impose basic customs duty of 40% on solar modules and 25% on solar cells (w.e.f. 1st April 2022) this is supported by the Ministry of Finance, as it looks to cut imports and boost local manufacturing capacities (MNRE 2021).

This is expected to inflate the system cost for solar plus energy storage systems.

# 07 WAY FORWARD

## • Market Design

Energy Storage will offer an increasing range of services for customers and utilities. Market design for ancillary services and aggregation of BtM solar energy and storage systems will have to be developed by the regulators.

The inclusion of all consumer tariff categories (HT and LT) under the net feed-in mechanisms will be required.

ToD tariffs for import and export (ideally short and high and with critical peak pricing) appear to be the low-hanging fruit in order to propel BtM solar plus energy storage systems. The design of the ToD feed-in tariff rates will need to be fair, for both the consumers and the utilities, and reflect the actual cost of generation and storage. The Tamil Nadu Solar Energy Policy 2019 already suggests the introduction of ToD tariffs for BtM solar and energy storage systems (TEDA 2019).

## • Forward-looking regulations

Forward-looking interconnection regulations and standardized communication and control protocols will be required to leverage grid-services that can be provided by BtM storage systems. 49.7% of the global battery storage capacities are currently used for frequency regulation and voltage control (Deloitte 2018).

Developing such regulations proactively will create an enabling environment for BtM solar plus energy storage systems in Tamil Nadu.

## • Utility / third party facilitated solar plus energy storage

Utilities / third party owners can focus on offering BtM solar plus energy storage as a service for HT consumer under a RESCO or lease model. At the same time, these storage systems can provide balancing and ancillary services to utilities. In such a case the energy storage systems will attract multiple revenue streams through value stacking.



## • CASE STUDY 3

### Advances in digital technologies spur new business models


Photo credit: (Recharge 2016)

## • Aggregator, ‘as-a-service’ business model and bill management

A US-based company called Stem, largely focused in the commercial and industrial (C&I) segment of the energy storage market, creating virtual power plants (VPPs) through connecting batteries at office buildings and industrial sites (Energy Storage News 2020).

From using stored renewable energy to reduce peak demand and lower energy costs for C&I customers and using their systems to provide grid services, Stem Inc has been one of the primary movers in the BtM energy storage-as-a-service market. Stem combined BtM energy storage with analytics via a platform that uses artificial intelligence to dispatch and reconfigure a network of batteries at a moment’s notice to keep demand charges in check for the C&I customer. Apart from energy cost reduction, Stem also provides various values streams such as solar self-consumption, resilience and sustainability. On the flip side, Stem offers utilities and grid operators the ability to absorb or discharge energy from the system to balance the grid and offset capacity shortfalls (Energy Storage News 2018, 2020).

# REFERENCES


1. Auroville Consulting (2021). Levelised Cost Calculator for Distributed Energy Resources V2.0. Available at: *https://www.aurovilleconsulting.com/levelized-cost-calculator-for-distributed-energy-resources/* (accessed on 02 February 2021)

2. Budget (2021). Budget speech 2021-2022, Minister of Finance, Government of India. Available at: *https://www.indiabudget.gov.in/doc/budget_speech.pdf* (accessed on 24 February 2021)

3. Capital Dynamics (2020). Switch and Capital Dynamics Break Ground on Massive Solar and Battery Storage Developments, Advancing Rob Roy's Gigawatt Nevada. Available at: *https://www.capdyn.com/news/switch-and-capital-dynamics-break-ground-on-massive-solar-and-battery-storage-d/* (accessed on 02 February 2021)

4. Citizen consumer and civic Action Group (CAG) (2020). Rooftop Solar Installation Guide For Tamil Nadu, First edition: 2020. Available at: *https://www.cag.org.in/sites/default/files/database/English%20-%20ROOFTOP%20SOLAR%20INSTALLATION%20GUIDE%20FOR%20TAMIL%20NADU.pdf* (accessed on 03 March 2021)

5. Deloitte (2018). Supercharged: Challenges and opportunities in global battery storage markets. Available at: *https://www2.deloitte.com/content/dam/Deloitte/bg/Documents/energy-resources/gx-er-challenges-opportunities-global-battery-storage-markets.pdf* (accessed on 02 February 2021)

6. Disrupt Africa (2020). SA's Sun Exchange begins African expansion with project in Zimbabwe. Available at: *https://disrupt-africa.com/2020/11/10/sas-sun-exchange-begins-african-expansion-with-project-in-zimbabwe/* (accessed on 08 February 2021)

7. Energy Department of Tamil Nadu (2015). Demand No.14, Policy Note 2014-15. Available at: *https://cms.tn.gov.in/sites/default/files/documents/energy_e_pn_2014_15_1.pdf* (accessed on 02 February 2021)

8. Energy Department of Tamil Nadu (2016). Demand No.14, Policy Note 2015-16. Available at: *https://cms.tn.gov.in/sites/default/files/documents/energy_e_pn_2015_16.pdf* (accessed on 02 February 2021)

9. Energy Department of Tamil Nadu (2017). Demand No.14, Policy Note 2016-17. Available at: *https://cms.tn.gov.in/sites/default/files/documents/energy_e_pn_2016_17.pdf* (accessed on 02 February 2021)

10. Energy Department of Tamil Nadu (2018). Demand No.14, Policy Note 2017-18. Available at: *https://cms.tn.gov.in/sites/default/files/documents/energy_e_pn_2017_18_0.pdf* (accessed on 02 February 2021)

11. Energy Department of Tamil Nadu (2019). Demand No.14, Policy Note 2018-19. Available at: *https://cms.tn.gov.in/sites/default/files/documents/energy_e_pn_2018_19.pdf* (accessed on 02 February 2021)

12. Energy Department of Tamil Nadu (2020). Demand No.14, Policy Note 2019-20. Available at: *http://cms.tn.gov.in/sites/default/files/documents/energy_e_pn_2019_2020.pdf* (accessed on 02 February 2021)

13. Energy Storage News (2018). The case for C&I storage investigated. Available at: *https://www.energy-storage.news/blogs/the-case-for-ci-storage-investigated* (accessed on 02 February 2021)

14. Energy Storage News (2020). AI energy storage pioneer Stem Inc to go publicly-listed. Available at: *https://www.energy-storage.news/news/ai-energy-storage-pioneer-stem-inc-to-go-publicly-listed* (accessed on 02 February 2021)

15. Greentech Media (2020a). This Swiss Asset Firm Is Buying Up America's Largest Solar Projects. Available at: h*ttps://www.greentechmedia.com/articles/read/meet-the-swiss-asset-firm-buying-up-the-largest-u-s-solar-projects* (accessed on 02 February 2021)

16. Greentech Media (2020b). World's Largest Customer-Sited Solar-Storage Plant Planned for Nevada Desert. Available at: *https://www.greentechmedia.com/articles/read/behind-the-meter-has-never-been-this-big* (accessed on 02 February 2021)

17. IESO (2021). Independent Electricity System Operator. Available at: *http://reports.ieso.ca/public/IndustrLoadBySector/* (accessed on 02 February 2021)

18. Mercom India (2020a). Sun Exchange's 1.9 MW Solar-Plus-Storage Project for Zimbabwe's Vegetable Exporter. Available at: *https://mercomindia.com/sun-exchange-1-9-mw/* (accessed on 02 February 2021)

19. Mercom India (2020b). South African Solar Company Sun Exchange Secures $3 Million Funding. Available at: *https://mercomindia.com/sun-exchange-secures-3-million-funding/* (accessed on 02 February 2021)

20. MNRE (2021). No. 283/3/2018-GRID SOLAR Dated 9th March 2021, Imposition of Basic Customs Duty (BCD) on Solar PV Cells & Modules/ Panels. Available at: *https://mnre.gov.in/img/documents/uploads/file_f-1615355045648.PDF* (accessed on 17 March 2021)

21. NHIMBE fresh (2021). Our infrastructure. Available at: *https://nhimbefresh.com/our-infrastructure/* (accessed on 02 February 2021)

22. NITI Aayog & World Energy Council (2018). Zero-Emission Vehicles (ZEVs): Towards a Policy Framework. Available at: *https://niti.gov.in/writereaddata/files/document_publication/EV_report.pdf* (accessed on 02 February 2021)

23. ORF (2020). Charging India's battery manufacturing capacity. Available at: h*ttps://www.orfonline.org/expert-speak/charging-india-battery-manufacturing-capacity/* (accessed on 02 February 2021)

24. PV Magazine (2020). Stem, a behind-the-meter energy storage company, is for sale. Available at: *https://pv-magazine-usa.com/2020/01/28/stem-a-behind-the-meter-energy-storage-company-is-for-sale/* (02 February 2021)

25. Recharge (2016). Intelligent distributed storage will be a game-changing factor on the grid. Available at: *https://www.rechargenews.com/solar/intelligent-distributed-storage-will-be-a-game-changing-factor-on-the-grid/1-1-1183207* (02 February 2021)

26. REopt (2021). REopt: Renewable Energy Integration & Optimization. Available at: h*ttps://reopt.nrel.gov/tool* (accessed on 02 February 2021)

27. Schmidt, O.; Hawkes, A.; Gambhir, A.; and Staffell, I. (2017). The future cost of electrical energy storage based on experience rates. Nat Energy 2, 17110. *https://doi.org/10.1038/nenergy.2017.110* (accessed on 02 February 2021)

28. Sun Exchange (2020). Solar PV cells powering a 510.30 kW solar plant with 1 MWh battery storage for Nhimbe Fresh, Marondera, Zimbabwe via Pick It Fresh (Botswana). Available at: *https://d1tsx6lhcafpu4.cloudfront.net/production/734da47bffa1487691e7a0d0f53cbd17.pdf* (accessed on 02 February 2021)

29. TEDA (2019). Tamil Nadu Solar Energy Policy – 2019. Available at: *http://teda.in/wp-content/uploads/2019/02/SOLARPOLICY2019.pdf* (accessed on 02 February 2021)

30. Telefocus (2019). Leaning Towards Li-ion: Towercos look to replace DG sets with more efficient battery solutions. Available at: *https://tele.net.in/leaning-towards-li-ion-towercos-look-to-replace-dg-sets-with-more-efficient-battery-solutions/* (accessed on 03 February 2021)

31. TNERC (2017). Determination of Tariff for Generation and Distribution, Order in T.P. No.1 of 2017 dated 11-08-2017. Available at: *http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2017/TariffOrder/TANGEDCO-11-08-2017.pdf* (accessed on 18 October 2020)

32. TNERC (2018a). M.P. No.10 of 2018 dated 04-01-2019, Available at: *http://www.tnerc.gov.in/orders/commn%20order/2019/EID-MPNo10of2018.pdf* (accessed on 02 February 2021)

33. TNERC (2018b). M.P. No.14 of 2018 dated 29-10-2019, Available at: *http://tnerc.gov.in/orders/commn%20order/2019/TANGEDCO-MPNo14of2018.pdf* (accessed on 02 February 2021)

34. TNERC (2019a). Order on Rooftop Solar Generation. Order No. 3 of 2019 dated 25-03-2019. Available at: *http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-25-03-2019.pdf* (accessed on 27 January 2021).

35. TNERC (2019b). Order on generic tariff for Solar power and related issues, Order No. 5 of 2019 dated 29 -03-2019. Available at: *http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2019/Solar-5-29-03-2019.pdf* (accessed on 02 February 2021)

36. TNERC (2020a). Order on procurement of Solar power and Related Issues. Order No. 9 of 2020 dated 16-10-2020, Available at: *http://www.tnerc.gov.in/orders/Tariff%20Order%202009/2020/Solar-Order-16-10-2020.pdf* (accessed on 02 February 2021)

37. TNERC (2020b). M.P. No.2 of 2020 dated 10-11-2020, Available at: *http://www.tnerc.gov.in/orders/commn%20order/2020/TEDA-MPNo2of2020.pdf* (accessed on 02 February 2021)



# ANNEXURE 1: Assumptions

- **Best Economic Returns and Towards Net Zero**

| | | |
|---|---|---|
| Solar PV System capital cost (w/o solar PCU cost) | INR/kW | 36,000 |
| Hybrid inverter capital in base year | INR/kW | 30,000 |
| Battery pack capital cost in base year | INR/kWh | 21,000 |
| Cost for storage container and others | INR | 1,050 |
| EPC cost | INR | 15,000 |
| | | |
| ToD Solar export – Normal hour (10 AM to 5 PM) | INR/kWh | 2.08 |
| ToD Solar export – Off-peak hour (10 PM to 5 AM) | INR/kWh | 1.98 |
| ToD Solar export – Peak hour (6 AM to 9 AM & 6 PM to 9 PM) | INR/kWh | 2.50 |

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- **Office (HT - III)**

| | | |
|---|---|---|
| ToD Grid Import – Normal hour (10 AM to 5 PM) | INR/kWh | 8.00 |
| ToD Grid Import – Off-peak hour (10 PM to 5 AM) | INR/kWh | 7.60 |
| ToD Grid Import – Peak hour (6 AM to 9 AM & 6 PM to 9 PM) | INR/kWh | 9.60 |

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- **Automobile Industry (HT - IIA)**

| | | |
|---|---|---|
| ToD Grid Import – Normal hour (10 AM to 5 PM) | INR/kWh | 6.35 |
| ToD Grid Import – Off-peak hour (10 PM to 5 AM) | INR/kWh | 6.03 |
| ToD Grid Import – Peak hour (6 AM to 9 AM & 6 PM to 9 PM) | INR/kWh | 7.62 |

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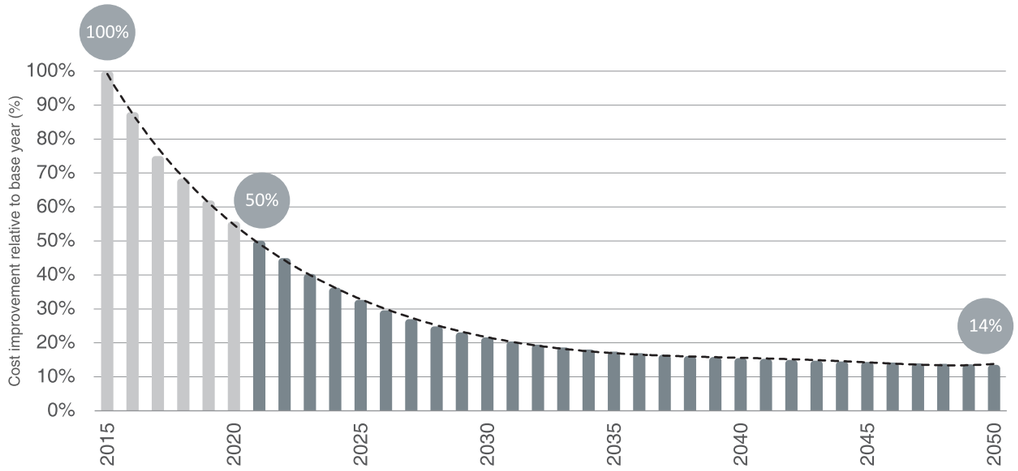
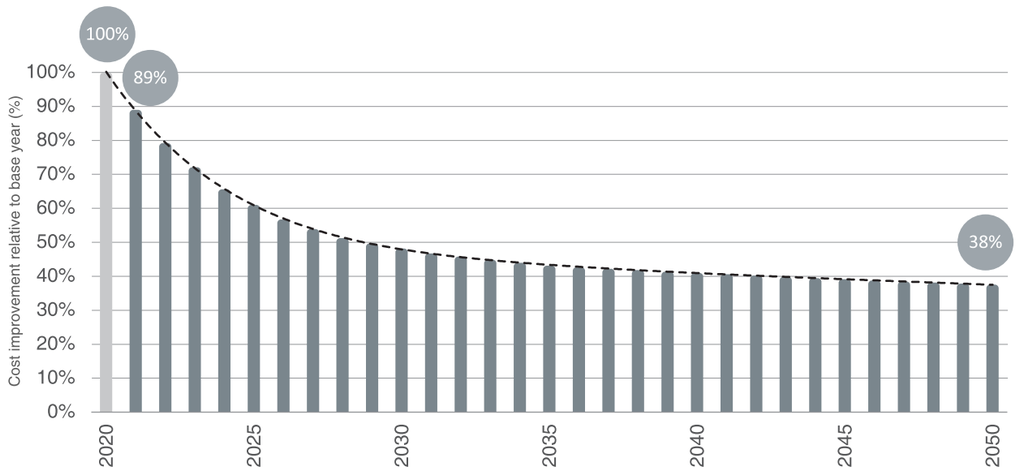
- **Educational Institute (HT - IA)**

| | | |
|---|---|---|
| ToD Grid Import – Normal hour (10 AM to 5 PM) | INR/kWh | 6.35 |
| ToD Grid Import – Off-peak hour (10 PM to 5 AM) | INR/kWh | 6.03 |
| ToD Grid Import – Peak hour (6 AM to 9 AM & 6 PM to 9 PM) | INR/kWh | 7.62 |

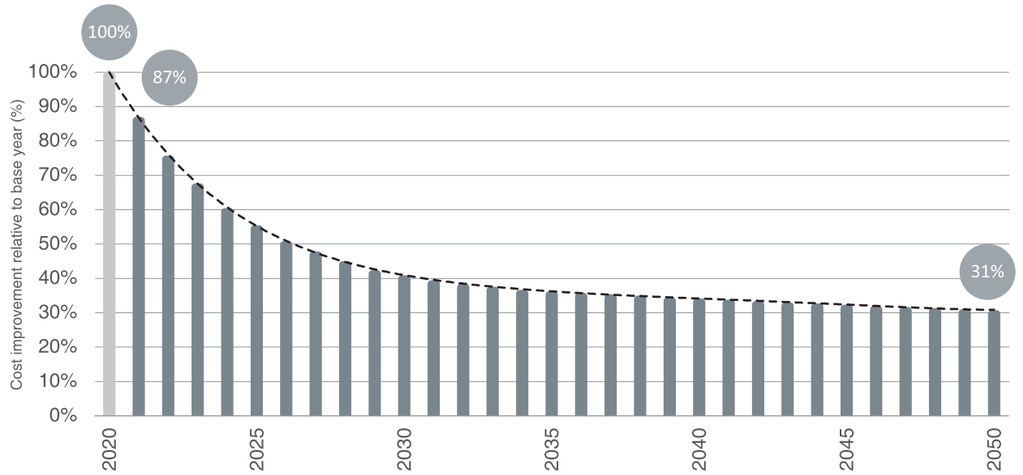
## Li-ion cost reduction curve (Schmidt et al. 2017)

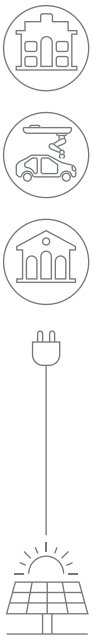



## Solar PV Cost reduction Curve (Auroville Consulting 2021)




## Inverter cost reduction curve (Auroville Consulting 2021)





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