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REPORT ON DEMAND POTENTIAL OF ROOFTOP SOLAR WITH STORAGE

Prepared By
South Asia Regional Energy Partnership (SAREP)
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TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

ACoS	Average Cost of Supply
APPC	Average Power Purchase Cost
BESS	Battery Energy Storage System
C& I	Commercial and Industrial
CAPEX	Capital Expenditure
CEA	Central Electricity Authority
CEEW	Council on Energy Environment and Water
CEIG	Chief Electrical Inspectorate General
CFA	Central Financial Assistance
DC	Direct Current
DER	Distributed Energy Resources
DHBVN	Dakshin Haryana Bijli Vitran Nigam Limited
DISCOM	Distribution Company
DRE	Distributed Renewable Energy
DT	Ratio Distribution Transformer Ratio
FiT	Feed in Tariff
GW	Gigawatt
HAREDA	Haryana Renewable Energy Development Agency
HERC	Haryana Electricity Regulatory Commission
KW	Kilowatt
kWh	Kilowatt hour
LCOES	Levelized cost of energy storage
Li-Ion	Lithium Ion
MNRE	Ministry of New and Renewable Energy
MU	Million Unit
MW	Megawatt
MWh	Megawatt hour
OEM	Original Equipment Manufacturer
REC	Renewable Energy Certificate
RESCO	Renewable Energy Services Company
RPO	Renewable Purchase Obligation
RTS	Rooftop Solar
SERC	State Electricity Regulatory Commission
SPV	Solar Photovoltaic
ToD	Time of Day
UHBVN	Uttar Haryana Bijli Vitran Nigam Limited
VGF	Viability Gap Fund
DC Overloading	Installing more panels than the capacity of the solar inverter

EXECUTIVE SUMMARY

As India endeavors to achieve its energy security and carbon mitigation goals, the electricity sector assumes a crucial role. A significant aspect of this transformation revolves around distribution utilities entrusted with delivering cost-effective and dependable energy to all consumers. Consequently, the efficient management of the electricity grid becomes imperative for India's ambitious mission to attain Net Zero by 2070. As outlined in the Intended Nationally Determined Contributions (INDCs), India is committed to increasing the share of installed electric power from non-fossil fuel sources to 50% by 2030, facilitated by the deployment of 500 GW of Renewable Energy Capacity by the same year.

However, the financial challenges distribution utilities face present a significant hurdle as they strive to navigate this transition. Over the past several years, these utilities have encountered losses for several reasons. First, substantial costs associated with supplying electricity over long distances are resulting in transmission and distribution losses. Second, outdated infrastructure requiring upgradation and augmentation is adding to the cost of delivery. Lastly, supplying energy to low-consumption consumer categories at discounted tariffs is resulting in cross-subsidization for other consumer categories

Distributed renewables such as solar photovoltaic (PV) plants have the potential to ease some of these issues. Stil, despite high aspirations, India fell short of its initial target of installing 40 Gigawatt (GW) of rooftop solar (RTS), achieving only 11 GW by 2023. Various obstacles, including disinterest from distribution companies (DISCOMs), high upfront costs of solar PV systems, a lack of adequate incentives, and the inability of solar to operate during power outages, have contributed to this performance.

Solar PV with battery energy storage can provide electricity during power outages and help DISCOMs and their consumers with a better tariff rationalization by reducing the procurement of high-priced power during peak demands.

Solar PV systems on their own are commercially viable for all consumer segments; however, the cost of battery energy storage is still high. This report focuses on addressing the viability of solar PV systems with battery energy storage in the state of Haryana and three other states. The states were chosen based on their specific requirements, such as demand management, peak load reduction, availability of low-cost power, and targeting higher renewable energy (RE) integration.

As per the analysis, residential solar PV systems for 3 kW load and above, coupled with an hour of energy storage, is financially viable without any viability gap fund (VGF) support. Additional hours of energy storage (more than an hour) are viable with direct current (DC) side overloading (increasing the PV panel capacity) or when a market for lower electricity tariff develops, supported by a higher share of low-cost renewable energy in the overall energy mix

An optimum level of 20% DC overloading (without increasing the inverter capacity) can result in better battery utilization. Through DC overloading, more solar energy will be available, and the battery can be better utilized which can reduce the lifetime cost of energy storage. However, solar panels of 1 kW and below capacity coupled with an hour of storage without any subsidy on battery energy storage systems (BESS) do not make a commercial case because of the higher capex cost of the system and highly subsidized retail tariff of the low consumption consumer category.

For commercial and industrial (C&I) consumers (25 kW), the system is viable without any VGF for one hour of storage. However, if the system is installed with 5-20% DC overloading, the system becomes viable for 2 and 2.5 hours of storage respectively. For systems size of 50 kW and above, up to two hours of storage is viable without any form of Central Financial Assistance (CFA) or DC overloading when compared to the levelized cost of grid tariff.

The cost of electricity during off-peak hours is still substantially high, making battery charging an unappealing proposition in the current scenario. However, the cost of the off-peak tariffs from the grid will go down with more RE integration. The lower tariff in the off-peak hours will make battery charging through the grid a more viable option between 3-5 hours of storage capacity.

Implementation of solar PV and BESS in the residential segment will also help the DISCOMs avoid the higher cost of purchasing electricity during peak hours. By avoiding the purchase of one hour of electricity during peak hours, on account of deploying a 50 MW solar PV plant with an hour of storage, the DISCOMs can achieve an annual saving of ~INR 71.0 lacs (USD 0.085 million).

Additionally, 10% solarization of the total energy consumption in the state of Haryana can lead to annual savings of up to INR 442 crore (USD 53 million) on account of avoiding charges (transmission and distribution). Based on findings from the study, the following recommendations are proposed:

- States Nodal Agency (SNA), such as the Haryana Renewable Energy Development Agency (HAREDA), to draft a battery energy storage policy and incentivize BESS for residential consumers in addition to the incentives under CFA provided on solar PV systems under the ongoing MNRE Phase II scheme;
- States regulators to allow installing solar PV systems with DC overloading up to 120%
- Increasing the Distribution Transformer (DT) ratio and allowing solar PV systems installed up to the transformer capacity from the current 50% and 30% on transmission and power transformers, respectively;
- We are providing compensation for the surplus generation fed to the grid at the settlement period under the net-metering mechanism;
- We are recognizing 'Behind the Meter Systems' by the states, where the system is connected for captive consumption with zero export device, and does not require any approval from any state agency;
- The state DISCOMs will prioritize outreach activities to increase the adoption of RTS with storage in their licensee areas.

INTRODUCTION

BACKGROUND AND RATIONALE FOR THE STUDY

The Indian RE sector has witnessed tremendous growth in the last decade. Large-scale integration of grid-connected solar and wind power projects is a testament to this regard. Solar energy is notonly limited to utility-scale applications, but attention has also been given to rooftop solar projects. As per the submitted NDC, India is committed to reducing its GDP's emission intensity by 45% by 2030 from the 2005 level and achieve about 50% cumulative electric power capacity installed from non-fossil fuels. To achieve this target, India plans to install 500 GW of installed renewable energy capacity by 2030, of which 40 GW would be through grid-connected solar rooftop plants. While the other RE technologies have slowly gained momentum, RTS has been lagging with 11.08 GW reported rooftop solar (RTS) installation in the country as of 15.11.2023 from all consumer segments.

The Ministry of New and Renewable Energy (MNRE) launched several solar policies to incentivize the installation of solar PV systems over the years. The policies aim to provide subsidies to make solar PV systems commercially viable for consumers. The Government of India, on December 30, 2015, approved an increase in the budget for providing Central Financial Assistance for rooftop installations, from INR 600 crore to INR 5000 crore for the implementation of the "Grid Connected Rooftop and Small Solar Power Plants Programme" up to the financial year 2019-20 (now referred to as Phase I of MNRE programme). This scheme covered residential, social, and institutional sectors and provided a 30% subsidy to the beneficiaries. The scheme led to achievement of cumulative installation of 1.796 GW as of 31.03.2019 as against targeted capacity of 2.1 GW at an expense of INR 1141 crore as of 08.03.2022. The SNAs were the implementing agencies for the Phase I scheme.

1 PIB- https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1847812 dated 03.08.2022
2 MNRE Physical progress- https://mnre.gov.in/physical-progress/
3 MNRE notification no 03/88/2015-16/GCRT dated 04.03.2016
4 MNRE Physical Achievements
https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/08/2023080345.pd
5 Lok Sabha Starred Question No 2635 dated 27.12.2018
6 Lok Sabha Unstarred Question No 2594 dated 17.03.2022
7 Note: The disbursed CFA may not be reflective of the installed capacity as there may be a delay in disbursement of subsidy for some projects.

Since then, MNRE launched the Phase II scheme for the deployment of rooftops in the residential sector with CFA support of INR 6600 crore. The ministry made DISCOMs the implementing agencies under the phase II scheme. The scheme focuses on residential consumers up to 10 kW (up to a maximum of 500 kW for CGHS and RWA). A subsidy of 40% is provided to consumers up to 3 kW, and 20% subsidy is provided for capacity above 3 kW and up to a maximum of 10 kW per household. The scheme has also provided an incentive for DISCOMs to install RTS within their area.

The DISCOMs are paid a yearly incentive based on the incremental capacity added during the year. They also receive service charges for the implementation of the scheme (3% of total 75% of CFA).

The ministry has spent INR 1557 crore under Phase II of the program. Based on the learnings fromPhase II, MNRE has further launched the simplified procedure for residential rooftops to escalate the adoption process further.

To date, MNRE has allocated targets of around 5.47 GW (2.1 GW in Phase I and 3.37 GW in Phase II as of 31.07.2023) for residential rooftop solar to the state implementing agencies and over 1.796 GW has been reportedly installed under Phase I and 2.207 GW capacity has been reportedly installed under the Phase II of the CFA program (under MNRE CFA supported scheme).

MNRE Scheme	Allocation/ Target	Achievement against Target
MNRE Phase I Scheme (with CFA support)	2.1 GW	1.796 as of 31.03.2019
MNRE Phase II Scheme (with CFA support)	3.37 GW	2.207 GW as of 31.07.2023
Total RTS (with or without CFA Support)	40 GW	11.08 GW as of 15.11.2023

8 MNRE Phase II Scheme
9 Lok Sabha Unstarred Question No 2594 dated 17.03.2022
10 Lok Sabha Unstarred Question No 3579 dated 10.08.2023
11 MNRE Physical Achievements
https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/08/2023080345.pdf
12 Lok Sabha Unstarred Question No 3579 dated 10.08.2023

Despite the efforts, estimates suggest that the country will not be able to meet the rooftop targets (40 GW).

The figure below is an estimation of the projected installed capacity of ~23 GW by 2030.

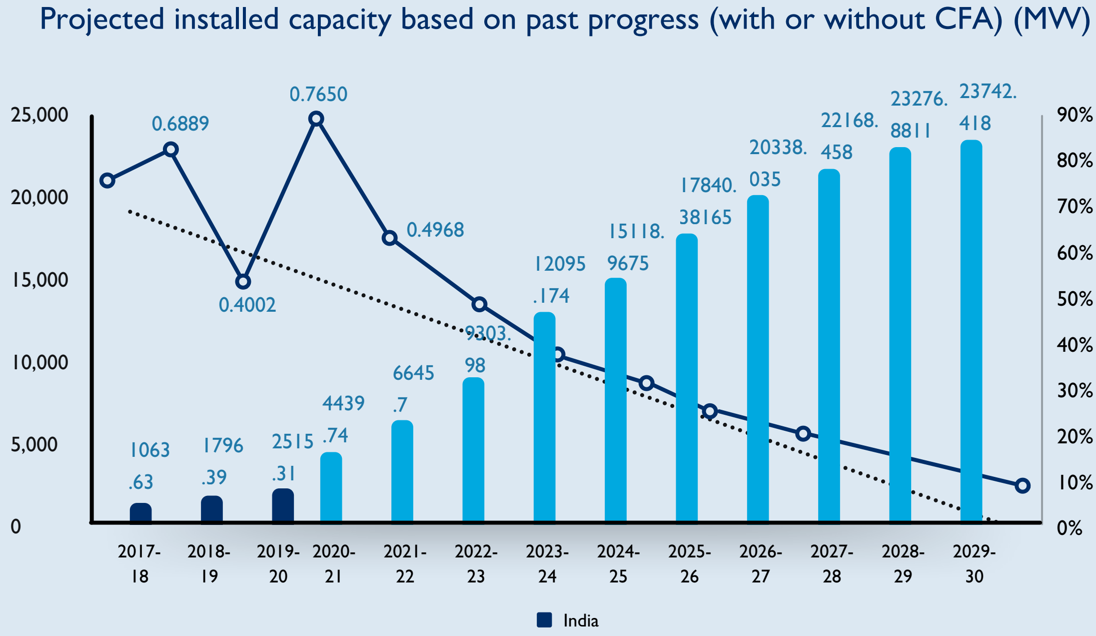


Figure 1: Project RTS Installed Capacity by 2030

Some of the reasons for the slow adoption of solar PV are as follows:

- DISCOM's lack of interest in promoting solar PV due to apprehension of loss of revenue;
- Lack of consumer awareness about the technology;
- Techno-economic viability of solar PV projects;
- Isolation of solar PV plants during grid outages.

The use of a battery energy storage system in conjunction with a solar PV system may be able to address some of the issues. To support the deployment of this technology, it is important to evaluate the technical and financial parameters to assess the benefits offered by the technology.

To carry out the study, USAID's SAREP has collaborated with the Ministry of New and Renewable Energy (MNRE) to assist in meeting the targets envisaged by the Government of India regarding the addition of RE capacity. Based on the discussions held between MNRE and USAID's SAREP, rooftop solar storage for residential and commercial segments has emerged as one of the significant areas where USAID's SAREP will evaluate the feasibility of solar PV with battery energy storage systems. The following sections will bring to light the need to examine the issues faced by key stakeholders, the techno-commercial viability of solar with storage and provide recommendations to key stakeholders.

13 Author's estimation based on MNRE Physical Achievement Data

SCOPE OF THE STUDY

Solar PV's technical and financial analysis with battery energy storage systems has vast applications for different consumer segments. It offers continuity of solar PV systems during grid outages, provides backup during days of autonomy and at night, offers better tariff rationalization for high-paying consumers such as commercial and industrial consumers, and, most importantly, supports DISCOM by making the grid more robust and reducing losses. To assess the benefit of solar PV with storage, the following are the considerations:

A. Demographics

The study is based on deriving the benefits for all consumer segments. The benefits of solar with battery energy storage can be entirely determined by parameters such as retail tariff, applicability of Time of Day (ToD) tariff, metering regulations, and treatment of surplus power.

Analyzing the above parameters, we see that the state of Haryana seems to be a viable state for the study. Haryana has received a net allocated target of 55.85 MW as of July 31, 2023 under the MNRE Phase II scheme for the deployment of rooftop solar in the residential sector of the state. The following is the progress in the state in the deployment of utility-scale solar and rooftop solar since FY 2017-18:

Figure 1: Rooftop Installation in the State of Haryana

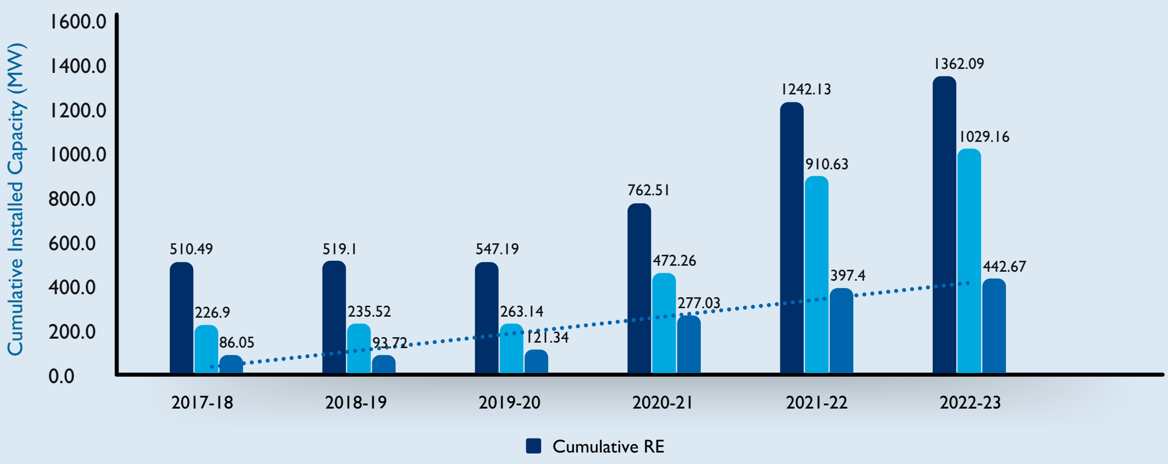
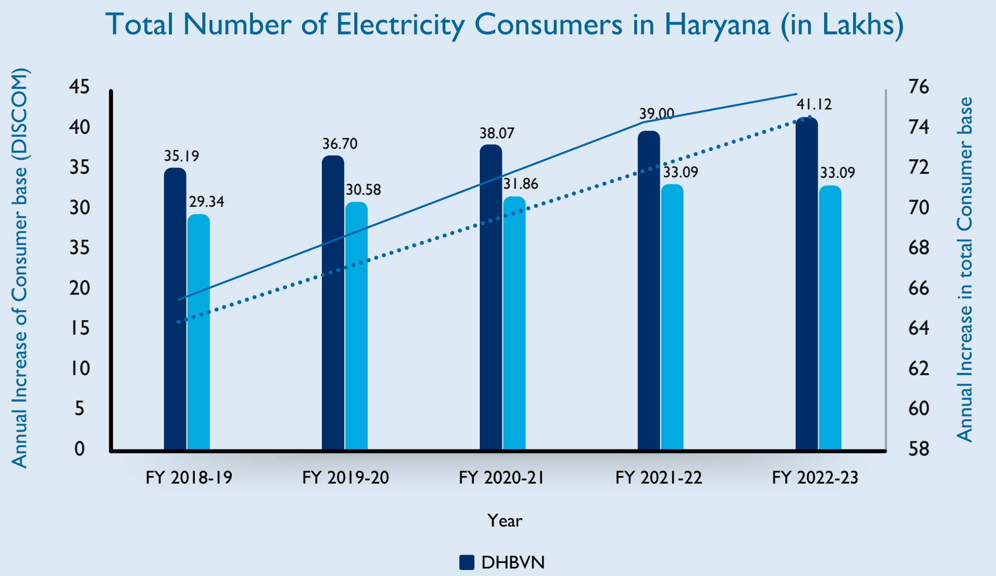


Figure 2: RE Installation in the State of Haryana

14 Lok Sabha Unstarred Question No 3579 dated 10.08.2023.



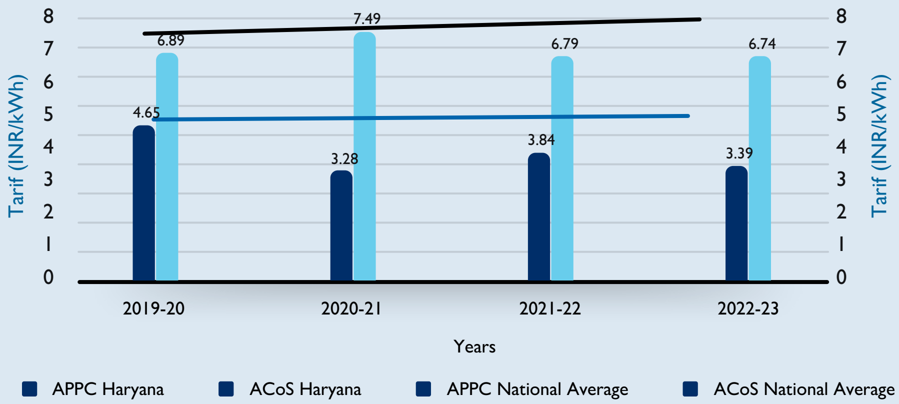
Haryana caters to the electricity demand of more than 3.3 million consumers in the Uttar Haryana Bijli Vitran Nigam Limited (UHBVN) licensee area and 4.1 million consumers in the Dakshin Haryana Bijli Vitran Nigam (DHBVN) licensee area. The consumer base has been growing at an annual rate of 2%.

The cost incurred for a unit of electricity delivered to the end consumer by distribution utilities is known as the Average Cost of Electricity Supply (ACoS). The distribution utilities purchase electricity from generators at a cost called Average Power Purchase Cost (APPC) and then sell it to the consumer at a rate called retail tariff which the state regulators determine. The actual cost of delivery, ACoS, is minimum for large industries connected at high voltage levels and is maximum for small consumers, such as residential consumers. The heightened losses and infrastructure costs of serving these consumers contribute to the elevated ACoS. To bridge the gap between the modest tariffs paid by these residential consumers and the ACoS, a cross-subsidy is employed, wherein the burden is transferred to high-paying consumers like industries and commercial enterprises.

However, the dynamics are shifting as an increasing number of high-paying consumers opt for open access, diverting from reliance on distribution utilities. Consequently, the utility's capacity to cross subsidize these consumers diminishes and even though the state has been improving its procurement efficiency over the years, leading to reduced APPC from INR 4.65 per kWh in FY 2019-20 to INR 3.39 per kWh in FY 2022-23 (~27% reduction) against the national average of INR 3.96 per kWh (in FY 2022-23), the ACoS has only reduced from INR 6.89 per kWh in FY 2019-20 to INR 6.74 per kWh in FY 22-23, a reduction of merely 2%. The gap between ACoS and APPC in terms of national average is lower than Haryana.

15 https://www.uhbvn.org.in/staticContent/documents/statistics/consumers.pd
16 https://dhbvn.org.in/staticContent/information/statisticaldata/Year_wise_Statistical_Data.xls
17 Key regulatory parameters of power utilities– REC

Total Number of Electricity Consumers in Haryana (in Lakhs)



The widening gap between the ACoS and APPC (ACoS-APPC) is indirectly indicative of a higher quantum of cross subsidization burden on the C&I consumers, higher operational expenses of the DISCOMs, and so on. This makes Haryana an ideal state to study the benefit of implementing solar PV with storage for all consumer segments and the DISCOM.

The solar PV with battery energy storage can also support the DISCOM to reduce the purchase of high-cost power during the Time of Day (ToD) hours. Solar PV coupled with BESS can enable banking of power during off-peak hours and its utilization during the peak hours (ToD hours) for C&I consumers. The state is also ideal, as Haryana has a good solar profile and limited scope of other RE technologies.

B. Identifying Stakeholders

The state has two DISCOMs, Uttar Haryana Bijli Vitran Nigam Limited (UHBVN) and Dakshin Haryana Bijli Vitran Nigam Limited (DHBVN). The implementation of the RTS project belongs to the DISCOMs. The implementation will also require regulatory support from the Haryana Electricity Regulation Commission (HERC) and policy amendments from the Haryana Renewable Energy Development Agency (HAREDA).

The Ministry of New and Renewable Energy (MNRE) is an important stakeholder as it provides subsidies to the residential consumers for solar PV systems.

The project also requires consultation with manufacturers, engineering, procurement and constr-uction (EPC) companies, developers, and consultants to understand their perspective on these systems. The stakeholders will be essential in providing feedback on the model.

18 MNRE Physical Progress Page, https://cdnbbsr.s3waas.gov.in/s3716e1b8c6cd17b771da77391355749f3/uploads/2023/11/2023110817199 50808. pd
19 Lok Sabha Unstarred Question 3579 dated 10.08.2023
20 https://www.mordorintelligence.com/industry-reports/india-battery-energy-storage-systems-market

C. Technical and Financial Model

In order to evaluate the feasibility of solar PV with battery energy storage systems, it is important to develop a technical model to estimate the following technical parameters:

- **Define the consumer segments:** This study is to estimate the feasibility of the solar PV system with BESS for residential consumers and C&I consumers;
- **Input consumption:** The model must estimate the benefits for C&I consumers that have a ToD tariff. The consumption pattern of the consumers over the entire day and throughout the year is of importance. Therefore, provision has been made to allow consumers to provide such inputs in the Excel mode;
- **Policies and Regulation:** The model incorporates the maximum capacity of SPV that can be installed as per the regulations. The model also encompasses the existing CFA provided to residential consumers (national portal subsidy);
- **Solar Generation profile:** Since the generation from the RTS system is dependent on the location of the solar plant, it is important to create the hourly solar PV generation profile for Haryana;
- **Energy Flow:** The model has to estimate the hourly flow of energy based on the load requirement, generation from SPV and status of BESS (charge);
- **Financial parameters:** This involves capital cost of the plant, discount rate, interest rate, and so on based on market feedback.

D. Consumer Survey

It is essential to get feedback from the consumers on the findings from the Excel model. Therefore, a consumer survey of the beneficiaries (residential consumers and C&I consumers) is also conducted to ascertain the willingness of consumers to adopt solar PV with battery energy storage.

MARKET ASSESSMENT

OVERVIEW OF THE ROOFTOP SOLAR AND STORAGE MARKET

The growth rate of installation of RTS in Haryana picked up since FY 2020-21. As of 31st July 2023, the cumulative installed rooftop solar capacity in - Haryana stood at approximately 486.23 MW, demonstrating a steady growth trajectory (as shown in the figure below with future projections):

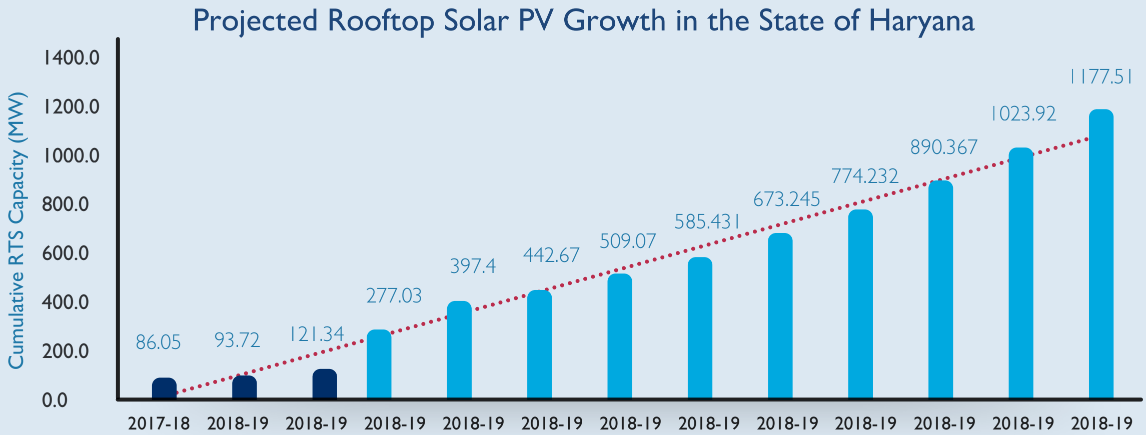


Figure 5: Projected RTS Growth

The residential sector in Haryana represents a smaller portion of the rooftop solar market with a commissioned capacity of approximately 33.8 MW (under subsidy program in the residential segment) as of 10.08.2023 under MNRE Phase II subsidy scheme.

India's battery energy market is estimated to be at USD 3.10 billion and is expected to reach USD 5.27 billion in the next five years at a Compound Annual Growth Rate (CAGR) of 11.2%. The prospect of reducing electricity bills and storage during power outages incentivizes homeowners to explore solar PV with energy storage systems.

KEY TRENDS AND DRIVERS

The RTS sector in Haryana has grown at an annual average rate of approximately 40% in the last five years. This can be further propelled with the integration of RTS with BESS, which offers numerous advantages for residential, commercial, and industrial consumers as well as for DISCOMs. Listed below are key benefits for different stakeholders:

Key Driver for Adoption of PV with BESS for Commercial and Industrial Consumers:

1. **Cost Savings:** By harnessing solar energy, commercial and industrial consumers can offset a significant portion of their electricity bills. The addition of battery storage allows them to store excess energy for use during periods of high demand or when grid electricity prices are at their peak (ToD hours);

2. **Energy Independence and Reliability:** With a BESS in place, commercial and industrial consumers gain a level of energy independence. They can rely on stored energy during grid outages or when grid electricity is temporarily unavailable, ensuring continuous operation of critical processes.

Key Driver for Adoption of PV with BESS for Residential Consumers:

1. **Cost Savings:** Residential consumers can also offset a significant portion of their electricity bills by harnessing solar energy;

2. **Energy Independence and Reliability:** With a BESS in place, residential consumers gain a level of energy independence. They can rely on stored energy during grid outages or when grid electricity is temporarily unavailable;

3. **Power Quality** Improvement: Controlled supply of power, free from any fluctuations in voltage and frequency from the grid.

BENEFITS FOR DISTRIBUTION COMPANIES (DISCOMS):

1. Loss Reduction:

The integration of solar and battery storage at consumer premises can significantly reduce losses incurred by DISCOMs at various levels of the electricity distribution chain. This includes loss due to transmission, distribution,open access, and wheeling of electricity;

2. Avoidance of Electricity Purchased at Spot Prices:

By installing solar rooftop and BESS systems, DISCOMs can reduce their reliance on purchasing electricity from the exchange at spot prices, which tend to be higher than the average grid rates. This can lead to cost savings for DISCOMs;

3. Enhanced Grid Stability and Reliability:

The widespread adoption of solar with BESS systems by consumers can lead to a more stable and reliable grid. It can help balance supply and demand, particularly during periods of high demand or intermittent renewable energy generation;

4. Reduced Need for Infrastructure Upgrades:

By encouraging consumers to generate and store their own energy, DISCOMs can potentially reduce the need for significant infrastructure upgrades like replacement of distribution transformers to meet increasing demand. This can lead to cost savings in grid expansion and maintenance.

REVIEW OF EXISTING REPORTS

OVERVIEW OF RELEVANT REPORT

Several reports have been reviewed before carrying out the assignment. Some of the more relevant work includes CEEW's 'Valuing Grid-Connected Roof-top Solar – A framework to assess costs and benefits to DISCOMs' and 'Improv-ing DISCOMs' Financial Viability Learnings from Uttar Haryana Bijli Vitran Nigam.'

Synopsis of Reports

Haryana, celebrated for its abundant solar irradiance and escalating energy needs, has been the focus of a few reports. These documents propose strategies to make the most of its solar capabilities. Principal sources include reports from the Haryana Renewable Energy Development Agency (HAREDA), the MNRE, and distinguished research institutions including Council on Energy Environment and Water (CEEW).

Valuing Grid-Connected Rooftop Solar: A Framework to Assess Costs and Benefits to DISCOMs-

There is a growing apprehension among DISCOMs that there is necessarily a revenue loss for them if a high paying consumer adopts solar PV. CEEW has carried out a study where the Valuing Grid-connected Rooftop Solar (VGRS) framework assesses individual DISCOM's benefits from solar PV installation.

The following parameters were used to evaluate the net impact on the DISCOMs revenue: Avoided Generation Capacity Cost (AGCC), Avoided Power Purchase Cost (APPC), Avoided Transmission Charges (ATRC), Avoided Distribution Capacity Cost (ADCC), Avoided Renewable Energy Certificate Cost (ARECC) and Avoided Working Capital Cost (AWCC). The technical study conducted by CEEW for BSES Rajdhani Power Ltd (BRPL) has shown that there is a net benefit on installing solar PV within the DISCOM licensee area. The benefit is estimated to be 75 paisa per kWh for single point society for BRPL 21 .

21 Valuing Grid-Connected Rooftop Solar– A framework to assess costs and benefits to DISCOMs

Improving DISCOMs' Financial Viability: Learnings from Uttar Haryana Bijli Vitran Nigam-

The publication focuses on the financial strength of UHBVN (Haryana) DISCOMs. The following factors have led to billing efficiency from 69.4% in FY 2015 to 82.8% in FY 2021 22 :

- Several factors including upgrades to the distribution network, consumer indexing and universal metering of consumers has led to loss reduction through targeted efforts;
- The DISCOMs efforts to create a universal database of rural and urban consumers has improved accuracy and timeline of bill;
- Establishment of grievances redressal mechanism has helped in consumer satisfaction;
- Replacement of cables with armored cable has led to reduction in electricity theft.

The collection efficiency has increased from 95% in 2015 to 100.8% in FY 2021. The following steps have helped Haryana DISCOM to improve collection efficiency:

- Incentive of 0.5% for digital payment and additional INR 50 incentive for six consecutive payments;
- Platforms such as bijli panchayat for consumer grievances redressal;
- Strengthening power distribution at village level under Mhara Gaon Jagmag Gaon (MGJG) scheme.

The cost of supply and Average Revenue Realized (ACS-ARR) gap dropped from INR 1.1 per unit in FY 2016 to INR 0 in FY 2019.

- The debt overtaken under Ujjwal scheme has strengthened the DISCOM financials.

22 Improving DISCOMs' Financial Viability– Learnings from Uttar Haryana Bijli Vitran Nigam

HARYANA'S SOLAR CAPACITY:

Haryana enjoys a remarkable solar resource potential, receiving an average solar irradiance between 5.5 kWh/m² to 6.5 kWh/m² per day and enjoys around 320 clear sunny days in a year.

This fact is highlighted by the State Solar Policy, which has outlined ambitious goals for solar capacity expansion. Below is annual and monthly irradiance received in the state of Haryana 23.

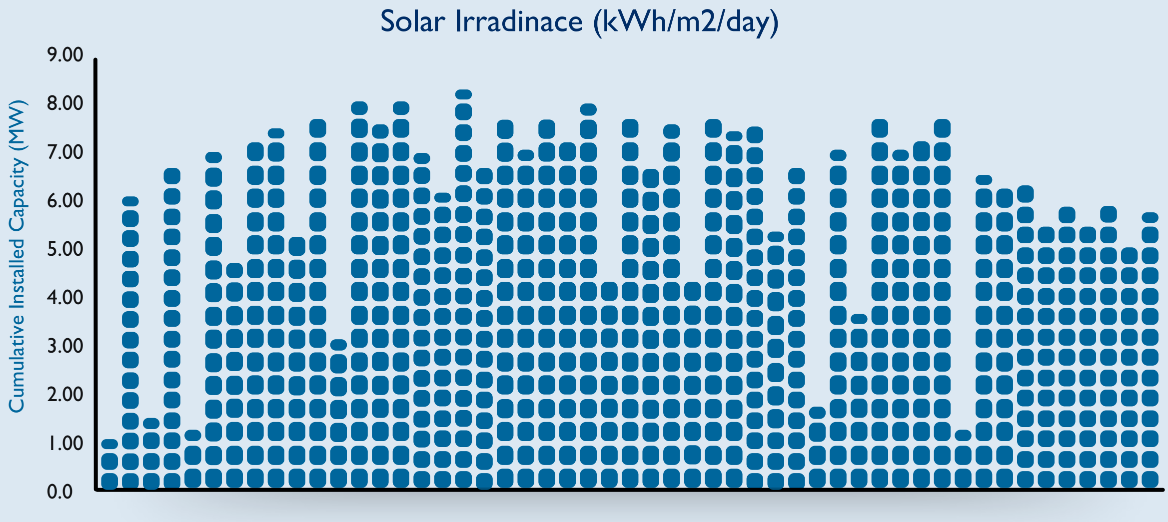


Figure 6: Solar irradiance (annual)

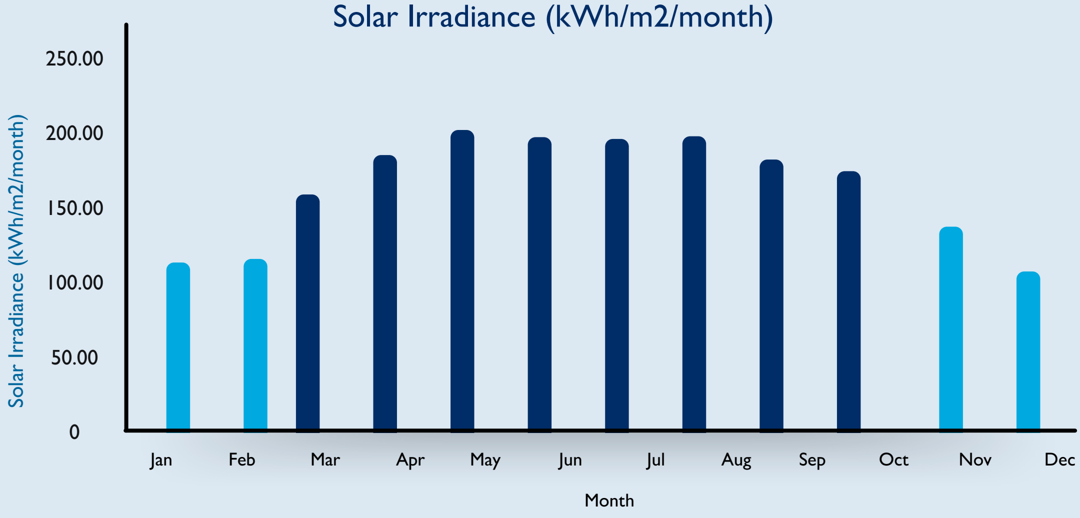


Figure 7: Solar irradiance (Monthly)

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23 Author's Analysis (based on generation data from NREL PVWatt tool)

REGULATORY AND POLICY ANALYSIS

OVERVIEW OF RELEVANT POLICIES AND REGULATIONS

The State Solar Policy of Haryana is an essential document that illuminates the government's commitment to renewable energy.

Moreover, the regulatory framework, managed by the Haryana Electricity Regulatory Commission (HERC), has a crucial role in regulating solar energy integration providing the much-needed framework for net metering.

A brief summary of the solar policy 24 issued by the nodal agency, HAREDA, is given below:

S.No.	Description	Summary of State Regulations
1	Operative Period	The policy will come into operation with effect from the date of its notification, that is, 14 th March 2016 and will remain in force till a new policy is notified.
2	Applicability	To achieve the solar RPO, following initiatives shall be taken by the government: • Rooftop grid connected solar power plants through net metering, • Rooftop grid connected solar power plants on clusters of government /PSU buildings.
3	Eligible Entities	Rooftop Grid Connected Solar Power Projects: The installation of 1kWp to 1 MWp of capacity grid connected solar rooftop power plants on the rooftops of Industries, public and private institutes, schools, colleges, commercial, and social institutions/ establishments, charitable trust bhawans, hospitals, residential buildings, and so on shall be promoted for their captive use/net meter as per the state government regulation.
4	State Nodal Agency	Haryana Renewable Energy Department/Haryana Renewable Energy Development Agency (HAREDA)

24HaryanaSolarPolicy-2016: https://cdnbbsr.s3waas.gov.in/s3f80ff32e08a25270b5f252ce39522f72/uploads/2020/12/2020120946.pdf

5	State Incentives	For installation of rooftop solar power plants, the state government shall provide capital/generation subsidy/incentives.
6	Metering and Billing Arrangements	• The grid connected rooftop solar photovoltaic systems of capacity equivalent to the sanctioned load can be installed for captive use, for which the net-metering facility shall be provided as per the Haryana Electricity Regulatory Commission regulations. The electricity generated from such systems shall be cumulatively adjusted at 90% of the electricity consumption during the financial year. • In addition, during the FY 2015-16 an incentive of 25 paise per unit shall also be provided in their bills on the solar power generated. The incentive payable under these regulations shall be reviewed by the commission every year along with Aggregate Revenue Requirement (ARR)/tariff petition for that year and the incentive payable accordingly for FY 2016-17 onwards.
7	Cap on Generation	The electricity generated from rooftop solar systems shall be cumulatively adjusted at 90% of the electricity consumption during the financial year.
8	REC (Renewable Energy Certificates)	A generating company engaged in generation of electricity from solar power plants shall be eligible to avail the Renewable Energy Certificates as per regulations of the Central Electricity Regulatory Commission.
9	Conducive Clauses for RTS Upliftment*	Generation Based Incentives: During the FY 2015-16 an incentive of INR 25 paise per unit shall also be provided in their bills on the solar power generated.

Table2: Summary of Haryana Solar Policy

The state has also mandated compulsory solar for project sizes below:

S.No.	State	Mandatory Solar Criteria		Category of building covered	Quantum of Mandatory Solar
		Above Plot Area	Connected Load		
1	Haryana	500 yards	-	Residential Buildings	5% of connected load (min 1 kW)
		-	30 kW	Educational Institutional	5% of connected load (min 5 kW)
		-	30 kW	Government	5% of connected load (min 2 kW)
		-	50 kW-1000 kW	Hospital, C&I	5% of connected load (min 10 kW)
		-	Above 1000 kW	Hospital, C&I	3% of connected load (min 50 kW)
		0.5 Acre to 1 Acre	-	New Residential Projects	min 10 kWp
		1 Acre to 2 Acre	-	New Residential Projects	min 20 kWp
		2 Acre to 5 Acre	-	New Residential Projects	min 30 kWp
		Above 5 Acre	-	New Residential Projects	min 40 kWp
		-	30 kW	Irrigation Department	3% of the connected load (min 50 kW)

HERC, the state regulators developed RE regulations based on the solar rooftop policy of the state25. Some of these regulations below, need to be amended to accommodate the latest developments in the country:

S.No.	Description	Summary of State Regulations
1	Net Metering	Yes -all categories except AP (Agricultural consumers) and Open Access consumers
2	Gross Metering	Yes -all categories except AP consumers
3	Capacity Limitation	NEM : Max. Sanctioned load up to 500kW Gross Metering: Max. Sanctioned load / Contract Demand
4	Excess/ FiT (INR/unit) approved	Net Metering: No Feed In Tariff (FiT). Electricity generated from a rooftop solar system shall be cumulatively capped at 90% of the electricity consumption by the consumer at the end of settlement period.
5	RTS Capacity Cap	500 kW for Net Metering Systems
6	DISCOM RTS Target (MW)	500 MW

25 Haryana Solar Regulations -2021:https://herc.gov.in/WriteReadData/Pdf/R20210719.pdf

7	Extracted Relevant Clause on Metering	The solar meter (uni-directional meter) is to be installed as an integral part of the net metering system at the point at which the electricity is generated by the Solar Energy System and delivered to the main panel of the grid. The net metering equipment (bi-directional meters), the solar meter and gross meter (uni-directional) shall be installed as per CEA regulations and maintained by the distribution licensee. The eligible consumer may procure net meter/solar meter/gross meter as per the technical specification of the distribution licensee and present the same to the distribution licensee for testing and installation. Provided further that for all rooftop solar systems of capacity 20 kW and above, net meter, solar meter as well as gross meter shall be Automated Meter Reading (AMR).
8	CEIG Approval Capacity	CEIG approval is not required for solar plants up to 20kW.
9	DT Capacity Ratio	Distribution transformer capacity and power transformer capacities are capped at 50% and 30% respectively.

The policy and regulations have been reviewed to identify the barriers to large scale adoption of PV, which are listed below:

S.No.	Description	State Regulation (barriers)	Description of the barrier
1	Metering and Billing Arrangements	The grid connected rooftop solar photovoltaic systems of capacity equivalent to the sanctioned load can be installed for the captive use, for which the net metering facility shall be provided as per the Haryana Electricity Regulatory Commission regulations. The electricity generated from such systems shall be cumulatively adjusted at 90% of the electricity consumption during the financial year.	The maximum electricity generation limited by the electricity consumption in a year puts a restriction on the capacity that can be installed on an RTS. This arrangement will strictly limit the use of PV for captive consumption only.
2	FiT for surplus generation	Haryana does not provide FiT for any surplus generation at the time of settlement under net metering mechanism.	This greatly impacts viability for cyclic industries.
3	Chief Electrical Inspector of the Government (CEIG)	CEIG approval is not required for solar plants up to 20kW.	This creates a requi-rement from the Chief Electrical Inspectorate of the government, thereby increasing the timeframe for installation of syst-ems.
4	DT Capacity Ratio	Distribution transformer capacity and power transformer capacities are capped at 50% and 30%, respectively.	This limits the overall capacity that can be connected to a distri-bution transformer.

ASSESSMENT OF DIFFERENCE SOCIO-ECONOMIC GROUPS OF CUSTOMERS

DISCOM BENEFIT FOR ~50MW SPV WITH BESS DEPLOYMENT IN RESIDENTIAL SEGMENT					
Income segment	Percentage of consumers	Reasons influencing the adoption of solar with storage system	Potential obstacles in the adoption of solar with storage system		
		High cost of electricity	Power cuts	High upfront cost	Lack of technology awareness
1	4.5	987.3	NIL	NIL	NIL
3	6	1,319.5	3,000.0	9,000.0	39.58
5	8	-1,450.9	3,200.0	16,000.0	46.43
10	9	-6,551.8	2,500.0	25,000.0	163.79
		Total	**8,700.0**	**50,000.0**	**249.81**

Table 11: DISCOM Benefit in 50MW Adoption in Residential Segment

MAXIMUM UTILIZATION OF BATTERY

In all the income categories, "Power cuts and high cost of electricity" have been the major factors proposed for the adoption of solar with storage solutions. Most of the consumers under different income categories have recognised "high upfront cost" as a major obstacle in the adoption of solar with storage solutions.

The EPC, developers, and OEMs are also important stakeholders in the implementation of these projects. The discussion with them was focused on the infrastructure requirement, changes to policy and additional support required for implementation of these projects (if any). The following feedback has been received from some of the developers/ implementing agencies:

CUSTOMER SURVEY ANALYSIS

A market survey was carried out to understand consumer awareness, requirements and perspective on solar PV with battery energy storage systems. The survey focused on consumers in the geography of Haryana and across all consumer income groups to get a holistic picture. The key findings from the survey are listed in the following section.

KEY FINDINGS OF CONSUMER SURVEY

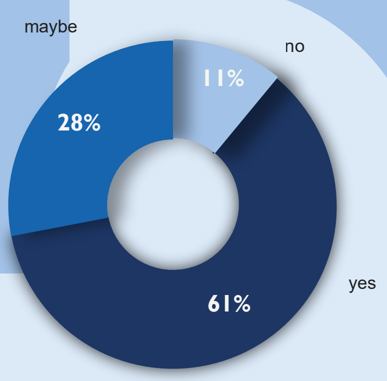
The consumer survey was conducted among the consumer categories such as residential, commercial, and industrial segments to assess the willingness to adopt rooftop solar with battery storage systems. The assessment was completed based on different parameters like the preference of number of hours of backup, willingness to replace any existing inverter with solar with battery system, choice of payment mode, etc., among several other questions.

A total of 167 participants with income between INR 3 lakh to INR 15 lakh (and above) participated in the survey. Around 95% of the consumers were found interested in solar with battery storage systems and were willing to invest up to 10% of their annual income on solar with battery storage systems.

Below are the findings based on key questions below:

1. Are consumers interested in replacing their existing conventional inverters with solar inverters battery energy storage systems (BESS)?

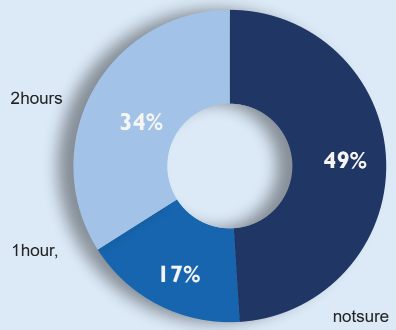
Out of 167 participants, 102 (61%) participants were interested in changing the existing inverters with solar with battery inverters while only 19 (11%) participants were not interested in making the switch.



Further, 34% of the consumers are seeking 1-2 hour backup. However, 24% of consumers selected to go with 3-4 hour backup and 40% of consumers chose to go with mort than 4 hour battery storage. This also reflects power outages conditi -ons in Haryana as the maximum consumers have opted for higher backup.

1. Are consumers aware of the benefits of investment in solar inverters with BESS? In how many backup hours do they want to invest?

51% (17% for 1 hrs backup) of consumers found the investment for the system with 1-2 hours backup beneficial while 49% were not aware if the systems would be beneficial.



2. What are the factors influencing the adoption of solar with storage systems?

Most of the participants cited 'clean energy, high cost of electricity, power cuts and government support, etc.' as key factors encouraging the adoption of solar with battery storage systems. High cost of electricity, power cuts and clean energy were the primary motivators for consumers to consider solar with storage solutions. Additionally, 55% of the participants found the current retail tariff structure to be high, which was the main reason for their interest in adopting solar PV with battery storage.

3. What is the major barrier for adoption of solar with storage systems?

Most of the consumers reported that the high upfront cost is a major deterrent, 62% consumers showed interest in having the system installed using financing options. Lack of financing options could be a major reason for slow adoption of renewable energy projects in the country. 45% consumers also shared concerns about the reliability and maintenance of solar with battery-based systems.

SUMMARY OF FEEDBACK FROM DEVELOPERS

The EPC, developers, and OEMs are also important stakeholders in the implementation of these projects. The discussion with them was focused on the infrastructure requirement, changes to policy and additional support required for implementation of these projects (if any). The following feedback has been received from some of the developers/ implementing agencies:

Table 6: Feedback from Stakeholders

Stakeholder : UHBVN
Area Of Expertise: DISCOM

Feedback:

Implementation of the BESS project is required in several rural parts of the country. The application process is scaling up in several areas around the country for microgrid projects.

Stakeholder : DHBVN
Area Of Expertise: DISCOM

Feedback:

Very interested in storage projects as there have been issues in delivering power in rural areas. Would like to see the application of solar PV with energy storage in microgrid projects in the state.

Stakeholder : EPC Player and Developer

Feedback:

- Specific policies on battery energy storage should be introduced.
- Since the technology is not viable for most segments, it is recommended that subsidies maybe provided to all consumer segments (including commercial and industrial).
- Subsidies should be provided for battery storage systems when used with solar PV.
- Existing financial institutions (FIs) have a delayed response to financing requirements. The financeing process needs to be made more robust.
- CEIG requirement should be eliminated.
- The GST on battery energy storage systems should be set to 5%, as is the case with other solar components. Reduced GST would also make these systems more viable.
- DISCOM net metering approval processes need to be simplified.
- Large scale adoption will require the government to do away with some of the barriers in procurement such as duties on imported cells and mandatory domestic cell requirements.
- Government should introduce more incentives for domestic manufacturers.
- Existing processes should be simplified through digitization.
- Solar should be mandated for large organizations and for new projects. FI are always apprehen sive of the default of payments from the vendors and therefore they offer interest rates which are not competitive. There should be some sort of guarantee fund to assist the situation. There should also be a guarantee fund specially in government schemes to ensure vendors' right to payment even in case of consumer default.

BUSINESS MODEL DEVELOPMENT

The Excel-based business model focuses on the flow of energy from the generation point meeting the consumer load and then charging the battery. This model mimics real life requirements based on the discussion with developers. The implementing agency, SNA or the DISCOM, may implement the project under various business models such as utility led aggregated models, or the conventional market driven by CAPEX model. The DISCOMs can also develop business models for low consumption consumers since that's where the cost of the delivery of the electricity is highest while the recovery is lowest.

The implementation of Solar PV with BESS will reduce DISCOMs expense in servicing the low consumption consumers and other consumer categories (C&I) will have a better tariff rationalization. The business models on their own will only be helpful if the solar PV systems and BESS offer value to the beneficiaries and therefore it is important to review the technical and financial benefits of the systems for the end consumers. The following section will deal with the technical and financial analysis of the model for residential, commercial and industrial consumers.

FUNCTIONING OF A BESS HYBRID SYSTEM

To make a model, it is important to know the requirements of the consumer. The success of solar PV with a battery storage system will depend on the monetary benefits in the project for the consumers, but sometimes there are also other benefits for the consumers, such as voltage and frequency regulation and support during grid outages.

The research will delve into trends in the market, consumer requirements and willingness and technology for the development of this solar PVwith storage model. A typical solar battery storage system is given in the figure below.

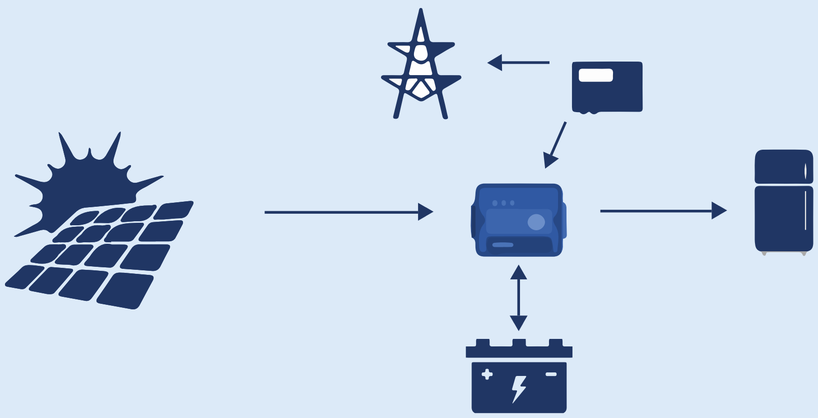


Figure 8: Typical arrangement of Solar with BESS System

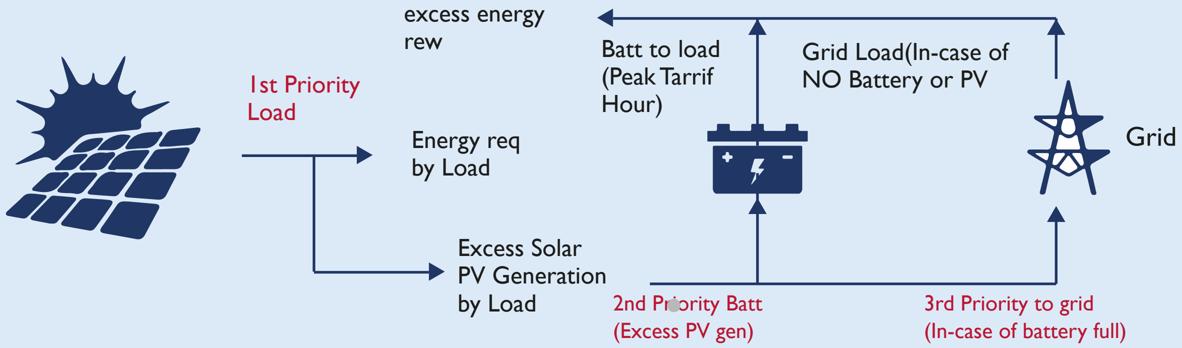


Figure 9: Energy Flow

The above figure refers to the actual flow of energy, that is, flow of energy generated from solar PV, utilization of energy stored in batteries, energy required by load etc.

GENERATION OF SOLAR PV ENERGY

The priority flow of energy generated from solar PV is as under:

- First priority: Cater the instantaneous energy required by the load during the daytime.
- Second Priority: After fulfilling the energy required by the load, the excess energy will flow to charge the battery.
- Third Priority: In case the battery is fully charged (by solar PV energy after feeding load), the surplus energy will be banked in the grid as per policy & regulation of the SERC

LOAD FULFILLMENT:

From the consumer standpoint, the energy requirement will be fulfilled in the following manner:

- Solar energy will first cater to the load during the daytime.
- In case of low SPV generation, the grid will feed the balanced energy required by the load.
- The energy stored in the battery will cater to the load requirements at only the time of day (ToD) hours to reduce the consumption of energy during peak tariff hours.
- In case there is no energy generated from the PV system (for example, on days of autonomy) and the battery is fully discharged, the load will be catered by the grid

The following data and assumptions have been used in the development of a financial model for a typical solar with battery storage system:

• **Sanction loads of consumers** are a very important factor in the development of the model, that is, selection of SPV capacity, battery capacity, inverter sizing, and other electrical components.

• **Daily profile** of a typical building is assumed based on the premises working at 50% of its sanctioned load and 100% during the evening or peak demand hours. Yearly load profile dataof a building has been taken to evaluate the actual load requirement and corresponding energy requirements.

• **The battery capacity is calculated** based on the actual use of the battery by the consumer or based on excess SPV power available after catering the load. About 1-4 hour battery storage capacity has been used to analyze and compare the levelized cost of the system with the levelized cost of the grid. This will help in the efficient selection and appropriate size of the system. The impact of overloading DC was also studied to estimate the additional hours of charging possible through the PV system.

•**The existing tariff of the DHBVN** has been used to evaluate the benefit of levelized cost of the system for residential as well as C&I consumers. Based on the existing tariff of both segments, the levelized cost of the grid is also calculated over the life of the SPV system.

• **The most efficient and economically** viable technologies available in battery, inverter, and SPV segments are used in the model. The other technical parameters, that is, capacity utilization factor (CUF), efficiency, capacity, and so on are used as per the MNRE guidelines, OEMs and other standards referred in India.

• **The capital expenditure of the major components** is also used based on market analysis and the availability of products.

• **The financial parameters** include rate of interest, cost of debt, or loan tenure are used based on CERC/market standards.

• **Current CFA/subsidy** has been considered for the evaluation of levelized cost.

COST ASSUMPTION FOR FINANCIAL MODEL

The financial model for evaluating the Levelized Cost of Energy from Storage (LCOES) for residential and commercial consumers, integrating solar photovoltaic (SPV) and BESS, considers the inclusion of specific parameters such as CAPEX, financing structure grid tariff, and battery technology as it is crucial for a precise and insightful analysis. This comprehensive approach ensures that the model considers not only the technical aspects but also the financial and economic feasibility of the proposed energy system, providing valuable insights for decision-makers and stakeholders in the residential/commercial sector. The table below highlights the range of cost estimates that are based on the prevailing market conditions and our discussions with relevant stakeholders.

COSTING ASSUMPTION (SPV+BESS)					
CAPACITY OF PROJECT (kWp)		SPV COST (INR/Wp)			COST (INR/Wh)
Greater than or equal to	Less than	PV Modules	Inverter	Balance of System	Battery
0.1	3	30	20	26	23
3	5	29	18	22	23
5	15	28	16	17	22
15	50	27	15	15	22
50	100	26	13	12	22
100	250	25	11	11	21
250	1000	24	10	10	20
1000	2000	23	9	9	20

Table 7: Costing Assumption (SPV+BESS)

ANALYSIS OF RESIDENTIAL CATEGORY

Solar PV with BESS (No VGF):

An essential parameter to evaluate a solar PV system with BESS is the Levelized Cost of Energy from Storage (LCOES). This metric plays a pivotal role in determining the cost-effectiveness and overall financial viability of such systems. LCOES of the system represents the unit cost of electricity storedand utilized by the load by the BESS over its operational lifespan, typically measured in rupees perkilowatt-hour (INR/ kWh).

he figure below represents different solar PV systems of capacities of 1, 3, 5, and 10 kW designed with battery backups of 1-4 hours. The LCOES of the system for each case has been compared with the current grid tariff (as per DHBVN tariff slabs) and levelized grid tariff (that is, current grid tariff levelized for 25 years with 4% of annual escalation).

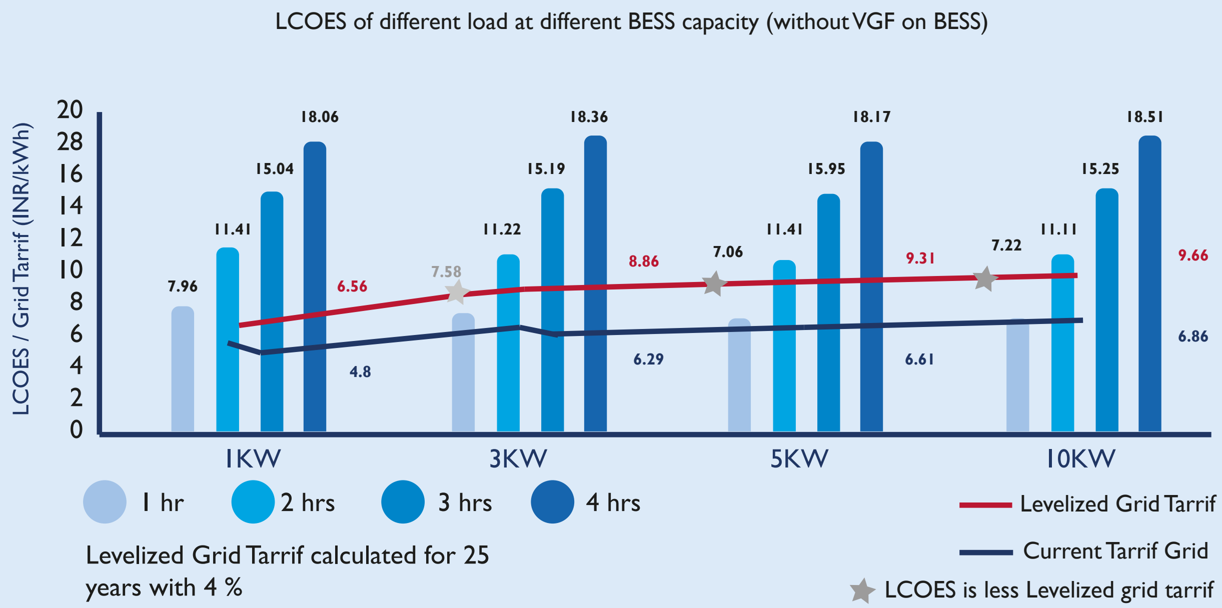


Figure 10: LCOES at different load

Solar PV with BESS (With VGF):

The MNRE in India provides CFA for grid-connected rooftop solar PV systems for residential and group housing societies. However, this is only applicable to solar PV systems and not on the cost of BESS. Given the higher cost share of BESS in the overall system, the LCOES significantly depends on it. Hence, the project team analyzed introducing a subsidy or VGF of 30% on BESS to assess the variation in the LCOES.

The figure below represents the LCOES of different solar PV system capacities with different BESS backup hours. Here a capital subsidy of 30% is included in the BESS cost, however, no major impact is observed on the viability of the overall system. With the increase in RE penetration, the grid tariff may decrease during off-peak hours, leading to the scenario where charging of batteries may become a viable option.

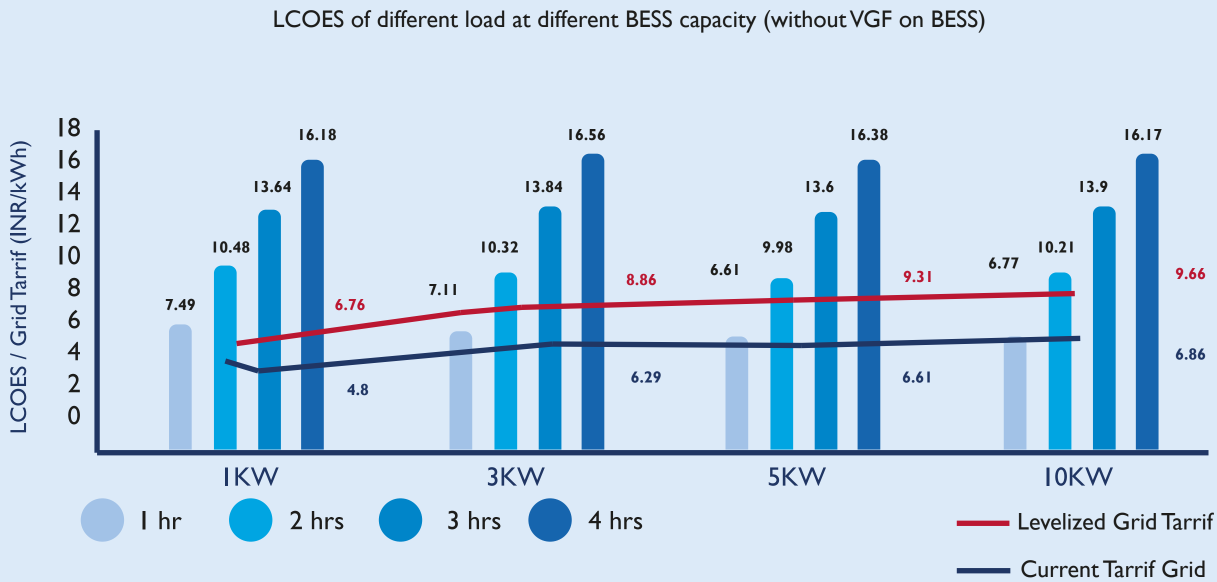


Figure 11: LCOES with 30% subsidy on BESS

ANALYSIS FOR COMMERCIAL AND INDUSTRIAL CATEGORY

The analysis focused on the commercial and industrial sector's energy needs, to harness the potential of solar and battery energy storage to optimize the cost savings. Examination of various scenarios, incorporating solar photovoltaic (PV) systems with capacities of 25 kW, 50 kW, and 100 kW was done.

Additionally, evaluation of d each of these solar systems with backup storage options ranging from 1 hour to 4 hours was done. The primary goal was to enable load requirements to be met predominantly by solar energy and leverage battery storage during higher tariff periods, such as Time of Day (ToD) tariff periods

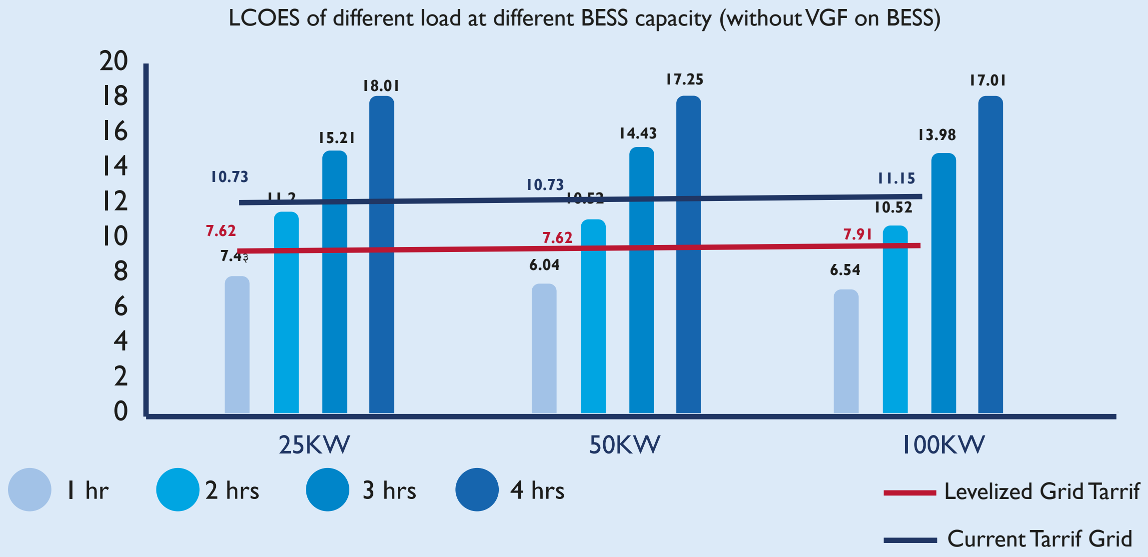


Figure 12: LCOES at different BESS – C&I

OBSERVATIONS:

Based on these findings, there are some cases where LCOES is less than the leveled grid tariff, thereby making these systems more viable.

- 25 KW and Above System With 1 Hour Backup Is Viable: This observation suggests that solar PV systems with a capacity of 25 kW or higher, combined with a 1-hour backup from the BESS, are economically feasible when compared to the leveled tariff of grid electricity.
- Battery Charging from Excess PV Energy: Larger solar PV systems (25 kW and above) consumers requirements and generate enough electricity to suffice the suffice the consumers requirements and surplus energy can be stored in BESS to be used during off-peak hours. A 5-20% DC overloading can increase the BESS capacity to 2 hour and 2.5 hour, respectively.
- 50 KW and Above PV Capacity Is Viable With 2 Hours of Backup: This observation suggests that solar PV systems with a capacity of 50 kW and above, combined with a 2 hours backup from the BESS, is economically feasible when compared to the leveled tariff of grid electricity

To illustrate the benefits of DC overloading (that is, going beyond the sanctioned load), the number of days when surplus generation is avail ble for a 10-kW system has been analyzed.

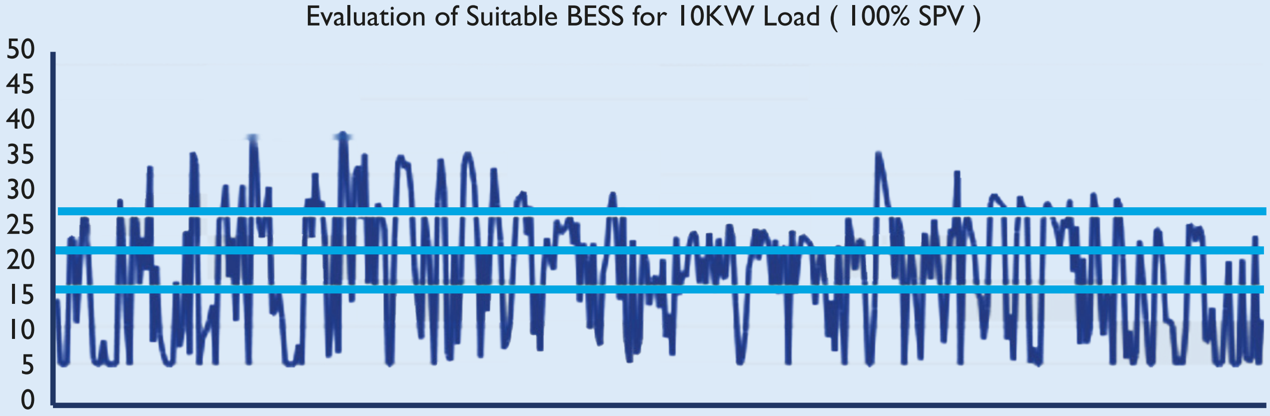


Figure 13: Suitability of BESS without any Overloading

Surplus energy data for evaluation of optimum BESS capacity has been taken and compared with the impact of an increase of solar energy in the overall mix. The days in the chart above indicate the number of days of charging that can be achieved by a 10kW load with a 10kWp solar PV plant at different levels of battery sizing. It is important to highlight that solar PV will cater to the load first and then charge the battery, hence surplus energy is required to optimize the size of the BESS.

In the above analysis, the maximum capacity of SPV that can be installed is limited to 100% of the sanctioned load. However, by increasing the PV capacity (DC side overloading), more electricity can be generated from the solar panels (figure below). This additional energy production can be used to charge the battery for an additional number of days and provide more energy for consumption, improving the overall battery charging efficiency. In the case below, the solar PV capacity has been increased by 20%, that is, for a 10 kW load, a 12 kWp solar PV system is used.

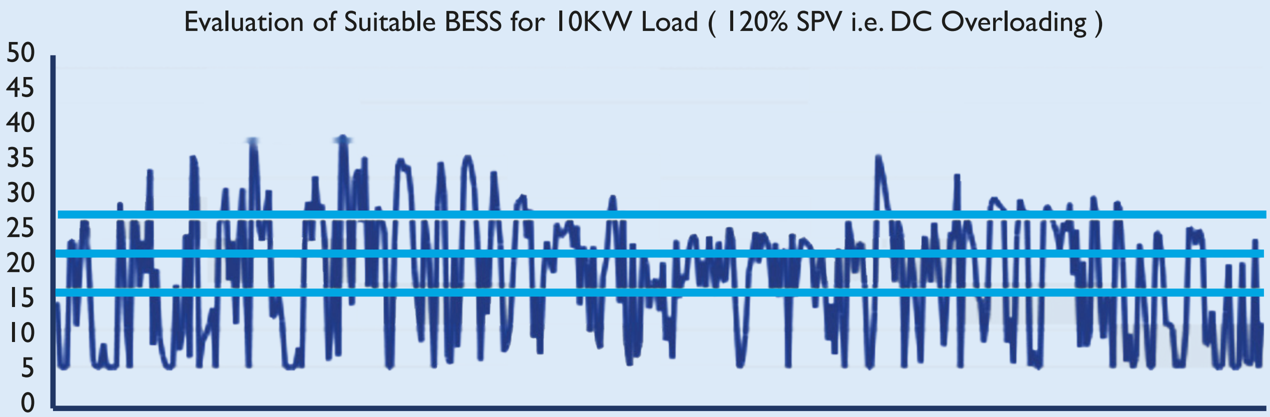


Figure 14: Suitability of BESS at 20% DC Overloading

AVOIDANCE OF LOSSES

The installation of the SPV system and BESS by consumers offers significant advantages to DISCOMs in terms of loss reduction. These benefits are particularly noteworthy:

• **Reduction in losses:** Solar and BESS installations at consumer premises can significantly mitigate losses incurred by DISCOMs at various levels of the electricity distribution chain. These losses encompass transmission losses during long-distance power transport, distribution losses within the local grid infrastructure, and additional losses associated with open access and wheeling of electricity.

• **Transmission and distribution losses:** Solar energy generated on-site reduces the need for electricity to traverse long distances, lowering transmission losses. Moreover, when consumers generate more electricity than they consume and store it using BESS, they effectively reduce their demand on the grid, minimizing distribution losses

These benefits have been further explained in terms of actual savings for UHBVN (Uttar Haryana Bijli Vitran Nigam Limited). For the year 2021-22, the *DISCOM losses* in terms of transmission, and distribution charges, accounted for *INR 1.46 per unit* of electricity sold to the consumer. The analysis below illustrates the penetration of SPV among different consumer categories like domestic, Low Tension (LT) industry and High Tension (HT) industry for UHBVN and DHBVN.

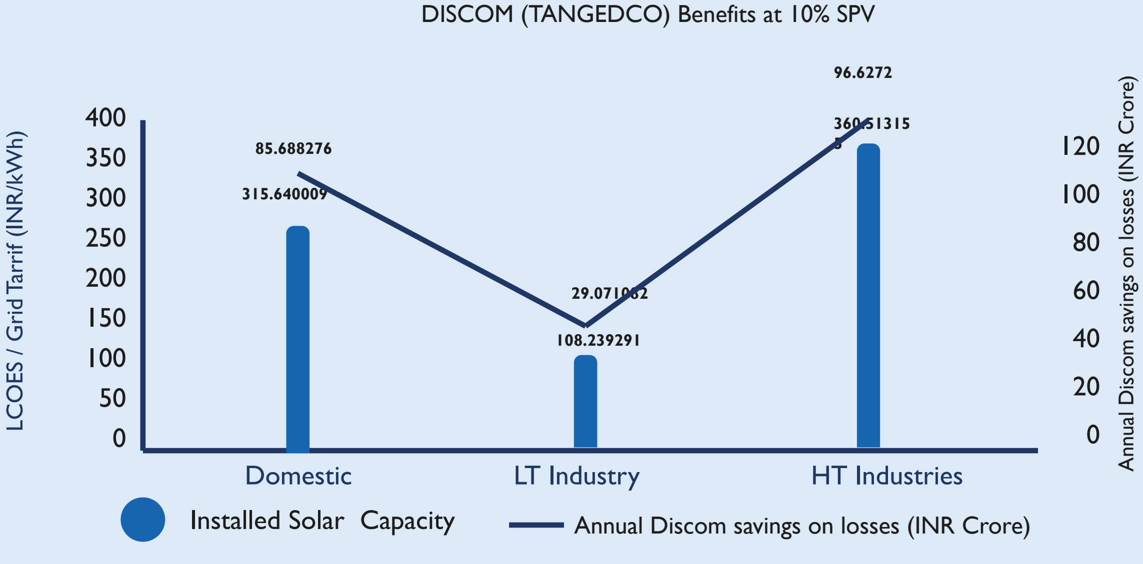


Figure 15: UHBVN Savings at 10% Solarization

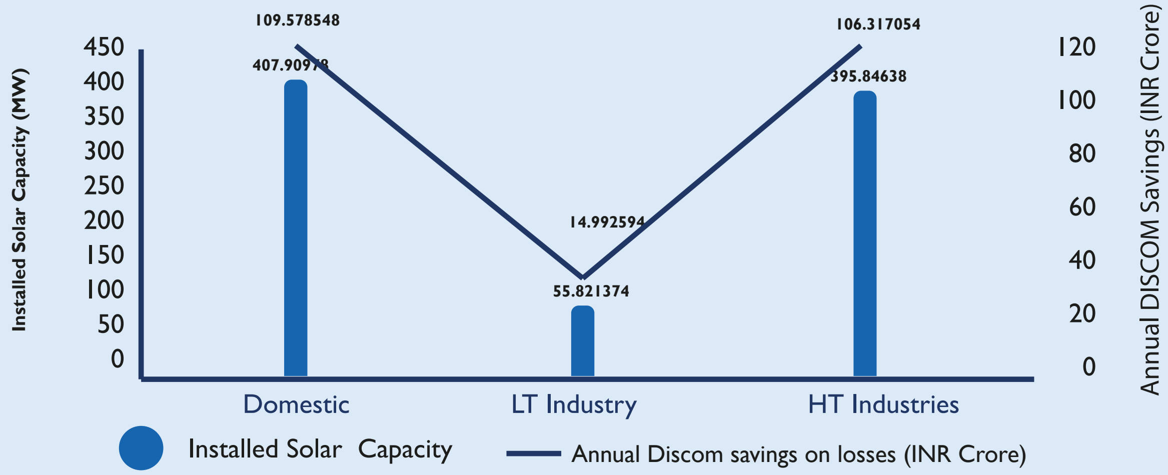
UHBVN: Category-wise sales to domestic, LT industry and HT industry for UHBVN in 2021-22 were 5869, 1,991 and 6632 MUs, respectively

By installing 10% SPV for total required capacity in UHBVN across:

o **Domestic category** (319 MW): INR 86 crore can be saved annually on account of avoiding charges

o **LT and HT Industry (108 and 361 MW):** INR 27 crore and INR 97 crore from LT and HT industry can be saved respectively (annual) on account of avoiding charges

DISCOM (DHBVNL) Benefits at 10% SPV



DHBVN: Category-wise sales to domestic, LT industry and HT industry for DHBVN in 2021-22 were 7505,1026 and 7281 MUs, respectively.

By installing 10% SPV for the total required capacity in the DHBVN across the:

o **Domestic category (408 MW)**: INR 110 crore can be saved annually on account of avoiding charges.

o **LT and HT Industry (56 MW and 396 MW respectively):** INR 15 crore and INR 106 crore can be saved from LT and HT industry, respectively on account of avoiding charges

AVOIDANCE OF ELECTRICITY PURCHASED AT SPOT PRICES

In addition to the benefits mentioned in the above section, DISCOMs can further enhance their cost savings and operational efficiency by avoiding the need to purchase electricity from the exchange at spot prices, which tend to be higher than the average grid rates.

In the table below, the average grid tariff for residential consumers with a different sanction load have been mentioned in the second column. The evening spot price for the Haryana region stands at INR 7.065 per kilowatt-hour (kWh) or INR 7065.74 per megawatt-hour (MWh) as reported by the Indian Energy Exchange (IEX). In the third a difference in spot prices and average grid tariff is mentioned in terms of profit/loss for DISCOMs. The negative value indicates that DISCOM is purchasing power at a higher cost from the exchange and is selling at a lower price to the consumer.

Additionally, it is estimated that installation of approximately 50 megawatts (MW) of solar photovoltaic (SPV) capacity by residential consumers in Haryana could result in a total benefit of approximately INR 71.07 lakh for the DISCOM on account of spot price.

DISCOM BENEFIT FOR ~50MW SPV WITH BESS DEPLOYMENT IN RESIDENTIAL SEGMENT

CAPACITY OF PROJECT (kWp)				SPV COST (INR/Wp)				COST (INR/Wh)
Sanctioned Load (KW)	Grid Tariff Avg. (INR/kWh)	Profit/Loss (INR/kWh)	DISCOM Saving INR (I	BESS Capacity (kWh/ per System)	Systems (Nos)	Capacity of System (KW)	BESS Capacity (MU/ Year)	Total DISCOM Saving (INR Lakh /Year)-Direct
1	4.8	-2.265	826.7	NIL	NIL	NIL	NIL	NIL
3	6.28	-0.785	859.6	3	3000	9000	3.3	25.79
5	6.61	-0.455	830.4	5	3200	16000	5.8	26.57
10	6.68	-0.205	748.3	10	2500	25000	9.1	18.71
				TOTAL	8,700	50000	18.3	71.07

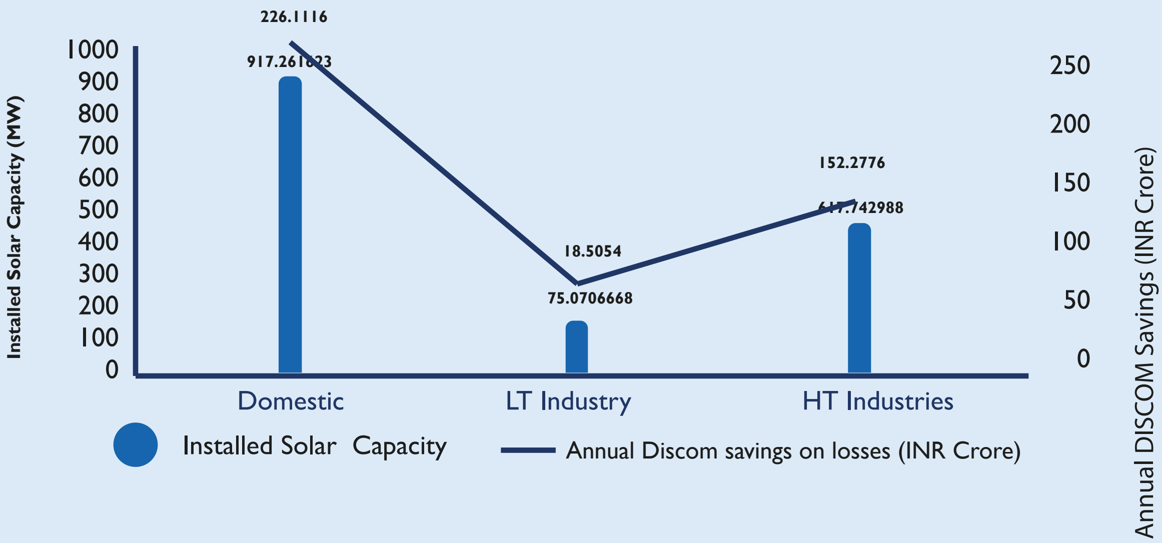
Table 11: DISCOM Benefit in 50MW Adoption in Residential Segment

ANALYSIS FOR OTHER DISCOMS:

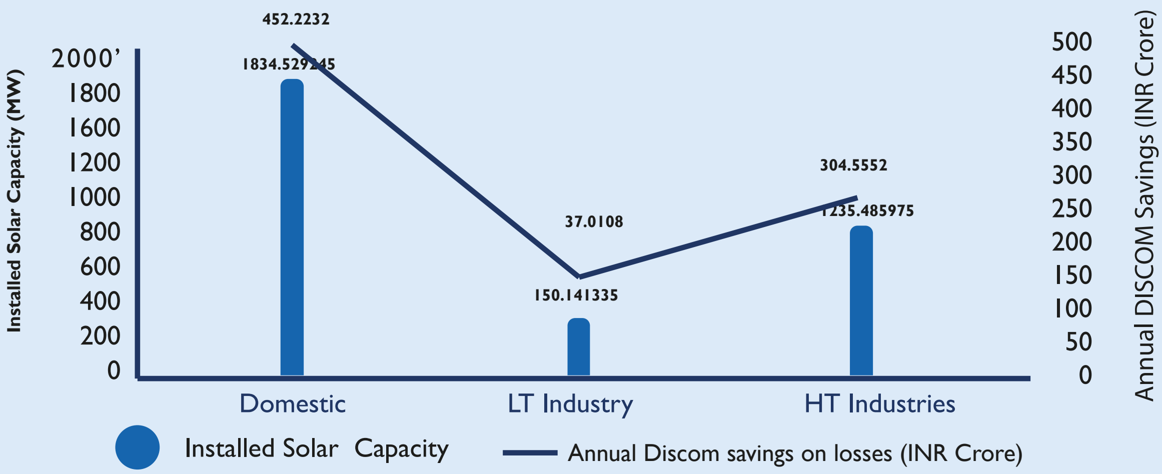
a) For MP DISCOMs:

For the year 2021-22, the MP DISCOMs losses in terms of transmission and distribution charges accounted for INR 1.34 per unit of electricity sold to the consumer. The analysis below illustrates the penetration of SPV among different consumer categories like domestic, Low Tension (LT) industry and High Tension (HT) industries for MP DISCOMs.

DISCOM (MP Discoms) Benefits at 10% SPV Penetration



DISCOM (MP Discoms) Benefits at 20% SPV Penetration



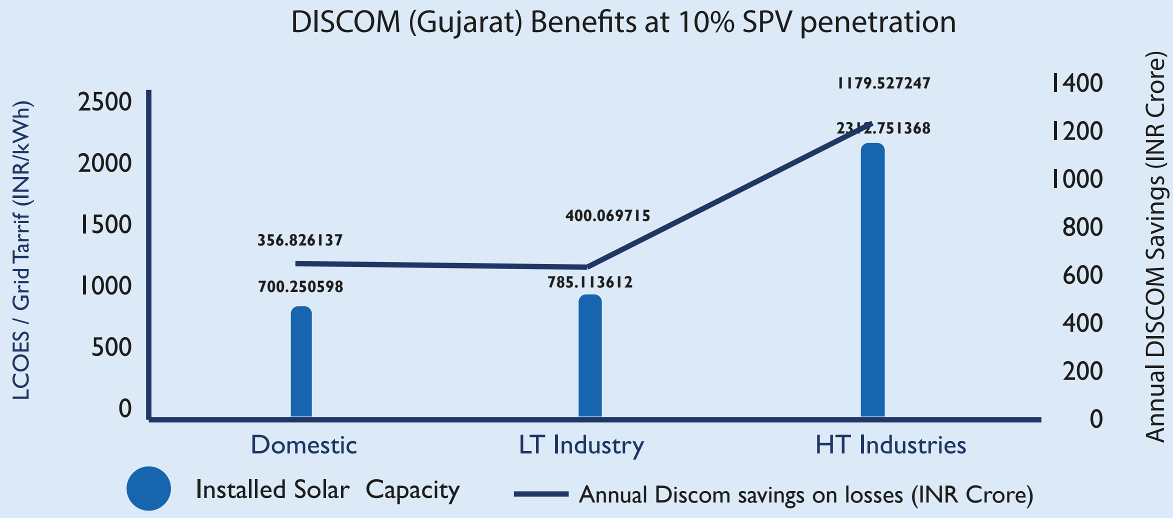
Further the DISCOM Benefit is provided in the table below:

DISCOM BENEFIT FOR ~50MW SPV WITH BESS DEPLOYMENT IN RESIDENTIAL SEGMENT								
CAPACITY OF PROJECT (kWp)			SPV COST (INR/Wp)				COST (INR/Wh)	
Sanctioned Load (KW)	Grid Tariff Avg. (INR/kWh)	Profit/Loss (INR/kWh)	DISCOM Saving INR (1hour BESS)	BESS Capacity (kWh/ per System)	Systems (Nos)	Capacity of System (KW)	BESS Capacity (MU/ Year)	Total DISCOM Saving (INR Lakh /Year)-Direct
1	4.27	-2.92	1065.8	NIL	NIL	NIL	NIL	NIL
3	5.23	-1.96	2146.2	3	3000	9000	3.3	64.39
5	6.61	-0.58	1058.5	5	3200	16000	5.8	46.43
10	6.8	-0.39	1423.5	10	2500	25000	9.1	163.79
				TOTAL	8,700	50000	18.3	249.81

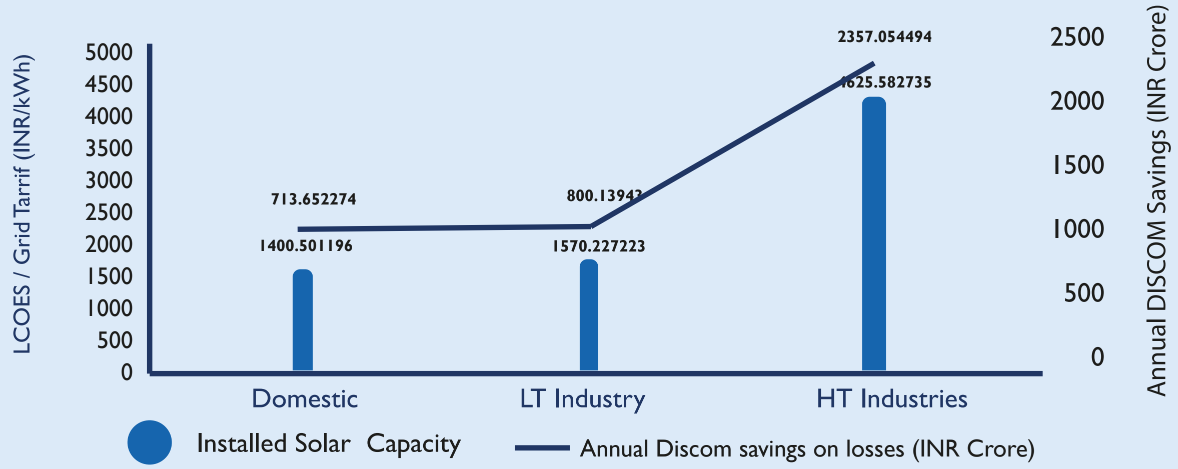
b) For Gujarat DISCOMs:

For the year 2021-22, the Gujarat DISCOM losses in terms of transmission and distribution charges accounted for INR 2.77 per unit of electricity sold to the consumer.

The analysis below illustrates the penetration of SPV among different consumer categories like domestic, Low Tension (LT) industry and High Tension (HT) industries for Gujarat DISCOMs.



DISCOM (Gujarat) Benefits at 20% SPV penetration



Further the DISCOM Benefit is provided in the Table below

DISCOM BENEFIT FOR ~50MW SPV WITH BESS DEPLOYMENT IN RESIDENTIAL SEGMENT

CAPACITY OF PROJECT (kWp)				SPV COST (INR/Wp)				COST (INR/Wh)
Sanctioned Load (KW)	**Grid Tariff Avg. (INR/kWh)**	**Profit/Loss (INR/kWh)**	**DISCOM Saving INR (I**	**BESS Capacity (kWh/ per System)**	**Systems (Nos)**	**Capacity of System (KW)**	**BESS Capacity (MU/ Year)**	**Total DISCOM Saving (INR Lakh /Year)-Direct**
1	3.05	-4.14	1511.1	NIL	NIL	NIL	NIL	NIL
3	3.50	-3.69	4040.6	3	3000	9000	3.3	121.22
5	4.15	-3.04	5548.0	5	3200	16000	5.8	177.54
10	5.20	-1.99	7263.5	10	2500	25000	9.1	181.59
				TOTAL	8,700	50000	18.3	480.34

Figure 10: LCOES at different load

a) For Tamil Nadu DISCOMs:

For the year 2021-22, the DISCOM losses in terms of transmission, and distribution charges, accounted for INR 1.06 per unit of electricity sold to the consumer. The analysis below illustrates the penetration of SPV among different consumer categories like domestic, Low Tension (LT) industry and High Tension (HT) industries for Tamil Nadu DISCOMs

A summary of the responses has been captured in the table below:

DISCOM (TANGEDCO) Benefits at 10% SPV

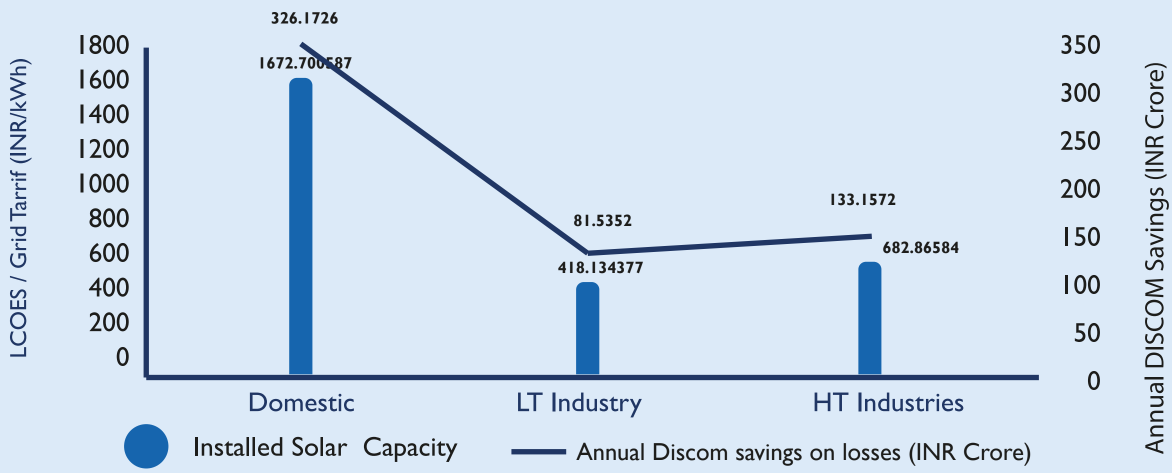


Figure 10: LCOES at different load

DISCOM (TANGEDCO) Benefits at 20% SPV

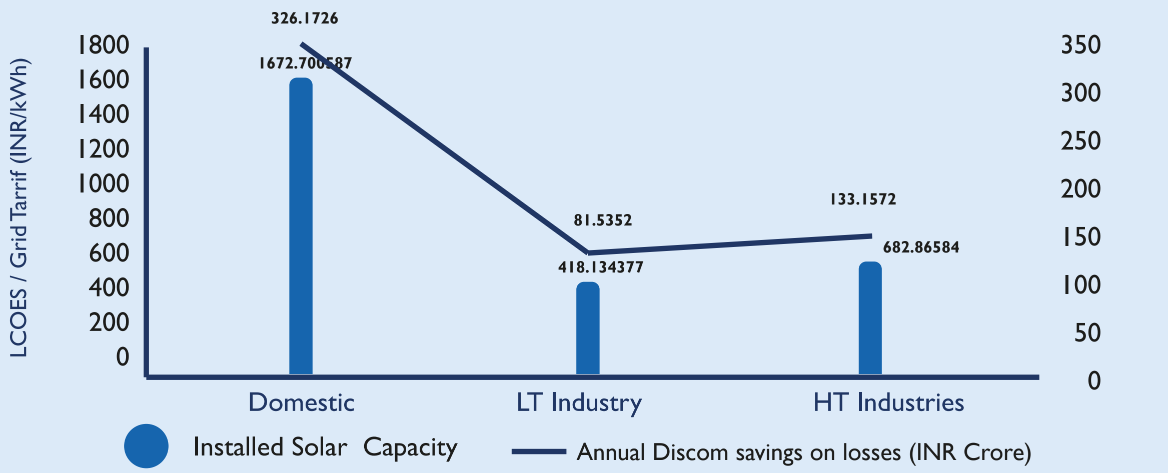


Figure 10: LCOES at different load

Further the DISCOM Benefit is provided in the table below:

DISCOM BENEFIT FOR ~50MW SPV WITH BESS DEPLOYMENT IN RESIDENTIAL SEGMENT

CAPACITY OF PROJECT (kWp)				SPV COST (INR/Wp)				COST (INR/Wh)
Sanctioned Load (KW)	**Grid Tariff Avg. (INR/kWh)**	**Profit/Loss (INR/k-Wh)**	**DISCOM Saving INR (I**	**BESS Capacity (kWh/ per System)**	**Systems (Nos)**	**Capacity of System (KW)**	**BESS Capacity (MU/ Year)**	**Total DISCOM Saving (INR Lakh /Year)-Direct**
1	4.5	-2.705	987.3	NIL	NIL	NIL	NIL	NIL
3	6	-1.205	1,319.5	3	3000	9000	3.3	39.58
5	8	0.795	-1,450.9	5	3200	16000	5.8	46.43
10	9	1.795	-6,551.8	10	2500	25000	9.1	163.79
				TOTAL	8,700	50000	18.3	249.81

RECOMMENDATIONS BASED ON THE STUDY

Based on the study the following recommendations are suggested for residential, commercial and industrial consumers and DISCOMs.

A summary of recommendations for different stakeholders is given in the table below:

Table 12: Recommendations for stakeholders

COSTING ASSUMPTION (SPV+BESS)

Sr. no	Stake holder	Domain	Current Policy	Proposed Change/ addendum	Remarks
1	MNRE	RTS Policy– MNRE Benchmark Notification	Subsidy for residential consumers is calculated at the lower of Module DC capacity or inverter capacity.	The subsidy should be calculated on the DC capacity	This will encourage people to utilize the benefit of RTS by DC overloading
2	MNRE/ State	Battery Energy Storage	No existing Policy	Battery Energy Storage Policy with provision of subsidy for all consumer segments.	The incentivization will make the projects financially viable
3	HERC	Net Metering Regulations	The Electricity generated from Rooftop Solar Systems shall be cumulatively adjusted at 90% of the electricity consumption during the financial year	The policy should remove this barrier	This restriction does not favor installation of PV beyond captive consumption
4	HERC	Net Metering Regulations	No FiT for surplus power at the settlement period	HERC should declare FiT for surplus power	This will make the projects more viable.
5	MNRE	CGM (Credit Guarantee Mechanism)	No policy in place	MNRE should initiate creation of a credit guarantee mechanism for FIs to easily facilitate loans for consumers	The survey and discussions with stakeholders have highlighted loaning as an important barrier
6	HAREDA	PSM (Payment Security Mechanism)	No policy in place	HAREDA should create a payment guarantee fund for RESCOs in the state	It is advised that the state government creates a payment guarantee fund for making projects more bankable
6	HERC	CEIG (Chief Ele ctrical Inspector-ate of theGover nment)- HERC Rooftop Regula-tions 2021	CEIG approval for projects above 20 kW for grid connection approva	It is proposed that the requirement for CEIG approval be removed	This will reduce the turnaround time for approval

ABOUT SAREP

The South Asia Regional Energy Partnership (SAREP) is the flagship regional energy program of the United States Agency for International Development (USAID) mission in India (USAID/I). This five-year initiative (2021-26) aims to enhance access to affordable, secure, reliable, and sustainable energy in six countries: Bangladesh, Bhutan, India, Maldives, Nepal, and Sri Lanka, aligning with these countries' climate and clean energy priorities. The program is a pivotal component of the U.S. Government's Asia Enhancing Development and Growth through Energy (EDGE) initiative and is in line with USAID's climate change priorities to promote equitable and ambitious actions in addressing the climate crisis. It aims to contribute to the realization of the US Government's Indo-Pacific Vision and foster collaboration among the six South Asian countries to expedite the shift to clean energy, mitigate climate change, and enhance energy security. SAREP will strengthen and expedite the implementation of clean energy technologies to facilitate the transition to net-zero emissions, assisting partner countries in achieving short-term climate goals and preventing the entrenchment of long-term emissions patterns. These technologies encompass renewable energy, energy efficiency, energy storage, off-grid solutions, behind-the-meter technologies, smart appliances, electric vehicles, green hydrogen, and other tools to support renewable energy integration, including market products.

Disclaimer: The data, information and assumptions (hereinafter 'data-set') used in this document are in good faith and from the source to the best of SAREP (the program) knowledge. The program does not represent or warrant that any data-set used will be error-free or provide specific results. The results and the findings are delivered on "as-is" and "as-available" data-set. All data-set ptrovided are subject to change without notice and vary the outcomes, recommendations, and results. The program disclaims any responsibility for the accuracy or correctness of the data-set. The burden of fitness of the data-set lies completely with the user. In using the data-set data source, timelines, the users and the readers of the report further agree to indemnify, defend, and hold harmless the program and the entities involved for all liability of any nature.

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