USAID
FROM THE AMERICAN PEOPLE

SOLAR PLUS ENERGY STORAGE SYSTEM AT DAHOD, GUJARAT TRACTION SUB-STATION BY INDIAN RAILWAYS

11, January 2021

(DELETE THIS BLANK PAGE AFTER CREATING PDF. IT'S HERE TO MAKE FACING PAGES AND LEFT/RIGHT PAGE NUMBERS SEQUENCE CORRECTLY IN WORD. BE CAREFUL TO NOT DELETE THIS SECTION BREAK EITHER, UNTIL AFTER YOU HAVE GENERATED A FINAL PDF. IT WILL THROW OFF THE LEFT/RIGHT PAGE LAYOUT.)

SOLAR PLUS ENERGY STORAGE SYSTEM AT DAHOD, GUJARAT TRACTION SUB-STATION BY INDIA RAILWAYS

Prepared for:

United States Agency for International Development (USAID/India)
American Embassy
Shantipath, Chanakyapuri
New Delhi-110021, India
Phone: +91-11-24198000

Submitted by:

Tetra Tech ES, Inc.
A-111 11th Floor, Himalaya House, K.G. Marg, Connaught Place
New Delhi-110001, India
Phone: +91-11-47374000

DISCLAIMER

This report is prepared for the M/s Tetra Tech ES, Inc. for the 'assessment of the Vendor Rating Framework (VRF)'. This report is prepared under the Contract Number AID-OAA-I-13-00019/AID-OAA-TO-17-00011.

DATA 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 PACE-D 2.0 RE (the program) knowledge. The program does not represent or warrant that any dataset used will be error-free or provide specific results. The results and the findings are delivered on "as-is" and "as-available" dataset. All dataset provided 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 dataset. The burden of fitness of the dataset lies entirely 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.

CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

INTRODUCTION

This note examines the technical, financial, and economic viability of replacing electricity supplied by the DISCOM- by solar power, expected per kWh electricity cost to Indian Railways (IR), and percentage replacement of DISCOM power at the various capacity of energy storage system (ESS), at the Dahod site near Ahmedabad. The selection of the site for this pilot was done by Railway Energy Management Company Limited (REMCL), an arm of IR responsible for meeting all electricity requirements of IR. The analysis assumed the project life cycle of 25 years e.g. the typical life of a solar project and other cost assumptions for the ESS based on the market assessment and available data from various reports.

PILOT LOCATION

The Dahod TSS is located near the Dahod Railway station, receives supply from the 132/33 kV sub-station near Dahod owned by Gujarat Electricity Transmission Corporation Limited (GETCO) to serve the traction load of IR. Close of the Dahod TSS IR owns two plots totaling 90 acre at Dahod which are considered for the developing the solar plus ESS project as suggested by the REMCL. Refer to Figure 1 for:

1. Location of nearest Traction Sub Station (TSS) location (marked in Red)
2. Plots (marked in Blue) located in east and west of the TSS
3. 132/33 kV GETCO substation (marked in Yellow) that feeds TSS

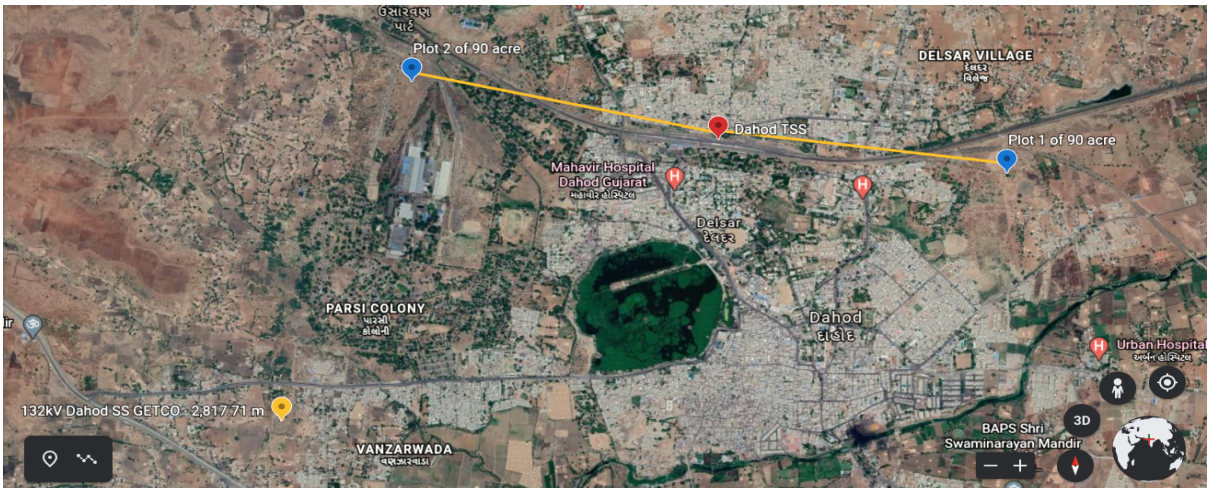

Figure 1: Location of sites for solar plus ESS pilot by IR

DAHOD TSS LOAD PATTERN ANALYSIS

Currently, the Dahod TSS receives entire electric supply from Madhya Gujarat Vij Compay Ltd, the distribution company (DISCOM). The PACE-D 2.0 RE Program carried out the assessment of the data from March 16, 2019 to March 15, 2020 to understand the power and energy requirement on a daily basis. Following are the observations from the assessment[1]:

[1] Data has been extrapolated for 96 times slots in a day and for 365 days from the available data for 86 time slots and 204 days.

1. Average daily consumption - 196 MWh (assuming a power factor of 0.80)
2. Highest day consumption - 320 MWh
3. Lowest day consumption - 109 MWh
4. Annual consumption - 76,838 MWh.

The tariff applicable for FY 2020-21 is INR 5/kWh[2] for DISCOM supply. Levelized tariff, for 25 years considering annual escalation rate of 4.25% [3], is estimated to be about INR 7.08/kWh.

POTENTIAL SOLAR GENERATION ASSESSMENT

The proposed site covers an area of 90 acres in two patches on either side of the TSS. PACE-D 2.0 RE Program has neither visited the site nor made any site measurements due to paucity of time and COVID pandemic. Thus, solar resource assessment is based on the popular rules of the thumb.

90 acres can accommodate maximum solar capacity of about 22.5 MWp considering 4 acres/MW. 22.5 MWp solar capacity can generate 38,345 MWh in a year i.e., 105 MWh per day on an average[4] . Solar generation of 38,345 MWh is about 49% of the total present electricity consumption at TSS. Thus, maximum replacement of DISCOM supply theoretically possible is 49% only.

Though the average expected generation (105 MWh) from solar project is lower than the average daily requirement (196 MWh), the solar project will generate more power than the demand during certain hours in a day (Refer Figure 2). Each year, out of 38,345 MWh generated from 22.5 MWp solar plant, 23,686 MWh (62%) will be consumed simultaneously, which is about 31% DISCOM supply while 14,659 MWh (38%) solar generation will remain surplus.

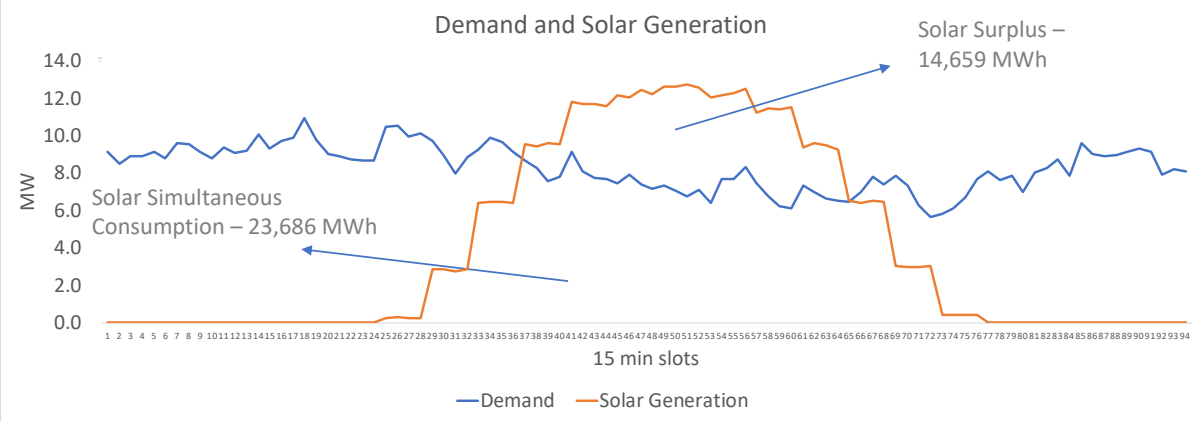

Figure 2: Average Daily TSS Demand and Solar Generation

This note considers three cases for the analysis:

1. Base case - Replacing DISCOM power with 22.5 MWp solar plant

2 Refer Annex for the source
[3] Refer Annexure for the basis of the annual escalation rate
[4] Based on simulation for the site on PVSyst

2. Case I – Use ESS for consuming the solar surplus from 22.5 MWp
3. Case II – Deploy 15 MWp solar plant with ESS

BASE CASE - REPLACING DISCOM POWER WITH 22.5 MWP SOLAR PLANT

Based on the current solar tariffs, the levelized cost of solar generation is assumed to be INR 3.00/kWh for the life of the project, while the levelized cost of DISCOM supply for same period is expected to be INR7.08/kWh.

At the base case, IR can save annually about INR 4.08/kWh for 23,686 MWh electricity supplied by the solar plant (Refer Figure 2). It is 31% of the TSS requirement. The rest of the TSS requirement, i.e., 69% will be met from DISCOM supply at a levelized tariff of INR 7.08/kWh. But it leaves 14,659 MWh of solar generation unutilized or surplus.

IR will have two options to dispose of this surplus solar generation; 1) either sell to power exchange like Indian Energy Exchange (IEX), or 2) use it for charging the ESS and using that power during non-solar/solar deficient hours. For base case, it is assumed that the entire solar surplus is sold on IEX. As India moves toward achieving its target of 100 GW solar by 2022, during the day the IEX prices are likely to continue to drop from the present value of INR 2.5/kWh5. **Table 1** provides a summary of the technical and financial analysis.

Annual IR power demand at Dahod TSS	76,383 MWh
Present electricity tariff at which IR purchases electricity from DISCOM	INR 5/kWh
Levelized DISCOM tariff of for next 25 years at escalation rate of 4.25%	INR 7.08/kWh
Potential solar capacity	22.5 MWp
Expected annual solar generation	38,345 MWh
Solar generation utilized at the time of generation by IR	23,686 MWh
% of solar in total TSS requirement	31%
Annual surplus solar generation	14,659 MWh
Levelized solar tariff for next 25 years	INR 3.00/kWh
Levelized price for selling solar surplus on IEX for next 25 years	INR 2.32/kWh
Levelized cost of electricity for IR (Solar Supply + DISCOM Supply – IEX Exports)	INR 5.94/kWh
Net savings to Indian Railways	INR 74 crore

Table 1: Solar Generation and meeting TSS Requirement for 22.5 Solar

CASE I – USE ESS FOR CONSUMING THE SOLAR SURPLUS FROM 22.5 MWP

[5] Refer the Annexure for details.

IR may consider using the surplus generation of 14,659 MWh to charge ESS and use it during the rest of the day. The ESS capacity has been determined with two objectives 1) maximum use of surplus solar generation in a day, and 2) solar plus ESS does not result into a financial loss to IR in comparison cost of meeting 100% requirement from DISCOM.

PACE-D 2.0 RE Program carried out an analysis to identify the size of ESS required to absorb various percentages of solar surplus. ESS is charged with the solar surplus to the extent of the ESS capacity and discharged to meet the unmet demand to the extent of the energy available with the ESS. This analysis is carried out for various ESS capacities to understand the utilization of solar surplus and an increase in demand met. Lithium-Ion batteries are considered for the ESS. Further, the expected tariff has been estimated for each of the ESS sizing and percentage utilization of the surplus solar generation. The cost of ESS has been assumed to be USD 207.5/kWh6 for estimating the solar + ESS tariff. To have a direct comparison, total cost of electricity for meeting entire demand of TSS has been determined for each scenario. Table 2 provides the results.

% Solar Surplus Utilized	0%	20%	40%	60%	80%	100%	65% (Break even)
ESS Capacity required to use solar surplus (MWh)	0.00	7.68	19.61	32.85	48.02	98.15	36.39
Unused Solar Electricity (MWh) after ESS charging	14,659	11,728	8,799	5,866	2,935	--	5,131
Met from Solar Simultaneously (MWh)	23,686	23,686	23,686	23,686	23,686	23,686	23,686
Met from ESS (MWh)	--	2,790	5,590	8,396	11,185	13,909	9,099
Total Supply from Solar + ESS (MWh)	23,686	26,476	29,276	32,081	34,871	37,594	32,785
Purchased from DISCOM i.e., Unmet by Solar + ESS (MWh)	52,697	49,907	47,107	44,301	41,512	38,788	43,598
Solar + ESS Tariff (INR/kWh)	3.00	3.66	4.71	5.89	7.24	11.67	6.20
Levelized cost of total supply (DISCOM +Solar + ESS) (INR/kWh)	5.94	6.11	6.46	6.88	7.39	9.45	6.99
NPV of Savings (INR Crore)	74	63	40	13	(20)	(155)	5
% of DISCOM supply substituted by Solar	31%	35%	38%	42%	46%	49%	43%

Table 2: Impact of ESS capacity on Total Solar Utilization and Savings for IR for 22.5 MWp Solar

From Table 2, it can be observed that :-

[6] Refer Annexure for the basis of the assumption

1. The cheapest option is solar without ESS. But only 31% of the DISCOM supply can be replaced by green power.
2. As the size of ESS increases to utilize more solar, tariff of solar + ESS increases, resulting in overall increase in cost of power to IR. To utilize entire solar power generated, ESS capacity of 98.15 MWh will be required but levelized cost of total supply would be INR 9.45/kWh which is 34% expensive than the estimated levelized cost of supply from DISCOM.
3. At the ESS capacity of about 36.39 MWh, there is a breakeven of cost of power to IR. The ESS capacity of 36.39 MWh will help utilizing 65% of the solar surplus and substitution of about 43% DISCOM power by solar. Levelized cost of total supply is estimated to be about INR 6.99/kWh.
4. Current limiting factor for higher use of green power is the cost of ESS. IR can start with lower capacity ESS capacity and as the cost of ESS decreases, which is predicted by industry experts, IR can install more ESS capacity and increase the solar share.
5. Also it is expected that the IR electricity demand will increase over time. So it may not require additional storage capacity.

Figure 3 and Figure 4 presents IR demand, supply from solar and ESS and how solar surplus is utilised for 22.5 MWp Solar and 36.39 MWh of ESS.

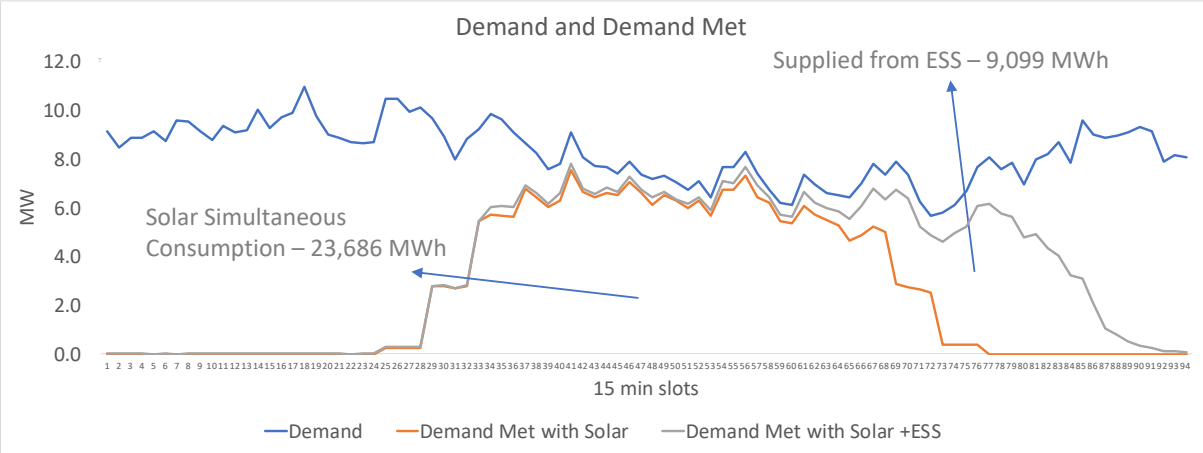

Figure 3: Average Solar Supply without and with ESS

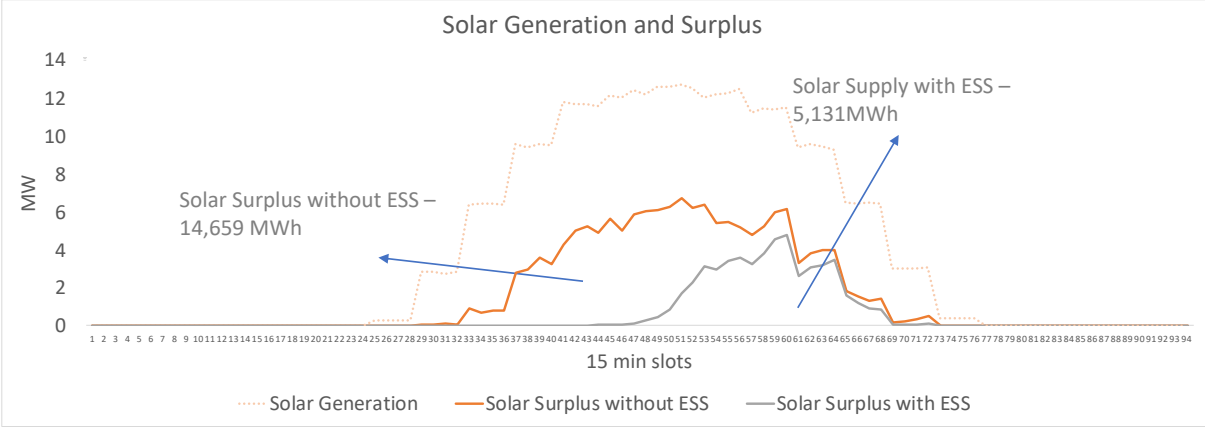

Figure 4: Average Daily Solar Generation and Surplus

CASE II - DEPLOY 15 MWP SOLAR PLANT WITH ESS

PACE-D 2.0 RE Program carried out a similar analysis for 15 MWp solar capacity. Breakeven for 15 MWp solar capacity will be at ESS capacity of 48.78 MWh which utilizes 100% solar surplus. However, the share of solar in meeting TSS requirement is 33% against 43% for 22.5 MWp.

% Solar Surplus Utilized	0%	20%	40%	60%	80%	100%
ESS Capacity required to use solar surplus (MWh)	0.00	1.18	4.89	10.51	17.95	48.78
Unused Solar Electricity (MWh) after ESS charging	6,025	4,821	3,615	2,412	1,205	--
Met from Solar Simultaneously (MWh)	19,538	19,538	19,538	19,538	19,538	19,538
Met from ESS (MWh)	--	1,144	2,290	3,442	4,598	5,743
Total Supply from Solar + ESS (MWh)	19,538	20,682	21,828	22,980	24,136	25,281
Purchased from DISCOM i.e., Unmet by Solar + ESS (MWh)	56,844	55,700	54,554	53,403	52,246	51,102
Solar + ESS Tariff (INR/kWh)	3.00	3.08	3.41	3.90	4.56	7.31
Levelized cost of total supply (INR/kWh)	6.09	6.05	6.08	6.18	6.33	7.18
NPV of Savings (INR Crore)	64	67	65	58	48	(7)
% of Electricity met from Solar	26%	27%	29%	30%	32%	33%

Table 3: Impact of ESS sizing on Total Solar Consumption and Savings for IR for 15 MWp Solar

It is not proposed to use solar capacity lower than 15 MWp as the pilot size will become small to use results for scaling. Secondly solar generation cost also increases as percentage cost of design, engineering and administrative activities increases significantly.

CONCLUSION

The above analysis has been conducted with several assumptions based on market assessment. It has been experienced in actual procurement the developers quote more competitively than the data they provide during the market assessment. Since the call for expression of interest (EoI) for Dahod is already out, our recommendation to IR is not to make any decision based on the above analysis and wait for actual quotes. However, using this indicative analysis IR may decide the objectives of this pilot such as a higher percentage of green power substitution, higher ESS capacity, and/or financial gain and loss. The setting objectives will help in the evaluation of the proposal received from various developers against the EoI issued by the REMCL.

ANNEX

In the above analysis below mentioned assumptions have been used. The results will change if assumptions are not valid. The market for solar and ESS is very dynamic and changes are taking place very fast. Thus, results should be used with due care.

Assumption	Value	Source/Reference
TSS Data	Data is missing for several time slots for many days. For analysis days with data for atleast 86 times lots available are considered i.e., 204 days. The results are extrapolated for 204 days are extrapolated to 365 days.	IR
Solar		
Capital cost	INR 32.5/W	Market estimate
CUF	19.45%	Simulated using PVSyst
Annual Degradation	1%	As per the technical specifications of PV modules
Annual O&M Expense	INR 4 lakh/MW (with 5% annual escalation)	Market estimate
Life of the solar plant	25 years	As per the technical specifications of PV modules
ESS		
Capital cost	INR 15.15/Wh (USD 207.5/kWh) for FY 2021-22 Replacement cost - USD 79.4/kWh	• Niti Aayog report on "India's Energy Storage Mission: A Make-in-India Opportunity for Globally Competitive Battery Manufacturing" expects ESS cost to be USD 175 MWh for FY 2021-22 • It was found that current cost of ESS USD 240/kWh from a brief survey of renewable energy developers • Average of USD 175/kWh and USD 240/kWh has been assumed
Depth of Discharge	80%	Technical specifications of Lithium Ion batteries

System efficiency	95%	Technical specifications of Lithium Ion batteries
Annual degradation	1%	Technical specifications of Lithium Ion batteries
O&M	5% of capital cost (with 5% annual escalation)	Market estimate
Life of ESS	10 years	Market estimate
Finance		
Debt	70% of project cost	Market estimate
Interest rate	10%	Market estimate
Repayment period	12 years	Market estimate
Equity	30% of project cost	Market estimate
Equity IRR	12%	Market estimate
Tariffs		
DISCOM Supply	INR 5.00/kWh	GERC Tariff Order for FY 2021-22
Annual escalation	4.25%	Based on consumer price index between April 2015 and March 2020
Revenue from surplus sale on IEX	INR 2.5/kWh	Based on price data for FY 2019-20
Annual escalation	-1%	Assumption. With high solar penetration, daytime surplus will be high reducing daytime IEX prices.
Discount rate for calculating net present value	10%	Assumption

United States Agency for International Development (USAID/India)
American Embassy
Shantipath, Chanakyapuri, New Delhi 110021