DETAILED PROJECT REPORT ON

SOLAR PV WATER HEATER SYSTEM FOR A HOSTEL CAPACITY OF 500 STUDENTS

Project report submitted to,

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INTRODUCTION

India is both densely populated and has high solar insolation, providing an ideal combination for Solar Power in India. Power is the lifeline of any development of the nation. At present the power requirement is being met by three main sources viz., Thermal, Hydel and Nuclear. While Hydel and Nuclear have their inherent limitations, Thermal Power is often confronted by the challenge associated with the availability of fuel. Currently Thermal Power stations which meet the major part of the power demand use coal as fuel. In order to bring down the dependence of finite fossil fuel for power generation, it is necessary to look into the viability of generating power locally using renewable energy sources.

Fortunately, India lies in sunny regions of the world. India can easily utilize the solar energy. Government of India has separately set up a Ministry called MNRE - Ministry of New Renewable Energy for the promotion of Power Generation through Renewable Energy. At the State level, promotion of Solar Power generation is being encouraged by local policies that cover buy back, wheeling and banking of the generated electricity by State Electricity Boards, besides other incentives.

In this report, the design and optimisation of a solar PVT-based electricity generation for a water heating system to be installed in Kameng Hostel, which has a capacity of 500 students and a daily hot water requirement of 1500 litres has been discussed.

The use of solar energy for water heating is a popular and cost-effective solution for residential and commercial buildings. A solar PVT system combines photovoltaic (PV) and thermal technologies to generate electricity and heat simultaneously. The PV cells convert sunlight into electricity, while the thermal collectors absorb the heat from the sun to heat the water. This type of system is highly efficient, as it allows for the simultaneous generation of electricity and heat. The Kameng Hostel, like many other hostels, requires a significant amount of hot water for the students' daily use. The traditional methods of heating water, such as electric heaters or gas boilers, are costly and can have a negative impact on the environment. By implementing a solar PVT-based system, the hostel can reduce its energy consumption and carbon footprint while also saving money on energy bills.

PROJECT DETAILS

Location	:	Guwahati
Place of installation	:	Kameng Hostel, IIT Guwahati
Latitude	:	26.19°N
Longitude	:	91.70° E
Annual Solar radiation	:	806 kWh/ Sq. m/year
Daily Solar radiation	:	2.76 kWh/Sq. m./day
Module Facing	:	True South
Module Tilt angle	:	10-15°
Average sunshine hours of Guwahati	:	3.6 Hrs.
Temperature (Max, Min)	:	35°C, 12°C
Water requirement (Max, Min)	:	1500L, 500L
Shading	:	No Shading
NOCT	:	45±2°C
Module efficiency	:	12%
Module efficiency loss	:	2%

Fig. 1: Site location: Kameng hostel, IIT Guwahati (Source: Google Earth Pro)

Fig. 2: Map of North-East India

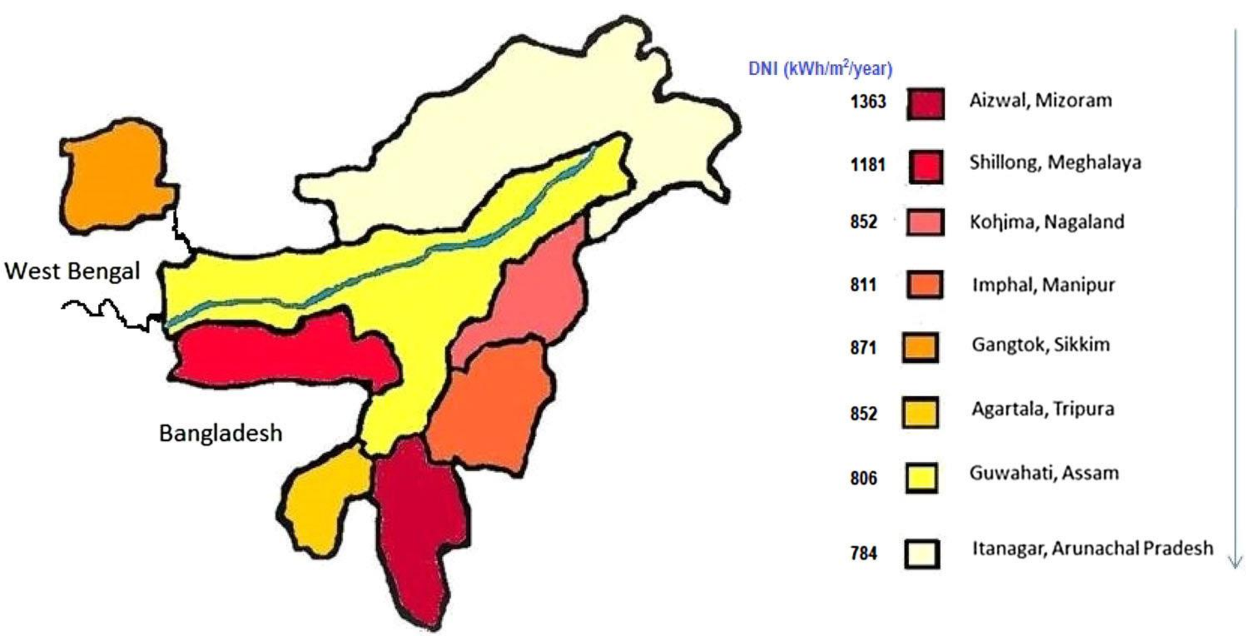

Fig. 3: Solar radiation map for North-East India

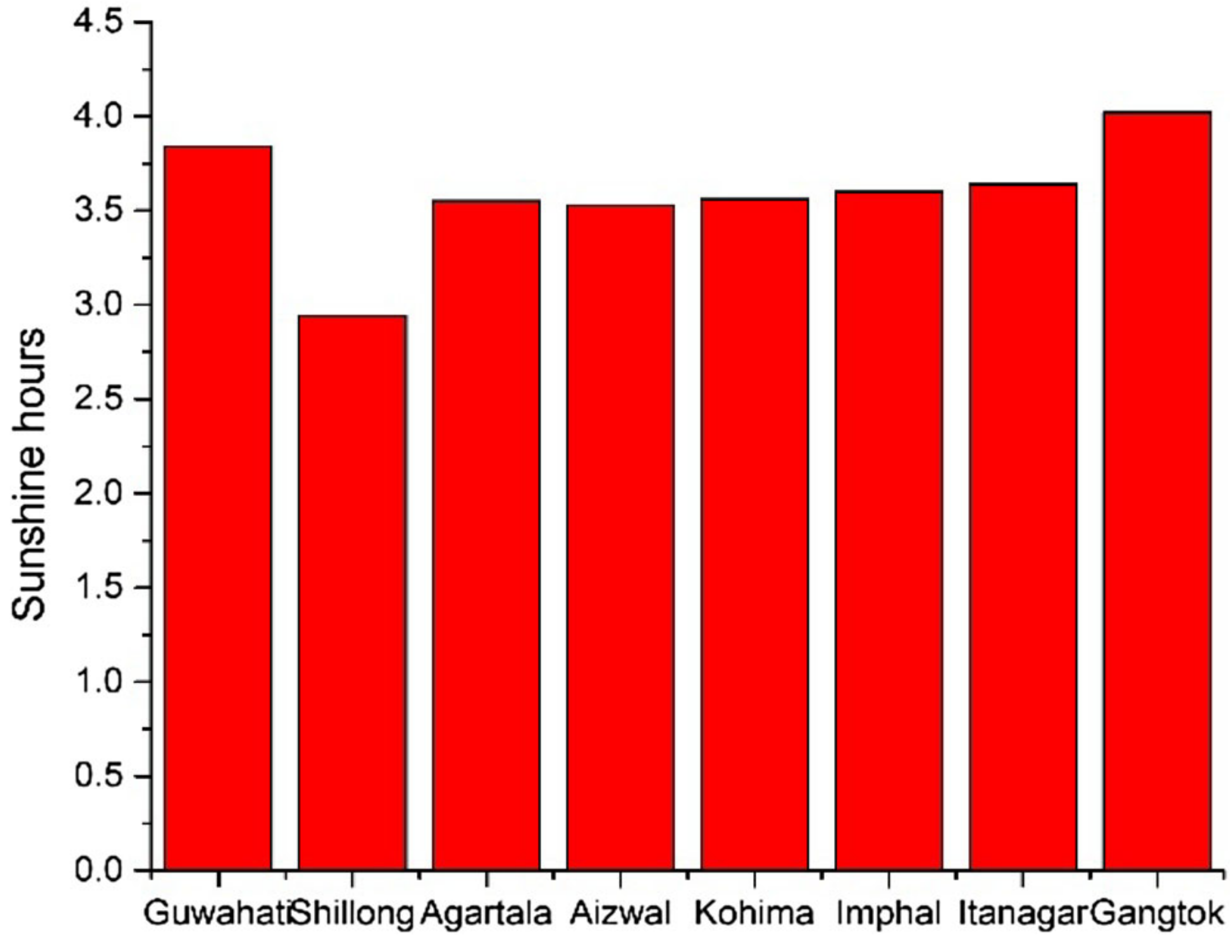

Fig. 4: Daily sunshine hours of NE India

Month	Average	Total
January	7.5	225
February	7.5	215
March	7	220
April	6.5	200
May	6	190
June	4.5	135
July	4	125
August	5	160
September	4.5	140
October	6.5	205
November	7.5	230
December	7.5	230
Year	6.2	2280

Table 1: Monthly Sunshine hours of Guwahati

Sl. No.	Component	Specifications	Units	Cost per unit (in Rs)
1	24V 330W Polycrystalline Solar Panel	Maximum Power: 330W Open Circuit Voltage (V_{oc}): 45.53V Short Circuit Current (I_{sc}): 9.22A Voltage at Maximum Power (V_{mp}/V_{mpp}): 38.03V Current at Maximum Power (I_{mp}): 8.68A Operating (Nominal) Voltage: 24V Area: 1.7m^2	81	15,000
2	Battery Lithium Iron Phosphate Battery (LiFePO4)	Nominal Voltage: 24V Nominal Capacity: 50Ah Norminal Energy: 1280Wh Dimension (L*W*H): 10.24*6.61*8.27in 260*168*210mm Series / Parallel Number: 8S1P Maximum Charge Current: 25A Maximum Discharge Current: 50A Charge Voltage / Charge Cut-off Voltage 29.2±0.2V Discharge Cut-off Voltage 20V	7	20,000
3	Inverter	20KW, 3Phase &MPPT; Vmax= 800V, efficiency = 85%	5	16,000
4	DC Cable	1C x 4Sq.mm	1000 Mtrs.	29/metre
5	AC Cable	4 C of 6sqmm armour Cu cable	25 Mtrs.	86/metre
6	AC Cable	4C of 70sqmm armour Alu cable	100 Mtrs.	440/metre
7	DC earthing kit	-	1 Set	20,000
8	Lightning Arrestor	-	1 Set	20,000

Table 2: Component details

POWER PLANT DESIGN

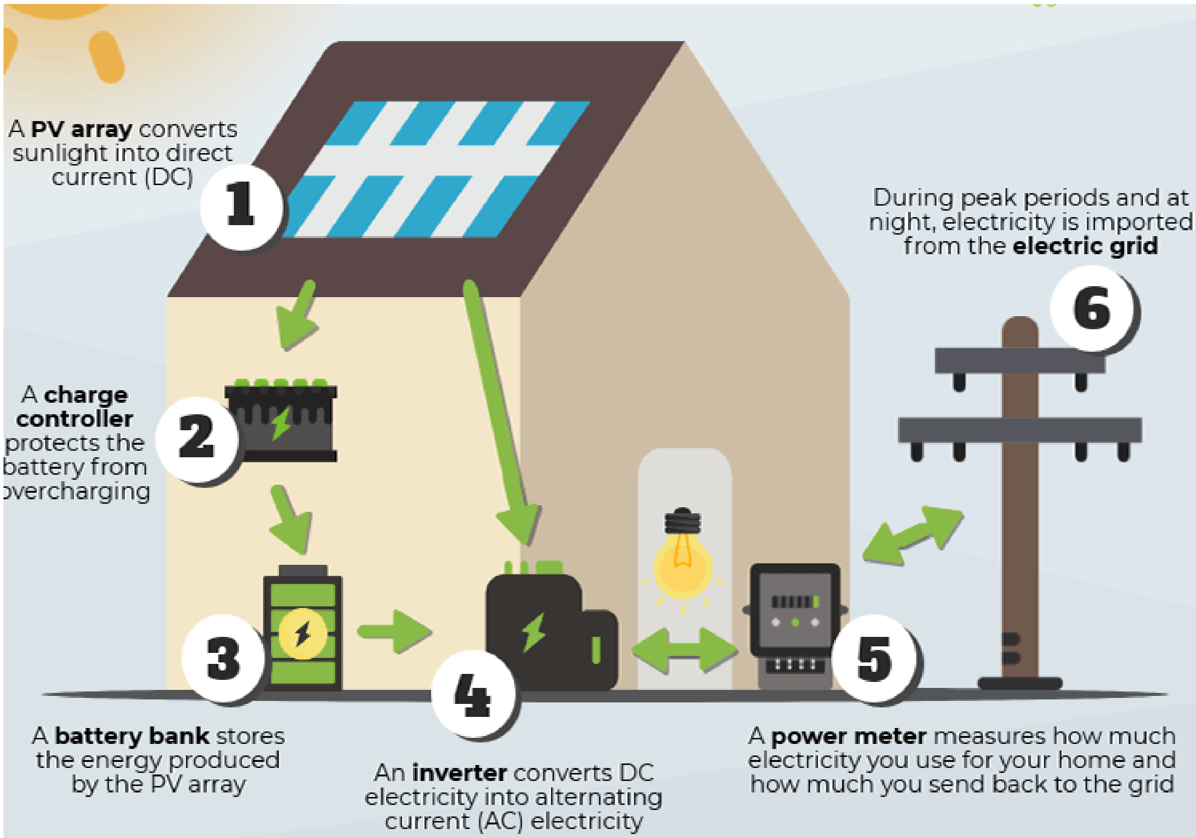

Fig. 5: Different components of PV system

The following are the major components of a solar PV system

- Solar Modules
    - Crystalline Modules –: Poly- or multicrystalline silicon (poly-Si or mc-Si) made from cast square ingots — large blocks of molten silicon carefully cooled and solidified. Poly-Si cells are less expensive to produce than single crystal silicon cells, but are less efficient. Crystalline silicon has average 10-15% efficiency.
- Battery bank: a battery is a device used to store excess energy generated by the solar panels. Solar panels generate electricity when sunlight falls on them, and this electricity can be used to power appliances or fed back into the grid.
- Inverter
    - String Inverter: String / Central inverters operate on MPPT (Maximum Power Point Tracking) mode to ensure maximum output from the solar generators at different ambient conditions. String inverters use higher system voltages to

reach very high plant efficiency. Furthermore, installations can be expanded with additions of more modules without problems.

- Module Mounting Structure: The module mounting structure is designed for holding suitable number of modules in series. The frames and leg assemble of the array structures is made of MS hot dip galvanized of suitable sections of Angle, Channel, Tubes or any other sections conforming to IS:2062 for steel structure to meet the design criteria. All nuts & bolts considered for fastening modules with this structure are of very good quality of Stainless Steel. The array structure is designed in such a way that it will occupy minimum space without sacrificing the output from SPV panels at the same time it will withstand severe wind speed up to maximum 100 kmph.
- Balance of System
    - Junction boxes: In the Junction boxes, individual module strings are bundled and safely routed to the inverter. It is a combination of an exact, well-organized string monitoring system and a safety concept adapted to the PV technology.
    - Cables: The size of the cables between array interconnections, array to junction boxes, junction boxes to PCU etc shall be so selected to keep the voltage drop and losses to the minimum. Cable is of high temperature resistance and excellent weatherproofing characteristics which provides along service life to the cables used in large scale projects.
    - Monitoring System: Monitoring systems is mainly used to monitor the performance of the Inverters, energy yield, temperature, irradiance level etc. It provides an extremely flexible interface to facilitate PC-based inverter monitoring via analog modem, GSM, Ethernet, or Internet connections.
    - Earthing & Lightning Protection:
        - Earthing: The array structure of the PV yard will be grounded properly using adequate number of earthing kits. All metal casing / shielding of the plant shall be thoroughly grounded to ensure safety ofthe power plant.
        - Lightning Protection: The SPV Power Plant shall be provided with lightning & over voltage protection.The main aim in this protection shall be to reduce the over voltage to a tolerable value before it reachesthe PV

or other sub system components. The source of over voltage can be lightning, atmosphere disturbances etc.

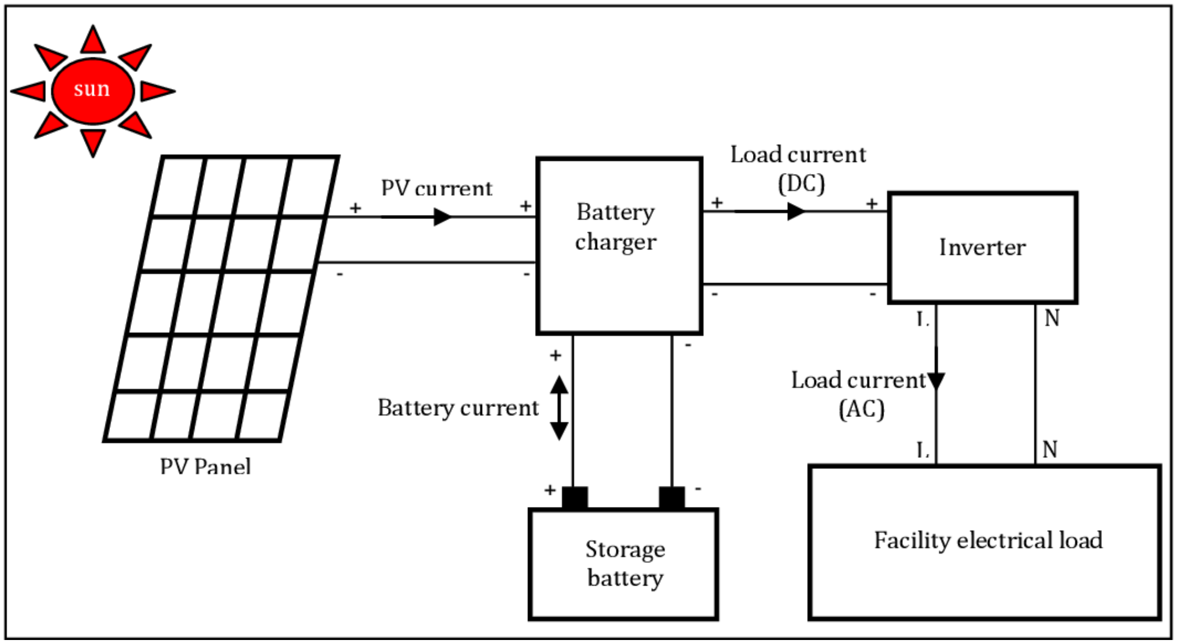

Fig. 6: Layout of proposed PV system

Design calculations:

Required energy for heating 1500L water:

The required energy to heat 1500 litres of water from 20°C to 60°C can be calculated using the following equation:

$$Q = m \times Cp \times \Delta T$$

where,

Q = required energy in Joules

m = mass of water in kg (1500 litres of water weighs 1500 kg)

Cp = specific heat capacity of water (4.18 kJ/kg-°C)

ΔT = temperature rise in °C (60°C - 20°C = 40°C)

Substituting the values, we get:

$$Q = 1500 \times 4.18 \times 40 = 250{,}800\ kJ$$

Energy required to heat the required amount of water = 250,800 kJ

$$Load\ requirement = 250800kJ/3600sec = 69.67\ kWh$$

Calculation of required number of panels:

Inverter efficiency = 85%

$$Inverter\ input\ =\ 69.67\ kWh\ /\ 0.85\ =\ 81.964\ kWh$$

Battery efficiencies: charging = 90%; discharging = 90%; DoD = .7

$$Battery\ input\ =\ 81.964\ kWh\ /\ (0.90 * 0.90 * 0.7)\ =\ 144.55\ kWh$$

$$Output\ of\ solar\ panels\ required = Battery\ input\ = 144.55\ kWh$$

Average daily solar irradiance = 2.76 kWh/Sq. m./day

Solar panel efficiency = 12%

Module efficiency loss = 2%

Area of one solar panel = 1.7 m2 * .9 = 1.53 m^2

$$Energy\ output\ from\ one\ panel\ =\ 2.76 \frac{\frac{kWh}{sq.m}}{day} * \ 1.53\ sq.m\ *\ 0.12 * 0.98$$

$$=\ 0.496\ kWh\ /day$$

Daily average sunshine hours = 3.6 hours

$$Total\ solar\ energy\ available\ per\ day\ =\ 0.496\ *\ 3.6\ =\ 1.7856\ kWh$$

Total number of solar panels required,

$$Number\ of\ solar\ panels\ =\ Required\ energy\ /\ Total\ solar\ energy\ available\ per\ day$$

$$Number\ of\ solar\ panels\ =\ 144.55/1.7856\ =\ 80.95\ \approx\ 81$$

Calculation of required number of batteries:

Maximum load requirement = 69.67 kWh

Output DC voltage of battery = 24 V

$$Daily\ DC\ energy\ requirement\ =\ Maximum\ load\ /\ Output\ DC\ voltage\ of\ battery$$

$$Daily\ DC\ energy\ requirement\ =\ 67.67\ kWh\ /\ 24\ V\ =\ 290.27\ Ah$$

Considering 20% system losses,

$$DC\ energy\ required\ to\ be\ stored\ =\ 290.27\ *\ 1.2\ =\ 348.33\ Ah$$

Estimated sunshine hours = 3.6 hours

$$Total\ current\ generated\ by\ the\ system\ =\ 348.33\ /\ 3.6\ =\ 96.75\ Ah$$

Battery capacity required for 2-day blackout = 3 * 96.75 = 290.25 Ah

Battery efficiency = 85%

Required battery capacity for giving 2-day power backup = 290.25 / .95 = 341.76 Ah

Capacity of 1-battery = 50 Ah

$Number\ of\ batteries\ required\ =\ 341.76\ /\ 50\ =\ 6.83\ \approx\ 7$

FINANCIAL ANALYSIS

Initial investment:

Sl. No.	Components / Services	Total cost (In Rs)
1	Solar Panel	12,15,000
2	Batteries	1,40,000
3	Inverter	80,000
4	Cables	75,150
5	Accessories and protective devices	70,000
6	Construction cost	2,50,000
7	Labour cost	1,50,000
8	Miscellaneous expenses	1,00,000
9	**Total**	**20,80,150**

Table 3: Initial investment details

Total expenses over the year for plant O&M and staffing (5% of ini. investment) = Rs. 1,00,000

Electricity cost per unit = Rs. 9.25 (industrial usage)

Load requirement per day @1500L per day = 69.67 kWh

$$Annual\ electricity\ bill\ = 69.67 * 365 * 9.25 = 235223$$

Amount saved on electricity bill by using Solar PV = Rs. 2,35,223

Cash Flow Analysis for 12 years

Assume that per unit cost increases by 5% pa.

According to Discounted Cash Flow method (considering @10% DCF)

Year	**Initial Investment**	**O&M and staffing cost**	**Annual Saving**	**Annual Sum**	**NPV**
0	2080150			-2080150	-2080150
1		100000	235223	135223	-1944927
2		100000	246984.15	146984.2	-1797943
3		100000	259333.3575	159333.4	-1638609
4		100000	272300.0254	172300	-1466309
5		100000	285915.0266	185915	-1280394
6		100000	300210.778	200210.8	-1080184

7		100000	315221.3169	215221.3	-864962
8		100000	330982.3827	230982.4	-633980
9		100000	347531.5019	247531.5	-386448
10		100000	364908.0769	264908.1	-121540
11		100000	383153.4808	283153.5	161613.1
12		100000	402311.1548	302311.2	463924.3

Table 4: Cash Flow Analysis using DCF method

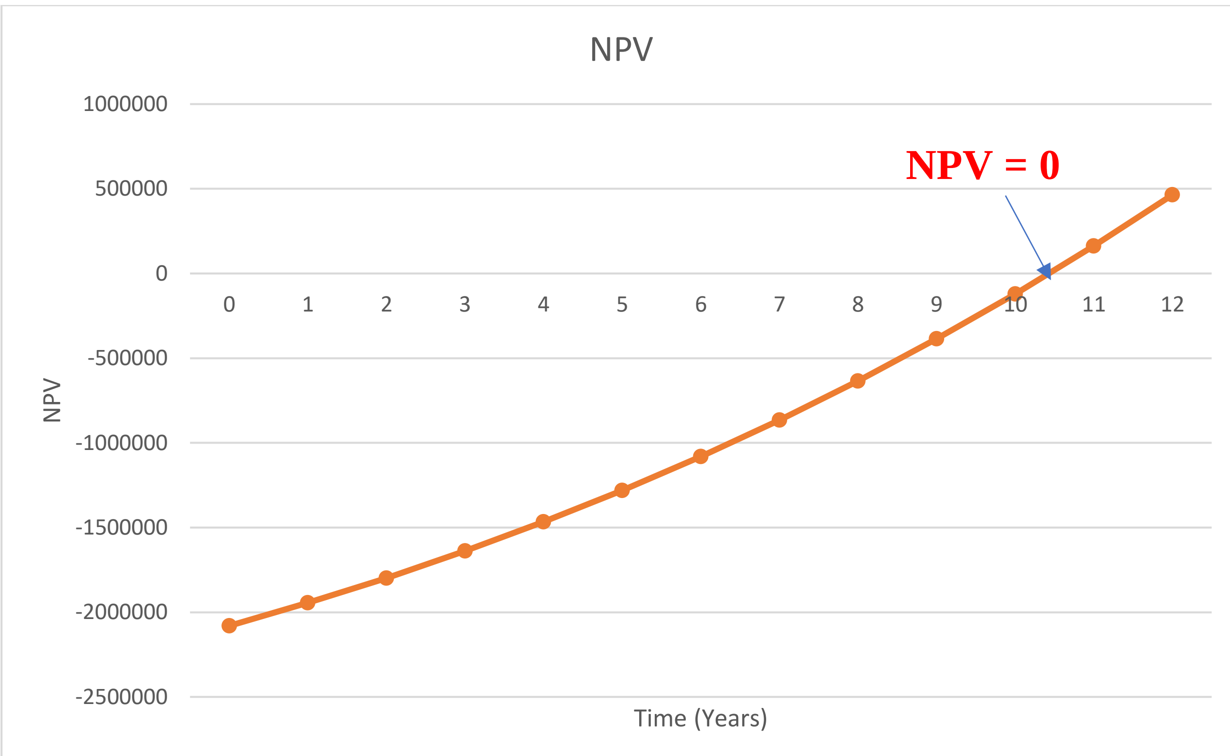

Fig. 7: NPV curve

At the end of 10 years, NPV is -121540.

At the end of 11 years, NPV is +161613.4.

CONCLUSION

The project proposes installation of a 26.73 kWp solar power plant with 81 solar panels, each with a capacity of 330 W, to heat 1500 litres of water by geysers for 500 students is a feasible and sustainable solution to meet the energy needs of the educational institution. To meet the estimated requirement, 81 solar panels are required. For a two-day blackout of solar PV, seven batteries are required to fulfil the required demand. The proposed project has significant environmental, economic, and social benefits and will promote the adoption of renewable energy sources to meet the energy needs of institutions in India.

The financial analysis of the project shows that the payback period is 11 years, and the NPV value at the end of 11 years is estimated to be Rs. 1,61,613.4, which indicates that the project is financially viable and has the potential to provide long-term energy security and cost savings to the institution as the life span of solar units is considered to be 20 years.

In conclusion, the installation of a solar power plant for heating 1500 litres of water by a geyser for 500 students is an eco-friendly, sustainable, and cost-effective solution to meet the energy needs of the educational institution. The project has significant environmental, economic, and social benefits and is in line with the Indian government's commitment to promoting renewable energy sources to meet the energy demands of the country.

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