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Economic Feasibility of Installing Mono Crystalline PERC Technology Solar Plants in Andhra Pradesh, India.

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ABSTRACT: India is absolute to promote renewable power share by displaying high improvements in technology in recent days. An efficient and financially healthy power sector is needed for the growth of economic development in states like Andhra Pradesh. This study intends to investigate the financial feasibility of a 10 MW photovoltaics plant installation in Andhra Pradesh on a project level with mono crystalline silicon passivated emitter rear cell panel technology. The present market and legal frames of investment in Andhra are studied. The research study includes net present values, internal rate of return, simple payback method, levelized cost of energy analysis for the implementation of the project plans proposed. The economic viability in photovoltaics installations are calculated for the project plan. The results illustrate the choice that a potential investor can look into and invest in the project. Solar product and component production sector in India is at an emerging stage and facing various challenges including funding, technology, research and development. By using panels with PERC cells, we get a higher energy yield in a complete day as compared with the panels using normal standard cells. Higher energy yield is nothing but higher rate of return on the installation.

KEYWORDS: Levelized Cost of Energy, Net Present Value, Internal Rate of Return, Simple Payback Method, Andhra Pradesh, PERC, Feasibility.

I. INTRODUCTION

The energy from renewable sources is regularly available for free but the renewable energy conversion technologies are mostly quite capital-intensive. Operation costs are replaced by installed capital costs which make renewables less attractive, particularly when high discount rates are applied depending on the level of investments needed as well as governmental involvements [1]. Solar technologies directly use sun's energy to produce energy for industrial processes, buildings and transportation as well as electricity for consumption in these three end use sectors. Due to the large solar resources, these technologies are not restricted by feedstock requirements but rather by costs and institutional obstacles such as perceived risks, performance and siting issues [2]. India is granted with abundance of solar energy and can generate clean energy of about 5000 trillion kW. The country has sunny days of almost 300 in every year and with a solar insolation of about 4 to 7 kWh/m²/day^[14]. We can reduce the situation of energy deficit easily with no carbon emissions if energy is proficiently harnessed. Solar energy potential has been recognized by some states in India and other states are oriented to meet increasing energy needs with endless and clean solar energy [3].

Multi crystalline solar cell production is started by silicon melting and by solidifying it to orient crystals in a stable direction. Manufacturing rectangular ingots of poly crystalline silicon to be cut into blocks and into thin wafers finally. This last step can be eliminated by cultivating thin wafer ribbons of poly crystalline silicon. Evergreen Solar developed this technology [4].

PERC technology improves and increases the performance of the panel, either monocrystalline or polycrystalline by increasing the ability of the solar cell to trap more light. By using panels with PERC cells in it gives a higher energy yield in a complete day as compared with the panels using normal standard cells. Higher energy yield is nothing but

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higher rate of return on the installation. These cells are more important in residential markets because the space for the rooftop installation of solar panel is limited and with these cells, power generation will be more of their installation [5]. The journey of photovoltaic energy conversion science has reached to efficiency percentage of 44 today with the multi-junction solar cell [6].

For this economic feasibility analysis of PERC technology, the standard indicators like net present values (NPV), internal rate of return (IRR), simple payback period and levelized cost of energy (LCOE) are considered. Each indicator is calculated with help of standard numerical data. For calculating payback period and levelized cost of energy undiscounted analysis is considered and calculated

II. RELATED WORK

The literature studies included gathering journal articles, reports, theses, conference papers, technical reports, trade publications and presentations relating to economic analysis for different solar technologies and most of the government policies in India and latest dated cost information on photovoltaic systems. To evaluate feasibility of the project, the significance of NPV, IRR, Payback period, LCA are studied through literature. Some important papers which were highly influential for this project are discussed below. Some important works are briefed below.

Asif et al., analyzed a 1 MW plant in Keshavpuram of North Delhi situated in India using LCA studies. They found that 5,571 panels were used in the plant made of mono-crystalline silicon and the power generated was fed into the main grid line of NDPL. Life time of the plant was 25 years in their study and they made cost analysis of individual components of the plant. It was found that installation cost was found to be Rs.13,23,77,184.4 which consisted of module cost to be significant part of total. Their works implies that solar potential is greater to cover the emissions than other conventional technologies [7]. This work can be used as guideline to find the feasibility for similar plants with different technology and compare them.

Pushpendra et al., examine the vital barriers and restrictions experienced by the solar power developers in achieving the growth in India. They further found that many new programs have been launched by government like adding capacity, providing 100% foreign direct investment, subsidizing and providing environment for different joint ventures, etc. These measures are attracting most of huge solar power investors globally in developing Indian solar power projects. However, it is a slow process and cannot be achieved in short duration. *Pushpendra et al.*, suggest developing more policies and programs like National Solar Mission that will add up more growth to Indian market by attracting large solar investors and developers which can ensure a sustainable future to India[8].

The objectives that were addressed in this study is to evaluate economic feasibility, indicators like NPV, IRR, Payback Period and LCOE for Crystalline silicon technology implementations on 10 MW solar project. Also, to help investors take investment decisions for which technology is more sustainable.

III. METHODOLOGY

In this work, Andhra Pradesh state is considered because it holds the rapid outrageous growth in solar power sector, mainly due to construction of ultra-mega solar power parks in Rayalaseema region of Andhra Pradesh. Project capacity is 10MW utility scale grid connected solar power plant with mono crystalline passivated emitter rear cell technology panels.

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Table 1: Panel Description and Total Cost estimation of 10 MW solar plant with project plan [9][10][11].

Technology	Mono Crystalline PERC	Components	Project Plan
Nominal Maximum Power	300 W	Solar Modules Cost	☐ 389,000,000.00
Efficiency	18.3 %	Inverter Cost (Power Conditioning Unit)	☐ 42,848,654.00
Annual Efficiency Degradation Rate	0.15 %	Mounting Structures Cost	☐ 35,000,000.00
Number of Panels Required (Pieces)	33,334	Civil and General Works Cost	☐ 35,000,000.00
		Land Cost	☐ 21,250,000.00
		Evacuation Cost up to Interconnection Points (Transformers & Cables)	☐ 44,000,000.00
		Accessories Cost	☐ 2,287,804.00
		Preliminary & Pre-operative expenses including IDC and Contingency	☐ 28,000,000.00
		Project Design and Management Cost	☐ 10,000,000.00
		Total Project Cost in INR	☐ 607,386,368.00

A. Energy and Revenue Generated

To estimate annual energy output generation from the solar plant, the global formula is [12].

$$E = A \times r \times H \times PR$$

Where E: Output energy, A: Total solar panel area (m²), r: Solar panel efficiency (%), H: Annual average solar radiation on tilted panels, PR: Performance ratio.

B. Net Present Values (NPV) and Internal Rate of Return (IRR)

NPV states the difference between the present value of all solar project cash inflows and outflows [13].

The formula used for NPV is given by equation below in Rupees [14]

$$NPV = \left[\sum_{t=1}^T \left(\frac{C_t}{(1+r)^t} \right) \right] - C_0$$

Here, C_t = Solar project annual cash inflows, r = Discount rate, C₀ = Initial investment for the solar project and t = years.

IRR is the rate at which the sum of project cash inflows and outflows are equal.

Therefore, IRR is written in % given by the equation [13].

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$$NPV = \left[\sum_{t=1}^T \left(\frac{C_t}{(1+r)^t} \right) \right] - C_0 = 0$$

C. Payback Period

It is used to determine the time taken by the solar project to return back the initial investment (cash outflow). We have used cash flow amounts by not taking time value of money into account.

The payback period is given by below equation in years [15]

$$\text{Payback period} = \left(\frac{\text{Initial investment}}{\text{Cash inflow per period}} \right)$$

D. Levelized Cost of Energy (LCOE)

LCOE signifies the operating and building cost (kWh) of the 10 MW solar power generation plant over a presumed financial life.

LCOE formula is calculated in rupees by the equation [16].

$$LCOE = \frac{\text{Sum of the costs over life time}}{\text{Sum of electricity produced over life time}}$$

Note: Undiscounted LCOE analysis is considered.

IV. EXPERIMENTAL RESULTS

The total energy and revenue generated from the plant with plant life of 25 years is calculated with the help of following input conditions: A: $1.6434 \times 33,334 = 54,781.10 \text{ m}^2$, PR: 75%, H: $2040.35 \text{ kWh/m}^2/\text{year}$ and power purchasing rate is 4 Rs/unit.

Total energy generated: 342652902.6kW

Total revenue generated: Rs. 1,370,611,610.60

Table 2:NPV and IRR

Interest Rates	NPV A with actual capital cost	NPV B with 10% inflation of actual capital cost	NPV C with 10% deflation of actual capital cost
0%	□ 763,225,242.60	□ 702,486,605.80	□ 823,963,879.40
6%	□ 112,279,247.90	□ 51,540,611.10	□ 173,017,884.70
7%	□ 51,214,934.89	□ -9,523,701.91	□ 111,953,571.69
8%	□ -1,880,934.71	□ -62,619,571.51	□ 58,857,702.09
9%	□ -48,274,586.18	□ -109,013,222.98	□ 12,464,050.62
10%	□ -89,005,745.47	□ -149,744,382.27	□ -28,267,108.67
IRR	7.963%	6.835%	9.293%

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	With actual capital cost	10% inflation in actual capital cost	10% deflation in actual capital cost
Year	Cumulative Cash Flow A	Cumulative cash flow B	Cumulative Cash flow C
0	□ -607,386,368.00	□ -668,125,004.80	□ -546,647,731.20
1	□ -546,526,182.72	□ -607,264,819.52	□ -485,787,545.92
9	□ 56,836,371.38	□ -77,751,863.06	□ -138,490,499.86
10	□ 56,333,394.64	□ -21,418,468.42	□ -82,157,105.22
11	□ 55,830,417.90	□ 34,411,949.48	□ -26,326,687.32
12	□ 55,327,441.16	□ 89,739,390.64	□ 29,000,753.84
Payback period	10.4	11.5	9.3

Table 3: Payback Period

With these following input conditions: Annual degradation: 0.50%, O&M Cost: 109 Rs/Unit, O&M escalator: 5.72%/year, Power purchasing rate: 4 RS/Unit. the total energy generated from the plant with 25 years plant life is 358,404,892kWh and total operation cost of the plant with 25-year plan life is Rs. 57,496,547.57.

Table4: LCOE

LCOE Outputs	Actual capital cost/unit	10% inflation of actual capital cost/unit	10% deflation of actual capital cost/unit
25 Year	□ 1.855117	□ 2.024586	□ 1.685647

V. CONCLUSION

We have calculated all the financial indicators with the help of standard literature and real time input data and found that with the implementation of mono crystalline passivated emitter rear cell panels in 10MW solar plant in Andhra Pradesh state will yields financially better results to the investors who would like to invest their money in this state of India.

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