An Economic Analysis of Ground-Mounted Solar Power Plant: A Case Study of 2MW Solar Power Plant, MCL, Burla, Odisha.

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***Abstract*— In today's world, energy is a crucial factor that drives socio-economic development. Nevertheless, renewable energy sources have gained increasing attention due to the concerning levels of environmental pollution. These eco-friendly options are receiving more and more focus, especially as the scarcity of fossil fuels becomes increasingly obvious. Solar energy stands out as a leading competitor for power generation among these alternative renewable sources. Solar energy has been acknowledged as a viable and eco-friendly renewable energy option for addressing increasing worldwide energy needs and reducing the impact of climate change. This paper thoroughly investigates methods of generating solar power, including Photovoltaic (PV) Systems and Solar Thermal Technologies. The paper also examines the status of solar power generation technology, highlights its benefits, and investigates the different obstacles preventing its widespread use. In addition, the research provides perspectives on possible remedies and highlights upcoming paths for improving solar energy production methods.**

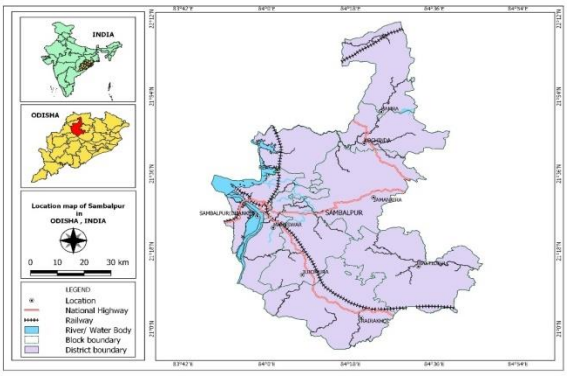
***Keywords*— Photo-voltaic solar panels, Renewable energy, solar energy.**

I. INTRODUCTION

As the need for energy grows globally, local governments in many areas are investing in a range of energy sources to meet the demand. While fossil fuels are dependable, they are not sustainable and have long-term consequences on the environment, including fine dust and carbon emissions. Solar and wind, which are renewable energy options, are readily accessible and have the potential to fulfil some of the energy needs. Electricity has become a crucial and necessary commodity due to the evolving way of life with rapid industrial growth. Over the past few decades, policy makers, investors, and customers have become increasingly concerned due to the rising demand and dwindling reserves of fossil fuels. Policymakers globally are actively seeking sustainable and viable alternative energy sources for electricity generation to address the concern. Solar power is a sustainable and eco-friendly technology that serves as a valuable energy resource and is considered one of the most important sources of renewable and environmentally friendly energy. It has a significant impact on attaining energy solutions for sustainable development. Hence, the abundant daily availability of solar energy makes it a highly appealing option for power generation. Both concentrated solar power and solar photovoltaic technologies are in constant development to meet our energy requirements. Therefore, a significant amount of solar energy systems in use around the world help bolster the energy industry and create opportunities for job growth to achieve adequate progress.

The use of photo-voltaic (PV) energy is increasing globally in the electricity production sector because of various reasons, such as the increasing concern about climate change and the need to transition to energy systems with minimal carbon emissions. The rise in demand has caused improvements in technology, leading to cheaper and more effective panels. Both governments and international organizations have actively supported and promoted the growth of renewable energies, particularly solar power, to address the challenges of energy availability and climate change. This paper focuses on the utilization of solar energy and its impact on sustainable development, while also exploring the employment opportunities associated with renewable energy. Therefore, it offers information and evaluation on the sustainability of solar energy, encompassing environmental and economic growth. Moreover, it has recognized the role of solar energy in sustainable development through meeting energy demands, generating employment, and promoting environmental conservation. Ultimately, the outlook for solar energy technology is considered within the energy industry and provides insight into potential growth in this field.

II. STUDY AREA



III. METHODOLGY

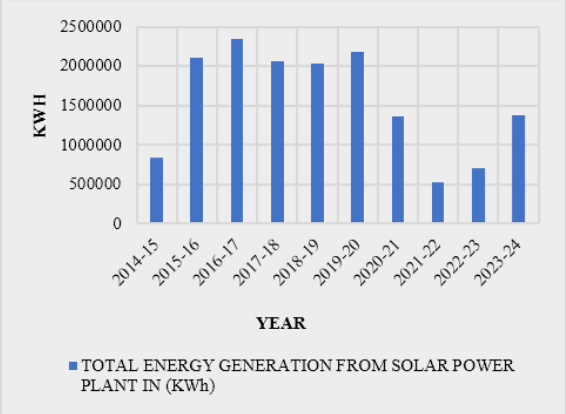
The research was conducted at a 2MW Solar PV facility situated in MCL, Burla, Sambalpur Odisha. This PV power plant was created with the goal of producing sustainable electricity, boosting economic growth in the energy industry, and advocating for green energy and sustainable development principles. Information has been gathered through interviews, observations, and document analysis. An interview was held with multiple stakeholders about the research's goals, including stakeholders from the electricity sector, the general sector, and staffing. The observation method was used to observe the equipment at the solar power plant and analyze their functions. Research is conducted by reading various materials such as articles, journals, blogs, and government reports.

IV. ANALYSIS AND INTERPRETATION

1. Power generation capacity:

Sl. no	YEAR	TOTAL ENERGY GENERATION FROM SOLAR POWER PLANT IN (KWh)
1	2014-15	835260
2	2015-16	2111025
3	2016-17	2337375
4	2017-18	2065680
5	2018-19	2029880
6	2019-20	2180070
7	2020-21	1362420
8	2021-22	527175
9	2022-23	697620
10	2023-24	1378665
	Total	15525170
	Average	2822758

Table 1:



The figure above illustrates the solar power plant's annual energy generation. The plant can generate up to 2MW of power. The amount of electricity produced by the solar power plant is determined by the daily/monthly sunlight exposure, sun angle, and voltage output of the solar PV module based on temperature and system module based on temperature and system losses. In the year 2014024, the solar PV system produced a total of 15525170kWh of energy.

2. Auxiliary consumption from the generated power:

Sl. no	YEAR	AUXILIARY CONSUMPTION (IN KWH)	% OF AUXILIARY CONSUMPTION FROM TOTAL GENERATION
1	2014-15	16680	1.99
2	2015-16	29265	1.38
3	2016-17	31620	1.35
4	2017-18	27996	1.35
5	2018-19	24295	1.19
6	2019-20	28320	1.29
7	2020-21	26535	1.94
8	2021-22	29175	5.53
9	2022-23	37035	5.3
10	2023-24	16935	1.22
	Total	267856	

	Average	48701.09	

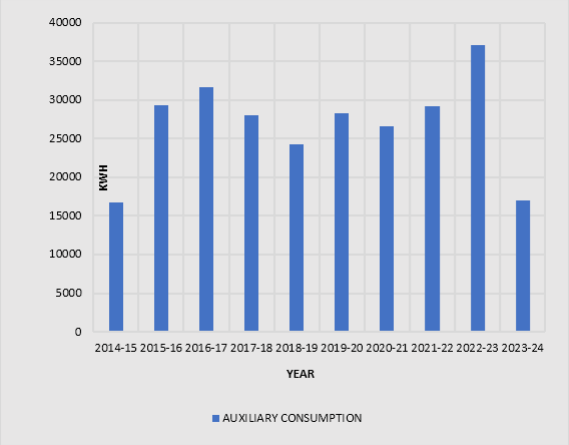
Table 2

The above table represents the year-wise auxiliary consumption of the solar plant. Auxiliary consumption in a solar power plant is the energy used to manage the system. A power plant must supply not only the grid but also its auxiliaries that keep the plant up for a certain period. For a PV plant, these auxiliaries are inverter control circuitry, transformer magnetizing circuitry, cooling fans, air conditioners, lights, and computers. This includes energy used by fans, air conditioning, lights, electronic devices, and other systems. Total auxiliary consumption is divided into two broad categories:

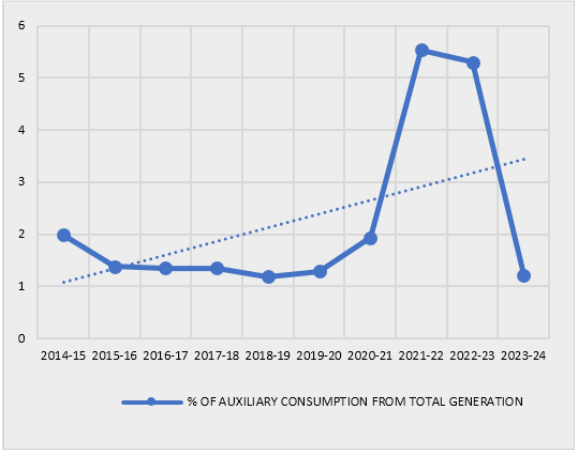
1. Plant-generated auxiliary (daytime consumption)
2. Total import (night-time consumption)

Some examples of auxiliary consumption in a solar power plant are:

- Power conditioning system – the power loss in the inverters that convert direct current into high voltage AC.
- Hydraulic circuits- the power used to maintain electrolyte circulation through the cells.
- Monitoring and controlling systems.



The total auxiliary consumption of the solar power plant during the year 2014-2024 is 267856kwh. The average consumption of 10 years is 48,701.09 kwh.



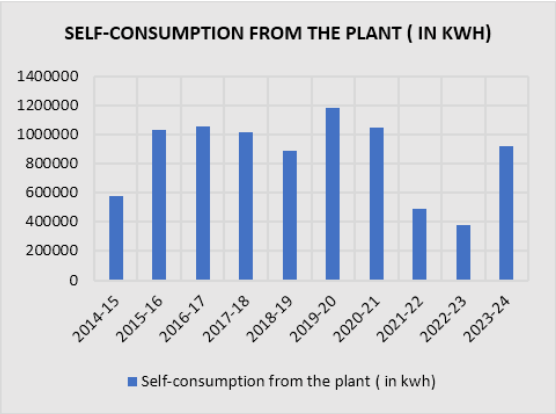
The above graph depicts the year-wise percentage of auxiliary consumption from total generation in kWh. It was observed that 2021-22 accounts for the highest % of consumption i.e.; 5.53% followed by 2022-23 which is 5.3%. 2018-19 accounts for the least 1.19%.

The consumption varies from year to year due to various factors such as plant size, larger plants have lower auxiliary consumption as compared to smaller plants. Secondly comes the plant load factor; a poor plant load factor can lead to higher auxiliary power consumption.

3. Self-consumption from the power generated at the solar power plant:

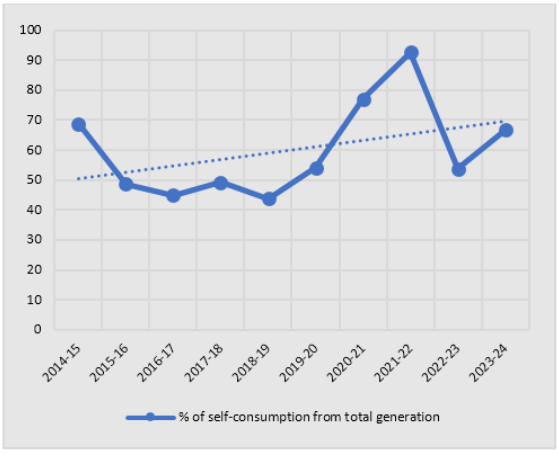
Sl. no	YEAR	SELF-CONSUMPTION FROM THE PLANT (IN KWH)	% of self-consumption from total generation
1	2014-15	574605	68.79
2	2015-16	1029540	48.76
3	2016-17	1051870	45
4	2017-18	1016389	49.2
5	2018-19	890696	43.87
6	2019-20	1179820	54.11
7	2020-21	1050410	77.09
8	2021-22	488010	92.57
9	2022-23	374815	53.72
10	2023-24	919435	66.69
	Total	8575590	-
	Average	1559198	-

Table 3



Solar energy self-consumption involves using the electricity produced by one's own solar panel now of its production. This helps reduce dependency on traditional electric grid and consequently achieve significant savings on electricity bills. The above figure represents the self-consumption from total generated power at the solar plant during the year 2014-2024. There are fluctuations in self-consumption over the years. The major influencing factor is the total amount of energy generated during the year followed by the auxiliary consumption. The determining factor for self-consumption is primarily the relationship between nominal PV system power and energy requirement. Solar energy self-consumption is a cost effective and sustainable solution to cope with rising costs of public electricity.

Self- consumption reduces reliance on external energy sources, lowers electricity bills and increases energy independence. It often promotes efficient use of generated power, minimizing wastage and enhancing sustainability. It supports long term energy savings and environment benefits.



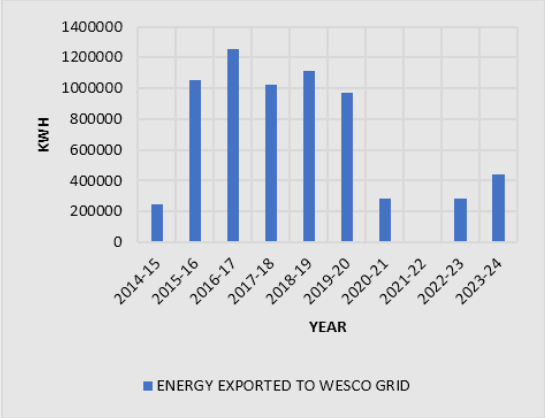
Modes of operation of the photovoltaic system for self-consumption:

Power consumption modes	Description
Autonomous systems	Electricity produced is stored in batteries for future use, reducing reliance on the grid for power consumption.
Instant consumption	The electricity produced is used right away to meet as many energy requirements as possible. Energy consumption from the external grid is low during the daytime when the sun is shining.
Self-consumption and Storage	Demand is exceeded by the amount of electricity being generated. Excesses are kept in energy storage systems for future use.
Self-consumption and sale of surpluses to the external grid	Excess electricity is produced and sold to the grid when more power is generated than required for their own consumption.

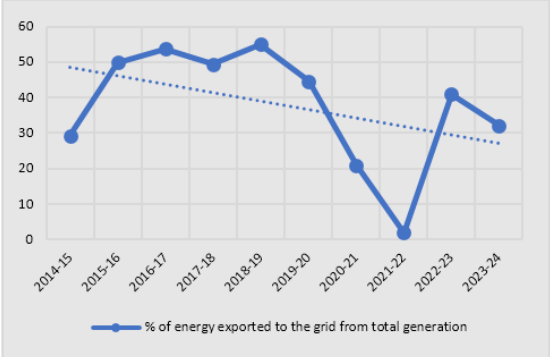
4. Energy exported:

Sl. no	YEAR	ENERGY EXPORTED TO WESCO GRID	% OF ENERGY EXPORTED TO THE GRID FROM TOTAL GENERATION
1	2014-15	243975	29.2
2	2015-16	1052220	49.84
3	2016-17	1253885	53.64
4	2017-18	1021295	49.44
5	2018-19	1114889	54.92
6	2019-20	971930	44.58
7	2020-21	285475	20.95
8	2021-22	9990	1.89
9	2022-23	285770	40.96
10	2023-24	442295	32.08
	Total	6681724	-
	Average	1214859	-

Table 4



The above graph shows the amount of energy exported to grid from total generated energy. After the auxiliary and self-consumption, the excess/ left out amount of energy is being exported to grid through net metering. It is found that surplus amount of energy was more in the year 2016-17 and lowest in 2021-22. The grid export facility allows for a more balanced and distributed energy supply, reducing the stress on grid during peak demand periods.



5. Savings from energy generated at solar power plant:

Sl. no	YEAR	SAVINGS IN ENERGY BILL
1	2014-15	2585722.5
2	2015-16	4838838
3	2016-17	4943789
4	2017-18	4472111.6
5	2018-19	3919062.4
6	2019-20	5191208
7	2020-21	4621804
8	2021-22	2391249
9	2022-23	1836593.5
10	2023-24	4505231.5
	Total	39305610
	Average	7146474

The above table reflects the savings in energy bill from total energy generated at the solar power plant during the year 2014-24. The amount of savings depends upon various factors such as energy generation, net metering, and electricity tariffs. A total of 39305610 INR is saved in energy bill during these 10 years from the generated power.

6. Carbon reduction:

Solar energy's main advantage is its flexibility in terms of size, with the ability to range from small individual panels for communities to large-scale setups for industrial power production. It is essential that we make extensive use of solar energy quickly to help businesses stop the increase in greenhouse gas and carbon dioxide emissions and build a sustainable, safer world for all. Solar power plants reduce carbon emissions by producing electricity without the need to burn fossil fuels, with each kilowatt-hour (kWh) of solar energy generated leading to around 0.8 kilograms (kg) of CO2 being released. The current research revealed a carbon decrease of 12,730,639.40 kg over a decade since the installation date.

Even though every production process creates some level of carbon emissions, the carbon footprint associated with solar energy firms is minimal and is consistently decreasing. There is also an emphasis on minimizing emissions during the production and manufacturing of solar power plants. As a result, the overall pollution generated by solar power is significantly less than that of alternative energy sources, even throughout the manufacturing process. This implies that customers opt for solar power suppliers for reasons beyond just the environmental benefits of solar energy. Furthermore, an increase in the use of solar energy alters the grid emission factor, showing that higher levels of solar power usage led to lower overall harmful emissions.

V. RESULTS AND DISCUSSION.

SL.NO.	YEAR	TOTAL ENERGY GENERATION FROM SOLAR POWER PLANT IN (KWh)	% OF AUXILIARY CONSUMPTION FROM TOTAL GENERATION	% OF SELF-CONSUMPTION FROM TOTAL GENERATION	% of energy exported to the grid from total generation	Total %
1	2014-15	835260	1.99	68.79	29.2	100
2	2015-16	2111025	1.38	48.76	49.84	100
3	2016-17	2337375	1.35	45	53.64	100
4	2017-18	2065680	1.35	49.2	49.44	100

5	2018-19	2029880	1.19	43.87	54.92	100
6	2019-20	2180070	1.29	54.11	44.58	100
7	2020-21	1362420	1.94	77.09	20.95	100
8	2021-22	527175	5.53	92.57	1.89	100
9	2022-23	697620	5.3	53.72	40.96	100
10	2023-24	1378665	1.22	66.69	32.08	
	Total	15525170				

The study revealed that a 2MW solar power plant was established in 2014, producing a total of 15525170 kWh of power in the following 10 years. Around 50-60% of the total electricity generated is typically used for self-consumption, resulting in lower electricity bills. The remaining energy is either exported to the grid or used for auxiliary consumption.

A greater level of self-consumption results in saving on energy purchases by relying more on one's own power sources, moving closer to being energy self-sufficient and less dependent on traditional energy providers. This contributes to decreasing the total carbon footprint, reducing the adverse effects on the environment, and advocating for sustainability. Over time, there have been important developments in technology and infrastructure for generating solar power, leading to the invention of different ways to capture solar energy. Despite improvements, solar power generation still encounters various challenges that must be resolved for widespread acceptance and optimal efficiency. Some of the challenges include costly initial investments, erratic storage problems, land management issues, environmental impacts, productivity limitations, technological obstacles, as well as government regulations and policies.

VI. CONCLUSION

This paper emphasizes the importance of sustainable energy advancement. Solar energy could stabilize energy costs and provide various advantages in the areas of society, environment, and economy. Solar energy has been shown to support sustainable development by meeting energy needs, generating employment, and preserving the environment. Therefore, it is crucial to examine a key element of long-term sustainability. Given the current state of fossil fuel reserves, which are running low as energy sources, it is crucial and anticipated to discover a new method for implementing clean energy technology. However, solar energy, particularly CSP technology, is still in the process of maturing in its development. Furthermore, as PV systems advance, there is a significant increase in global demand for PV technology applications. More effort is required to promote sustainable energy development and explore alternative clean energy sources. Furthermore, a thorough experimentation and verification process is necessary for these applications to create more sustainable energy sources and reduce carbon emissions on Earth.

REFERENCES

[1] Shruti Sharma, Kamlesh Kumar Jain, Ashutosh Sharma a review on “Solar Cells: In Research and Applications”,Materials Sciences and Applications, 2015, 6, 1145-1155 Published December 2015 http://dx.doi.org/10.4236/msa.2015.612113

[2] Askari Mohammad Bagher, Mirzaei Mahmoud Abadi Vahid, Mirhabibi Mohsen. “Types of Solar Cells and Application”. American Journal of Optics and Photonics.Vol. 3, No. 5, 2015, pp. 94-113. doi: 10.11648/j.ajop.20150305.17

[3] Missoum, M., & Loukarfi, L. (2021). Investigation of a Solar Polygeneration System for a Multi-Storey Residential Building-Dynamic Simulation and Performance Analysis. International Journal of Renewable Energy Development, 10(3), 445-458. https://doi.org/10.14710/ijred.2021.34423

[4] Wasfi, M. (2011). Solar energy and photovoltaic systems. Journal of Selected Areas in Renewable and Sustainable Energy, 1-8.

[5] Watts RG. Engineering Response to Climate Change. 2nd edn. Boca Raton, FL: CRC Press, 2013.

[6] Sorensen B. Renewable Energy: Physics, Engineering, Environmental Impacts, Economics and Planning. 4th edn. London: Academic Press, 2010.

[7] IEA, IRENA, WMO, WBG, WHO. Tracking SDG7: The Energy Progress Report 2021. Washington, DC: The World Bank, 2021.

[8] Edenhofer O, Pichs-Madruga R, Sokona Y, et al. Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press, 2011

[9] Ram Kumar, R., et al, “Solar Energy Conversion and Storage System for the Future,” IEE, Trans, Power Apparatus and Systems, Vol.PAS-94, 1975.

[10] Jatoi, A. R., Samo, S. R., & Jakhrani, A. Q. (2021). Performance Evaluation of Various Photovoltaic Module Technologies at Nawabshah Pakistan. International Journal of

Renewable Energy Development, 10(1), 97-103. https://doi.org/10.14710/ ijred.2021.32352

[11] Wasfi, M. (2011). Solar energy and photovoltaic systems. Journal of Selected Areas in Renewable and Sustainable Energy, 1-8.

[12] Khezri R, Mahmoudi A, Haque MH (2020). Optimal capacity of solar PV and battery storage for Australian grid-connected households. IEEE Transactions on Industry Applications, 56: 5319–5329.

[13] Obaideen K, AlMallahi MN, Alami AH, et al. On the contribution of solar energy to sustainable developments goals: case study on Mohammed bin Rashid Al Maktoum Solar Park. International Journal of Thermofluids, 2021, 12:100123.

[14] Chun-sheng, Z., Shu-Wen, N. I. U., & Xin, Z. (2012). Effects of household energy consumption on environment and its influence factors in rural and urban areas. Energy Procedia, 14, 805–811. Deshmukh, A. (2009). The role of decentralized renewable energy for rural electrification: Maharashtra case study, India (Master's Thesis). Lund University, Sweden. https:// core.ac.uk/download/pdf/289931446.pdf

[15] ECC. (2008). Decentralized energy options in the tribal belt of the Eastern Ghats region in India. Laya Resource Centre.