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Feasibility Analysis of On-Grid PV Power Plant as a Source of Electric Vehicle Charging Station (EVCS).

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ABSTRACT

The reliance on fossil fuels for Energy and transportation has detrimental effects on the environment, contributing to CO2 emissions, global warming, and air pollution. The Ministry of Energy and Mineral Resources (KESDM) has set an ambitious target to achieve a primary energy mix of 31% renewable sources by 2050 as part of Indonesia's commitment to reach Net Zero Emissions (NZE) by 2060. In alignment with this goal, Indonesia has enacted Presidential Decree No. 55 of 2019 to promote accelerating electric vehicles (EVs) for road transport. This initiative and developing the necessary charging infrastructure for electric vehicles (EVCS) are essential. Harnessing Solar Power Plants to supply Energy for EVCS is a viable solution for achieving a sustainable future. EVCS is powered by the PLN network, which predominantly relies on fossil fuels. Implementing an On-Grid PV Power Plant as an energy source for Electric Vehicle Charging Stations (EVCS) is intended to decrease reliance on fossil fuels and facilitate the transition to clean Energy. The approach involves optimizing the system's configuration by analyzing technical performance, emissions, and economic feasibility. A PV Power Plant with 75 modules can generate up to 58.54 MWh of Energy per Year, sufficiently covering the EVCS 's electric demand of 17 MWh annually. This system is projected to reduce carbon emissions by 1,029 tCO_2 eq. From an economic and investment perspective, the analysis indicates a positive Net Present Value (NPV), a Payback Period of approximately 11.57 years, and a Profitability Index of 1.38, suggesting that the project is financially viable.

Keywords: On-Grid PV Power Plant; EVCS; Net Zero Emissions; NPV.

INTRODUCTION

Electricity is a fundamental aspect of modern life due to its widespread use across various sectors (Aghenta & Tariq Iqbal, 2019). However, relying on fossil fuels for energy generation negatively impacts the environment, including CO2 emissions, global warming, and air pollution. In response, the Indonesian government, through the Ministry of Energy and Mineral Resources, has set a target that 31% of the primary energy mix will come from renewable energy sources (EBT) by 2050 as part of efforts to achieve Net Zero Emissions (NZE) by 2060 (Arief et al., n.d.). Indonesia is endowed with abundant renewable energy potential, particularly in solar Energy, which has a capacity of 3,295 GW. This potential serves as a crucial asset in facilitating Indonesia's energy transition. The renewable energy revolution represents a hopeful pathway toward a sustainable future, with solar power plants contributing to the prosperity and well-being of communities. (Foster et al., n.d.).

According to projections of greenhouse gas emissions by user sector, transportation emerges as the most significant contributor to emissions (Perda_No_9_Tahun_2019_tentang_RUED_Provinsi_Lampung, n.d.). In response, the government has implemented Presidential Regulation No. 55 of 2019, which aims to accelerate the adoption of Battery-Based Electric Motor Vehicles (Battery Electric Vehicles) for road transportation (Peraturan Presiden Republik Indonesia 55 Tahun 2oi9 Program Kendaraan Bermotor Listrik Baterai (Battery Electric Vehicle) Untuk Transportasi Jalan, 2019). Electric Vehicles (EVs) present a viable solution for reducing reliance on fossil fuel-powered vehicles (Kempston et al., 2025). EVs promise more environmentally friendly operation, low emission, noise-free, better energy efficiency, and less engine maintenance than ICE engines (ABDI YONIS et al., 2023) (Gopi & Ramesh, 2024).

A comprehensive charging infrastructure must accompany electric vehicles (EVs) advancement. Charging can occur at home, or public charging stations referred to as EVCS (Arief et al., n.d.). EVCS's are directly linked to the PLN (Indonesian State Electricity Company) electricity network, which still predominantly relies on fossil fuel power plants for energy generation. The number of operational charging stations and the amount of simultaneous charging significantly influence the stability of the electrical system. Solar power plants can be employed as a renewable energy source to address this challenge of providing electricity at EVCS, effectively accommodating the increasing energy demands. PV Power Plant offers a sustainable solution for the energy transition, helps reduce carbon emissions, and alleviates potential strains on the electricity grid's stability (Elektro et al., n.d.). Solar power plants are facilities that capture Sunlight is an energy source that can be converted into electrical Energy using the photovoltaic principle. The photovoltaic effect takes place when solar cells absorb sunlight. In this process, photons from the light stimulate the release of electrons, which then flow through semiconductor materials classified as n-type and p-type, producing direct current (DC) electricity (ABDI YONIS et al., 2023) (Elektro et al., n.d.).

An On-Grid Solar Power Plant is a solar system interconnected with the PLN electricity network (Grid) (Samsurizal et al., n.d.). This system generates power when sunlight is exposed, reducing PLN's electricity consumption. Solar panels consist of multiple interconnected cells that absorb sunlight and convert it into DC electricity. The electricity produced by solar modules is influenced by the amount of solar irradiation they receive. These modules can still generate electricity on cloudy days, albeit at a reduced power output due to lower irradiation levels. Photovoltaic (PV) cells are constructed from light-sensitive semiconductor materials. There are two primary categories of technology used in PV cell production: crystalline silicon, which is the most commonly utilized, and thin film, which represents a newer category (BUKU PANDUAN ENERGI TERBARUKAN, 2023; David Tan & Ang Kian Seng, n.d.). An array comprises several solar panels containing numerous solar cells (BUKU PANDUAN ENERGI TERBARUKAN, 2023). Maximum Power Point Tracking (MPPT) is utilized to optimize the output power from the photovoltaic (PV) array, with adjustments made through a DC/DC converter (Jaladi et al., 2020). The DC voltage generated by solar panels fluctuates based on the sunlight they receive, making it inherently unstable. An inverter is a device used to convert DC into AC (Foster et al., n.d.). In a photovoltaic (PV) system, solar modules produce DC, which is then transformed into AC based on the load requirements (Foster et al., n.d.). KWH Exim is a device installed in photovoltaic power plants that monitors electricity usage for export and import purposes. It tracks the capacity of power exported from the PV Power Plant to the grid and the capacity imported by the PV Power Plant from the grid.

The operation of solar panels is influenced by various factors, including solar irradiance, the angle of incidence (defined as the angle between the incoming solar rays and the surface normal of the solar panel),

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the temperature of the solar panels, and the presence of shading. Each factor plays a critical role in determining solar energy systems' efficiency and overall performance. Understanding their Interactions are essential for optimizing solar panel deployment and maximizing energy capture (Samsurizal et al., n.d.; BUKU PANDUAN ENERGI TERBARUKAN, 2023; Sheik et al., 2022).

An Electric Vehicle Charging Station (EVCS) is an electric vehicle charging station connected directly to the electricity distribution panel. The charging station has a cable equipped with a connector similar to a nozzle, which connects it to the Electric Vehicle charging socket to charge the battery (Herdian et al., n.d.). Charging station classifications include Residential Charging Stations and Charging While Parked, which are often found in shopping centers or offices, can be used in general, and can be commercial. Public charging stations, usually found in public places or rest areas provided for motorists traveling, can be used for general and commercial purposes.

Electric vehicles (EVs) utilize electricity as their primary energy source for operation. Electric motors power EVs and some models may incorporate a combination of an internal combustion engine (ICE) that burns fuel (Kumara, n.d.). In the context of electric vehicles, several types of batteries are commonly used based on various chemical compositions. Lithium-ion (Li-ion), nickel-metal hydride (Ni-MH), and lead-acid batteries are the most prevalent types. (Wellten et al., 2025).

Carbon emissions refer to the release of gases containing carbon into the Earth's atmosphere. Burning fossil fuels in the industrial and transportation sectors produces a significant amount of CO_2 emissions, which are a primary contributor to greenhouse gases and global warming (KEMEN-ESDM, 2023). While solar power technology aims to support the transition towards net-zero emissions (NZE), the PV Power Plant system is not entirely emissions-free. Emissions are generated during the energy production process due to the components of the system. Emission reduction involves lowering or eliminating the effects of carbon dioxide and greenhouse gas emissions to help prevent global warming. Strategies for reducing carbon emissions include improving energy efficiency, optimizing electricity transportation, and expanding the use of clean and renewable energy sources (Maka et al., 2024). Mitigation actions strive to reduce greenhouse gas emissions from fossil fuel consumption by building and operating interconnected solar power plants linked to the power grid (Direktorat Teknik dan Lingkungan Ketenagalistrikan, 2020).

RESEARCH METHODS

The design of connected solar power plants integrated with the AC network is an energy source for Electric Vehicle Charging Stations (EVCS). The configuration of the photovoltaic (PV) the system is optimized using PVsyst software. Simulation results indicate significant potential energy generation from the solar power plant system. During periods of maximum solar radiation, the power generated by the PV system meets the load requirements, with surplus Energy being exported to the grid. Grid power is Utilized when the Energy produced by the solar power system is insufficient to meet demand or when solar generation is not possible, such as at night (Wahyu Bagus Rahmatulloh & Aris Heri Andriawan, 2024). The optimization of the solar power system configuration includes an analysis of technical feasibility, economic viability, and reduced carbon emissions in the design of the on-grid solar power system as an energy source for EVCS.

Planning Techniques

When planning the installation of rooftop solar power systems, we utilize Helioscope software for technical designs. The 3D modelling feature helps us determine the optimal panel orientation and tilt based on geographic location, ensuring maximum solar radiation absorption by the panels(Malla & Gautam,

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2023). In configuring the system design, we specify the quantity, capacity, and specifications of the components used, including the solar panel array configured in series or parallel, employing PVsyst software. Additionally, we model and simulate real-time data, factoring in the probability of consumption load to estimate the potential Energy produced by the photovoltaic power generation system.

Table 1 Information

GlobHor (Global Horizontal Irradiation)	The total solar radiation received by the Earth's horizontal surface, including direct radiation
DiffHor (Horizontal Diffuse Irradiation)	Solar radiation is scattered (diffuse) on a horizontal surface
T_Amb (Ambient Temperature)	Air temperature in the surrounding environment
GlobInc (Global Incident in Coll. Plane)	Total solar radiation falling on a solar panel, including direct and scattered radiation
GlobEff (Effective Global, corrected for IAM and shadings)	Effective solar radiation on the panel after correcting for Incident Angle Modifier (IAM) and shading effects.
E_Array (Effective Energy at the Output of the Array)	Net Energy is produced at the PV array output (after system losses, cables, etc.).
E_User (Energy Supplied to the User)	Energi listrik yang langsung digunakan oleh pengguna dari sistem PV
E_Solar (Energy from the Sun)	The total energy received by a solar panel from solar radiation
E_Grid (Energy Injected into Grid)	Electrical Energy produced by a PV system and supplied to the electricity network (grid)
EFrGrid (Energy from the Grid)	Electrical Energy is supplied from the electricity network (grid) to meet EV load needs when the PV system is insufficient.

Integration and selection of components in a system can affect overall system performance, efficiency, and reliability (Foster et al., n.d.). The careful selection of appropriate components is crucial, as it can mitigate losses within the system and optimize cost-effectiveness (Malla & Gautam, 2023).

The capacity of the Photovoltaic (PV) system is optimized by maximizing the available roof area of the building. This involves determining key components such as module capacity, tilt, and azimuth angles, as well as the orientation and spacing design of the solar panels. The solar panel array is designed to operate at optimal capacity, producing enough power to meet the required load. Calculate array capacity based on

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equation (2.1).

$$\text{Capacity of PV Power Plant} = \text{Module Capacity x Number of Modules} \quad (2.1)$$

The panel is designed to be oversized compared to the inverters, with a DC/AC ratio of 1.1 to 1.3. The inverters must have a maximum PV input power capable of handling the panel's DC power output. The system DC/AC ratio is 1.25.

Determine configuration module solar can use equations (2.2), (2.3), and (2.4).

$$\text{Min series module per string} = \frac{V_{min}\text{Inverter}}{V_{oc}\text{Modul}} \quad (2.2)$$

$$\text{Max series module per string} = \frac{V_{max}\text{Inverter}}{V_{mp}\text{Modul}} \quad (2.3)$$

$$\text{Max parallel module per string} = \frac{I_{max}\text{Inverter}}{I_{mp}\text{Modul}} \quad (2.4)$$

Information:

V_{min}Inverter = Min DC Inverter Voltage (V)

V_{max}Inverter = Voltage Max DC Inverter (V)

I_{max}Inverter = Maximum DC Inverter current (A)

V_{oc}Modul = Panel open-circuit voltage (V)

V_{mp}Modul = Maximum panel voltage (V)

I_{mp}Modul = Maximum panel current (A)

The output of an on-grid solar power plant depends on various factors, including solar irradiation, temperature, panel efficiency, and the area of the panels. The system accounts for module array losses of 17.1% and inverter losses of 2.05%. The nominal energy output of the array, referred to as nom Energi, represents the maximum Energy that the photovoltaic (PV) system can generate without considering any losses, as shown in equation (2.5). The Energy produced by the PV array before it enters the inverter is denoted as E_Array, which can be calculated using equation (2.6). The clean electrical Energy produced by the solar power plant system after the inverter, available for use by the load or for export to the grid, is referred to as E_Production. This value can be determined using equation (2.7).

$$\text{Array}_{\text{nomEnergy}(\text{STC}_{\text{Eff}})} = \text{Glob}_{\text{Eff}}\ \text{xArray area x}\ \eta\text{P} \quad (2.5)$$

$$E_{\text{Array}} = \text{Array nonenergy} - \text{Modul ArrayLosses} \quad (2.6)$$

$$E_{\text{produced}} = E_{\text{Array}} - \text{Inverter losses} \quad (2.7)$$

Planning Economical

Planning economical On-Grid PV Power Plant as supply energy at EVCS. Economic analysis used BoQ, O&M Cost, LCC, LCoE, and CRF parameters.

A Bill of Quantity (BoQ) is a list that includes component required components and the price charged for each component (Malla & Gautam, 2023).

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Operation and maintenance costs refer to the costs incurred during the lifetime of the On-Grid PV Power Plant system as an EVCS energy source. These costs include component replacement, system maintenance, and others (Helmi Nur Jannah et al., 2023).

$$\text{O \& M costs} = 1\% \text{ Investment Costs} \quad (2.8)$$

Life Cycle Cost (LCC) refers to the total costs incurred throughout the operational period (Helmi Nur Jannah et al., 2023).

$$\text{LCC} = \text{C} + \text{Mpw} + \text{Rpw} \quad (2.9)$$

Information:

LCC = Cost cycle life (Life Cycle Cost)

C = Cost investment beginning

Mpw = Total cost of maintenance and operations for n years or during the age project

Rpw = Cost replacement tools that must be issued during the age project

The Levelized Cost of Energy (LCoE) is utilized to assess the cost of producing each kilowatt-hour (kWh) of electricity over the operational lifespan of a photovoltaic (PV) system. It is a valuable measure for evaluating the cost-effectiveness of a solar power system while it continues to generate Energy. The LCoE is calculated by taking the total present value of the life cycle costs (LCC) incurred throughout the project's duration and dividing it by the total amount of Energy produced by the system during its useful life (Ali & Khan, 2020).

$$\frac{\sum_{t=1}^{n} \frac{\text{LCC}}{(1+r)^t}}{\sum_{t=1}^{n} \frac{\text{Et}}{(1+r)^t}}$$

(2.10)

Capital Recovery Factor (CRF) is a factor used to recover capital. It converts the cash flow cost cycle life (LCC) into uniform annual costs (Ali & Khan, 2020).

$$\text{CRF} = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (2.11)$$

Information:

CRF = Capital Recovery Factor

i = Discount rate

n = Period in leaves (investment life)

Net Present Value (NPV) is a parameter used to determine the future demand for and spending of money (Ali & Khan, 2020; Sitorus et al., 2024).

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$$NPV = \sum_{t=1}^{n} \frac{NCF_t}{(1-t)^t} - IA \qquad (2.12)$$

Information:

NCFt = Net Cash Flow period 1st Year to Year to -n

IA = Initial Investment

i = Discount rate

n = Period in years (age) investment

The Payback Period (PP) is the time required to recover an investment through the revenue generated by a project. It is calculated using a discount factor (Helmi Nur Jannah et al., 2023).

$$PP = n + \frac{a-b}{c-b} \times 1 \text{ tahun} \qquad (2.13)$$

Information:

n = Year final amount negative cash flow

a = Total investment beginning

b = Cumulative total cash flow in the Year to -n

c = Cumulative total cash flow in the Year to -(n+1)

Profitability Index (PI) is a comparison between the total Now net cash flow (NCF) and the initial costs and investments incurred (Helmi Nur Jannah et al., 2023).

$$PI = \frac{\sum_{t=1}^{n} NCF_t(1+i)^{-t}}{I_A} \qquad (2.14)$$

Information:

$\sum_{t=1}^{n} NCF_t(1+i)^{-t}$ = Total value Now net cash flow

I_A = Initial Investment

Table 2 Criteria Economic Feasibility

Feasibility Analysis	Criteria	
	Worthy	Not feasible
Net Present Value (NPV)	NPV > 0	NPV < 0
Discounted Payback Period (DPP)	DPP < Age Project	DPP > Age Project
Probability Index (PI)	PI > 1	PI < 1

Emission Analysis

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Baseline emissions are greenhouse gas emissions that arise if V Power Plant is not built. The Electricity Factor is the combined margin Co2 emission factor for electricity generation in the electricity interconnection system, which was calculated and published by the Ministry of Energy and Mineral Resources. The combined margin emission factor used is the lowest value of the ex-post and ex-ante emission factors (Direktorat Teknik dan Lingkungan Ketenagalistrikan, 2020).

Equations (2.15) and (2.16) can be used to calculate baseline emissions per year and during the project.

Baseline Emission Calculation

$$EB_y = PL_y \times FEG_y \quad (2.15)$$

Information:

EB_y = baseline emissions in period y (tonsCO2)

PL_y = Net electricity production (clean electricity) produced by PV Power Plant and distributed to the interconnection network in year y (MWh)

FEG_y = GHG emission factor of the electricity system in year y (ton CO2/Mwh)

The calculation of total baseline emissions in year Y can use the equation.

$$EB_{total} = \sum_{y=1}^{25} (P_1 \times (1-d)^{y-1} \times FE) \quad (2.16)$$

Emission Reduction Calculation

$$PE_y = EB_y - EP_y \quad (2.17)$$

Information:

PE_y = Emission reduction due to mitigation actions in period y (tonsCO2)

EB_y = Baseline Emissions

EP_y = Mitigation Action Emissions

RESULTS AND DISCUSSION

Technical Feasibility Analysis

The design system utilizes part of the building's roof, covering an area of 245 m². PLN's Electric Vehicle Charging Station (EVCS), located on El's Coffee property, serves as infrastructure to support the transition to electric vehicles. The electric load refers to the electric car's battery that charges at the EVCS. The voltage and battery capacity are tailored to meet the needs of electric cars.

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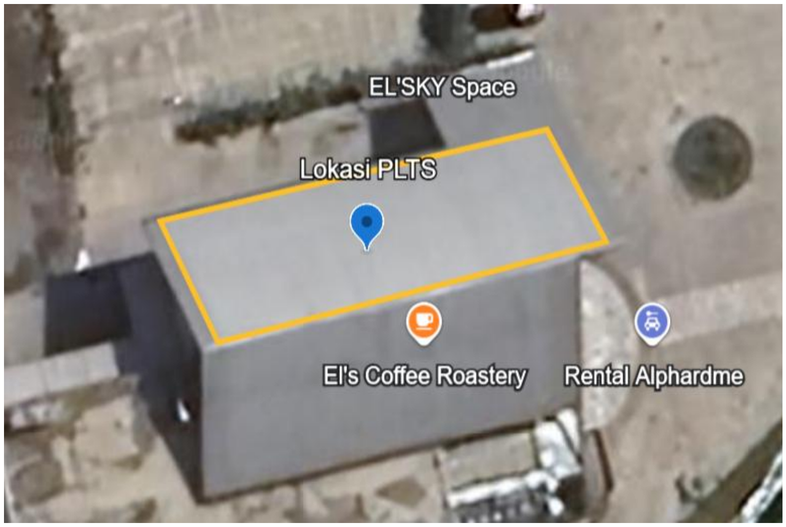

Figure 1 Installation location, El's Coffee Bypass, Lampung, Coordinates 5.3938884,105.2860069,749m

Table 3 presents EV charging data at EVCS monthly over a Year, showing an overall total load of 37.88 MW/year and an energy requirement of 17,025 MWh/year.

Table 3 Electrical Energy Needs

No	Month	Power (kW)	Energy (kWh)
1	September 2023	979.66	697.82
2	October 2023	882.21	819.14
3	November 2023	475.01	281.69
4	December 2023	1376.96	650.53
5	January 2024	2561.98	1185.21
6	February 2024	2958.84	1225.53
7	March 2024	1860.33	1196.02
8	April 2024	5840.12	2467.4
9	May 2024	1867.28	1604.64
10	June 2024	3786.74	1683.98
11	July 2024	6419.35	1883.52
12	August 2024	8875.09	3329.9
	TOTAL	37883.57	17025.38

Table 4 presents the number of EV charges recorded over one Year, with a total frequency of 792 units and a bin step of 12.35 kW.

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Table 5 presents the irradiation and temperature data from the El's Coffee Meteonorm database at latitude -5.39389372 and longitude 105.2885. The highest level of irradiation is observed In October, while the lowest occurs in June. The total annual irradiation amounts to 1,782.6 kWh, resulting in an average daily irradiation of 4.88 kWh/m².

Table 4 Load Profile

No	Bin step (12.35 kW)	Frequency	Probability (%)
1	0.86 – 13.21	168	22
2	13.21 – 25.57	167	21
3	25.57 – 37.92	70	9
4	37.92 – 50.28	51	6
5	50.28 – 62.63	75	9
6	62.63 – 74.99	83	10
7	74.99 – 87.34	56	7
8	87.34 – 99.70	25	3
9	99.70 – 112.05	26	3
10	112.05 – 124.41	31	34
11	124.41 – 136.76	21	3
12	136.76 – 149.12	19	2
	TOTAL	792/ year	100%

Table 5 Meteorological Data

Month	Global Heat (kWh/m2)	T_Amb (degrees Celsius)
January	153.5	26.66
February	146.5	26.61
March	161.7	26.98
April	149.4	26.91
May	142.8	27.39
June	133.0	26.63
July	142.0	26.62

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August	141.9	26.91
September	145.3	26.82
October	164.3	27.48
November	147.1	26.83
December	155.3	26.88
Year	1782.6	26.90

The configuration and simulation of the on-grid PV Power Plant system were performed using PVsyst software to assess the potential energy generation. The solar panels selected for this system are Trina Solar TSM-DE19 Vertex, with a capacity of 550 Wp. The inverter chosen is the SUNGROW SG33CX-P2, which has a capacity of 33 kW with number of Inverter 3* MPPT of 33%. The design of the PV Power Plant uses 75 modules with three strings and 25 series. Power generated The PV Power Plant system obtained 41.3 kWp from mark Max Power Voltage system (Vmp) of 790 V (31.6 @25), and the Max Power Current system (Ipp) is 52.5 A (17.4 @3), so the nominal PV power of 41.3 kWp. DC/AC ratio of 1.25. PV Potential energy produced from the system simulation using PVsyst software can be seen in Table 7.

The 3D Design of PV Power Plant utilizes part of the building's roof, which has an area of 245 m2. The area of the solar panel is 2.6 m2, assuming that the building's height is 10m; the PV Field parameters are Orientation Portrait (Vertical), Tilt/Azimuth 8 / 346o interrow Spacing 1.5 ft, and setback 1 ft. Then, the number of panels used is 75 units.

The capacity of the solar panel array can also be counted by multiplying the capacity module and quantity module as in equation (2.1).

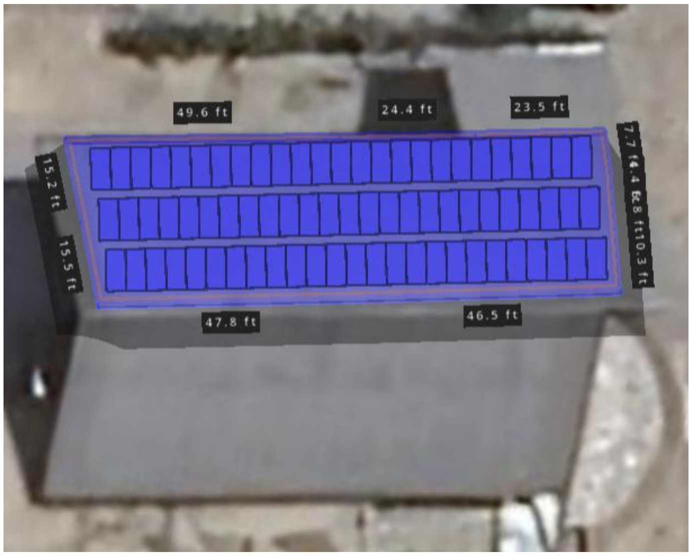

Figure 2: 3D design of PV Power Plant using Helioscope. Design of PV Power Plant with used array area 196 m2.

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Table 6 Solar panel configuration based on equality

Calculation	
Minimum series modules per string	4
Maximum certificate modules per string	34
Maximum parallel modules per string	5
Number of strings	3

Table 6 shows the Solar Panel Configuration based on equations (2.2), (2.3), and (2.4). The solar panel configuration based on the available roof area is obtained by arranging the modules in series of as many as 25 modules and the number of strings as many as 3, obtained from the number of modules divided by the number of series modules per string. So, the configuration used in the system is within safe limits.

Table 7 Energy Potential

E_Array (kWh)	**E_user (kWh)**	**E_Solar (kWh)**	**E_Grd (kWh)**	**EFrGrid (kWh)**	**Total (kWh)**
4.912	32,563	4.167	627	29,915	4,794
4.788	29,827	3.886	790	26,332	4.676
5.406	33,550	4.290	990	30.113	5.280
5.136	32,777	4.012	1.003	27,459	5.015
5.016	34,289	4.078	821	30,306	4.899
4,747	31,464	3,846	790	28,898	4.636
5,048	34,040	4.190	741	29,864	4.931
4.923	34,001	3,939	869	29,929	4.808
4.903	31,400	3.927	860	26,480	4,787
5.394	33,655	4.359	910	29,249	5.269
4,742	32,484	3,791	839	28,005	4,630
4.929	34,807	4.103	708	28,081	4.811
59.94	**394.86**	**48.59**	**9.95**	**344.63**	**58.54**

The simulation output of the PV Power Plant system obtained a total produced energy of 58.54 kWh/ year, Which was obtained from the summation of E_ Solar + E_ Grid. Total Produced Energy can fulfil the EVCS load needs, namely 17,025 kWh/ year. When the energy solar panel output exceeds need energy load, excess production energy will be sent to the Grid as production capital. Used Energy or the amount of

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Energy consumed by the load of 394.86 kWh/Year is a summation from E_Solar + EFrGrid. EFrGrid is energy from the grid when the PV Power Plant cannot supply the burden, like at night or when the weather is overcast, which marks the irradiation sun low, and the energy produced is incapable of fulfilling the burden of need.

Table 8 Output System Based on Calculation

Calculation	
Array Nom Energy (STC_eff)	72,083 kWh
E_Array	59,757 kWh
E_Produced	58,531 kWh

Table 8 shows the output of the PV Power Plant system based on equations (2.5), (2.6) and (2.7).

Feasibility Analysis Economical

The Bill of Quantity for planning the On-Grid PV Power Plant design totals Rp. 471,289,325. This amount includes costs for system components, cables, licensing, shipping of PV Power Plant components, and installation.

According to the system, the Cost of Operations and Maintenance issued during the PV Power Plant system provides Energy to the EVCS, amounting to Rp.4,712,893/year.

Life Cycle Cost encompasses all expenses, including both recurring and non-recurring costs. In the planning system, the total investment cost is Rp. 471,289,325. Additionally, the amount for Mpw is Rp. 103,683,646, and for Rpw, it is Rp. 55,320,692. Therefore, the total

Life Cycle Cost, the sum of these three parameters, amounts to Rp. 630,293,663.

The Levelized Cost of Energy (LCoE) is calculated based on the Total Present Value of the Life Cycle Cost (LCC), Rp 630,293,663. Over the operational period, the total energy production from the solar power system is 1,300,545 kWh. As a result, the LCoE is determined to be Rp 484,638. The LCoE represents the cost of generating Energy over the system's lifespan.

The system's Capital Recovery Factor (CRF) is 9.7%, with the discount rate (i) corresponding to the average Basic Interest Rate for General Bank Credit as of September 2024, precisely 8.44%.

Equations (2.12), (2.13), and (2.14) show the Economic Feasibility Analysis.

The project's Net Present Value (NPV) is Rp.177,073,429, which is positive (NPV > 0). This means the PV Power Plant project is feasible and capable of generating profit. The system's Payback Period (DPP) is 11.57 years, as shown in Figure 3.

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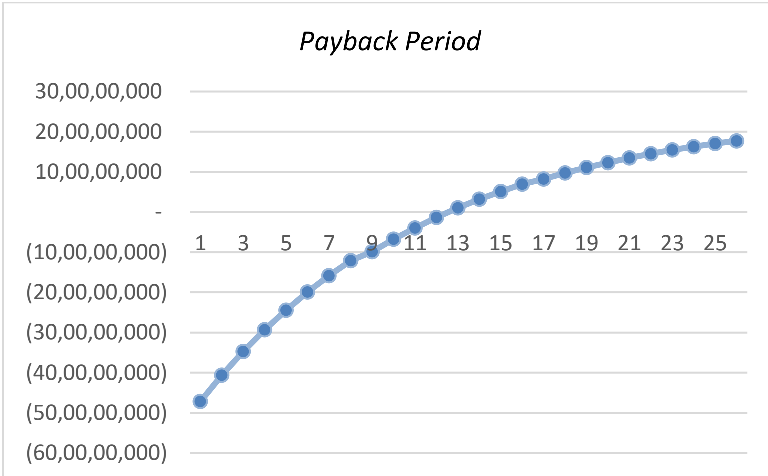

Figure 1: The graph shows that the investment project's payback period is faster than the operational period, indicating that the project is worthwhile.

The Profitability Index (PI) for the system is 1.38, indicating that it is more significant than one (<1). Therefore, the implementation of the On-Grid PV Power Plant investment is feasible. Based on the PI value, the investment project can yield a profit of 38% over the initial investment amount.

Based on the feasibility parameters outlined in Table 10, the economic feasibility metrics—NPV (Net

Present Value), DPP (Discounted Payback Period), and PI (Profitability Index)—indicate that the project is viable based on calculations. Additionally, the On-Grid PV Power Plant project, which partially supplies Energy to EVCS, is considered worthy of execution from an economic standpoint.

Table 9 Summary of Economic Analysis

Parameter	Information
Investment (IA)	Rp. 471,289,325
Age Investment (n)	25 years
Interest Rate (i)	8.44%
Solar Panel Degradation	1% per Year
Electricity Tariff Price	Rp. 1,444.7 / kWh
O&M Cost	Rp. 4,712,893 / year
Cost Substitution Component	Rp. 55,320,692 / 25th
Life Cycle Cost (LCC)	Rp. 630,293,669
LCoE	Rp. 484,638 per kWh
CRF	9.72%

Table 10 Economic Feasibility Analysis

Feasibility Analysis	Mark	Conclusion
Net Present Value (NPV)	Rp. 177,073,429	Worthy
Discounted Payback Period (DPP)	11.57	Worthy
Probability Index (PI)	1.38	Worthy

Emission Analysis

The On-Grid PV Power Plant system produces 62.92 tons of CO2 during its operational period, including emissions from production, use, and maintenance activities related to components such as modules, inverters, and cables. The system's resulting CO2 emissions are significantly lower than the amount of CO2 emissions that were successfully reduced. Detailed information about the emissions the PV Power Plant system produces can be found in Table 11.

Table 11 Emissions produced by the PV system

System Life Cycle Emissions Details (LCE System)			
Item	**LCE**	**Quantity**	**Subtotal (tonsCO2)**
Modules	1713 kgCO2/ kWp	34.7 kWp	59,346
Inverter	485 kgCO2/units	1 unit	0.485
Support	4.90 kgCO2/kg	630 kg	3,084
Total			62.92

Table 12 shows the Potential reduction emission of carbon clean for 25 years of 1,029 tCo2eq obtained from the total reduction emission carbon capable produced by reduced PV Power Plant system with emission from the PV Power Plant lifecycle process.

Table 12 Emission Balance

Save CO2 Emission		
CO2 Emission Balance	196 tCo2/yr 24,967 tCO2/ kWp 0.999 tCO2/ kWp /yr	1,029 tons of CO2
LCE system		
Total		62.92 tCO2

Replaced Emissions	
Total	1,092.28 tCO2
Production System	58.6 MWh/yr
LCE Grid	840 gCO2/kWh
Source	IEA List
Country	Indonesia
Lifetime	25 years
Annual degradation	1%

Total Potential PV Power Plant energy of 58.6 MWh/year with a lifetime project for 25 years and degradation annually by 1% and factor emission electricity of 0.84 tonsCO2/MWh, then the total baseline emissions per Year and during the project can known using equations (2.15) and (2.16). Total baseline emissions for 1 year of 49.2 tonsCO2/MWh/ year with total baseline emissions in the 25th Year of 1,092.28 tCo2eq which is the amount of emissions that will happen If overall burden supplied by Network or No existence On-Grid PV Power Plant project as planned. With the existence of the On-Grid PV Power Plant project as a supply, EVCS energy successfully reduced 1,092.28 tCO2eq during the operating period of the PV Power Plant and system contribution to Indonesia in reaching Net Zero Emissions.

CONCLUSION

The on-grid photovoltaic (PV) system has been installed with 75 solar modules, resulting in a power output of 41.3 kW and a potential energy generation of 58.54 MWh per Year. This system can meet the electricity needs of electric car charging stations (EVCS), which require approximately 17 MWh per Year. This research indicates that the project is financially viable, as evidenced by a positive Net Present Value (NPV) and a payback period of 11.57 years. The Profitability The index is greater than 1, precisely 1.38, suggesting that the project could yield a profit of 38%. This system reduces carbon emissions by approximately 1,029 tons of CO2 equivalent, supporting the transition toward net zero emissions.

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