Techno-Economic of Rooftop Solar Power Plants for Residential Customer in Indonesia

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Abstract— This study evaluates the financial viability of grid-connected rooftop photovoltaic (PV) systems across seven Indonesian residential types (2.75-19.8 kWp) under current market conditions. Using a discounted cash flow model with 8% discount rate and a 20-year project lifetime, key metrics including Net Present Value (NPV), Levelized Cost of Electricity (LCOE), and payback period have been analysed. Results demonstrate that system economics improve significantly with scale: while small systems (2.75 kWp) yield negative NPV (-Rp 9.71 million) and 12.4-year payback, larger installations (>7.7 kWp) achieve positive NPV (up to Rp 89.95 million for 19.8 kWp systems) and sub-10-year payback periods. The LCOE ranges from Rp 1,082-1,205/kWh, representing 11-36% cost savings compared to PLN's tiered tariffs (Rp 1,352-1,699.53/kWh). Monthly savings scale proportionally with system size, from Rp 323,378 (2.75 kWp) to Rp 2.84 million (19.8 kWp). A critical 7.7 kWp capacity threshold emerges for self-sustaining viability without subsidies, with 3500+ VA customers benefiting most due to higher avoided tariffs. These findings provide policymakers with evidence to design tiered incentive programs targeting underperforming market segments (<6 kWp systems), while confirming the commercial readiness of larger residential-commercial hybrid systems in Indonesia's solar transition.

Keywords— ***Rooftop Photovoltaic; Solar power Plant; Techno-Economic.***

I. INTRODUCTION

Indonesia, a country with a rapidly growing population and economy, faces the challenge of meeting its increasing energy demands while transitioning to a more sustainable energy future. One of the main pillars in this transition is the expansion of new renewable energy sources, particularly vertical build-up of household's rooftop solar power system (PLTS). The index of energy consumption in Indonesia grew about 65% between the years 2000 to 2014 and is expected to grow by 80 percent by the year 2030. This increasing energy demand is associated with robust economic growth, rapid urban expansion, and steady population increase [1]. In this regard, Indonesian government has put forth targets that are ambitious on the renewable energy source to boost the proportion of that energy source [2]. Accordingly, rooftop solar power systems seem to be a viable solution to the problem. There is metered potential for new and renewable energy in Indonesia, especially solar energy from rooftops [3]. One of the key strategies is expanding rooftop solar photovoltaic (PV) systems for households [4]. Indonesia has a solar potential of over 200 GW, yet the installed capacity remains underutilized. Rooftop PV offers a decentralized solution, particularly beneficial in remote areas lacking stable grid infrastructure, where it can reduce reliance on costly and polluting diesel generators [5].

Increasing the utilisation of available renewable energy resources in Indonesia will future avert the country from being a net importer of fossil fuels. One such model that offers opportunities for renewable energy integration in Indonesia is energy trading with particular focus on decentralized peer to peer (P2P) markets. This would allow individual prosumers, such as households with rooftop solar systems, to negotiate energy trading parameters without a central authority's control. These kinds of energy trading platforms that enable decentralization may foster the deployment of renewable energy such as rooftop solar systems which will increase the portion of renewables in the national energy mix [6]. In addition, the deployment of rooftop solar energy systems can also be a cheaper option for strengthening the electricity supply of more remote regions in Indonesia. Several regions in Indonesia have not been able to meet their electricity requirements owing to lack of fossil fuel resources as well as unfavourable geography for the deployment of electrical grids. Renewable energy sources, especially solar power, could be utilized relating to these problems and cut down the reliance on expensive and polluting diesel generators [7]. The opportunities of using rooftop solar systems are ample for Indonesia, however, still certain barriers exist for its larger deployment. Weaning Indonesia's energy sector to self-govern sustainable goals will take an all-inclusive effort, in developmental policies, infrastructural investments, and participation of both public and

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private enterprises. The fast expansion of the solar energy industry in Indonesia has created the need for a complete set of regulations for the installation and utilization of rooftop solar units. Indonesia has come a long way in formulating policies and structures which facilitate the use of rooftop solar energy systems [3][8]. The Indonesian government has acknowledged that it is possible to utilize rooftop solar to help meet the energy demand of the country and additionally meet renewable energy targets [3]. Steps have been taken to introduce incentives such as feed-in tariffs, net metering, and others to persuade individual residents and corporate landlords to have rooftop photovoltaic systems installed. Nonetheless, there are barriers to the execution of these policies such as the domination of the coal sector and political elites [8]. There is also ambiguity regarding the policy outlook of Indonesia's renewable energy which can deter investors [2]. Several techno-economic studies indicate that residential rooftop PV systems in Indonesia are financially viable under recent policy frameworks, such as MEMR Regulation No. 26/2021, showing positive Net Present Value (NPV) and Internal Rate of Return (IRR) exceeding 21% in some regions [4][9]. These findings support further integration of rooftop solar to diversify the energy mix and empower local energy resilience.

The adoption of rooftop photovoltaic (PV) systems in Indonesia faces several economic and technical barriers, particularly in the residential sector. Existing studies have primarily focused on general feasibility analyses of rooftop PV systems in urban areas such as Jakarta and Denpasar [10], often without distinguishing the impact of variations in residential building types, rooftop areas, and household electricity consumption patterns. Recent works have identified that the levelized cost of energy (LCOE) for residential rooftop PV systems typically remains higher than prevailing electricity tariffs, which discourages adoption despite increasing energy awareness [10]. Furthermore, the payback periods for small-scale systems (e.g., 2-kWp) are considered unattractive, ranging between 10.3 to 12.5 years [11]. Additional studies have noted that integrating battery storage may enhance self-consumption and reduce payback periods [12]. However, none of these studies have specifically analysed the techno-economic performance of rooftop PV systems based on detailed classifications of residential house types and rooftop capacities, which is critical for providing practical and targeted guidance to homeowners and policymakers.

This gap creates uncertainty among potential users regarding system sizing, investment feasibility, and expected financial benefits tailored to their specific home conditions. Therefore, the main objective of this study is to evaluate and compare the techno-economic performance of rooftop PV systems across various types of residential houses in Indonesia by considering key parameters such as installed PV capacity, rooftop area, household electricity demand (based on installed VA limits), and electricity tariffs. Metrics such as Levelized Cost of Energy (LCOE), Payback Period, Net Present Value (NPV), and potential monthly savings are employed to quantify feasibility. This study aims to offer practical insights that can assist households in making informed investment decisions and contribute to accelerating rooftop PV adoption by aligning system recommendations with typical residential characteristics in Indonesia.

II. Method

As Indonesia is a tropical country, there is a high opportunity to harness solar energy through the utilization of PLTS. The availability of sunshine all year long in this country makes this a good location for tapping this alternative source of energy. When combined with the desire to lower the demand of fossil fuels and seek alternatives that are less harmful to the environment, the increasing electricity demand within the residential sector has become a great influence towards investigating solar PV alternatives for residential clients [13]. The purpose of this is to determine the case and the possible use of solar PV systems by residential customers for rooftops located in Indonesian households. As the study intends to do, it should present technical and economic analyses aimed at generating knowledge for energy planners, developers and policymakers in support of solar PV sustainable development in the country [14].

The study will begin by reviewing the practices on solar PV currently in use in the residential sector in Indonesia, as well as the existing conditions. It will further assess the possibility of rooftop solar PV systems being a solution to the continually increasing demand for electricity in the residential sector and will look into solar irradiation, roof area available and economic viability [13]. In conclusion, the study addresses a number of significant elements, and its objectives are focused on demonstrating the potential, practicality and application of rooftop photovoltaic systems in the Indonesian residential sector and assisting the country's efforts to enhance the renewable energy share and move towards sustainable development. To strengthen the methodological framework of this techno-economic analysis of rooftop photovoltaic systems in Indonesian residential areas, several recent studies have been considered. [15] applied a GIS-based multi-criteria approach to evaluate rooftop PV potential in Bandung, incorporating solar irradiation, rooftop availability, and socio-economic indicators. [16] conducted a year-long performance evaluation of a 5 kWp rooftop PV system with multi-directional orientation in Jakarta, assessing key parameters such as performance ratio (PR), capacity factor (CF), and CO_2 emission reductions. Furthermore, [10] employed the System Advisor Model (SAM) to conduct a techno-economic feasibility study of 2 kWp systems in Jakarta, Denpasar, and Kupang, demonstrating the impact of net-metering policies and installation incentives on profitability. [17] analysed the technical and economic performance of a 112.5 kWp rooftop PV system on a government building in Denpasar, showing a 72.12% reduction in grid electricity consumption and a favourable payback period of 3.4 years. Additionally, [18] used the Theory of Planned Behaviour (TPB) to model public and utility employee acceptance of rooftop PV adoption, revealing that attitudes, subjective norms, and economic incentives significantly influence adoption intentions.

This study employs an area-based approach to estimate the potential capacity of rooftop photovoltaic (PV) systems in residential buildings by using house type classifications (e.g., type-36, type-45, type-120) as proxies for rooftop area instead of household electrical load. This method allows for the calculation of the maximum number of PV modules that can be installed based on available roof surface, making it especially useful in early-stage planning, policy development, or in cases where detailed load data are unavailable. While actual energy consumption may vary due to occupant behaviour and appliance usage, the focus of this approach is to assess the technical potential of PV installations constrained by physical space. Similar assessments have been applied in prior studies to evaluate rooftop PV feasibility in urban contexts. The simulation for this study was conducted using HelioScope, a widely adopted web-based tool for solar PV system design and performance modeling. The analysis was carried out for a specific location in Jakarta, Indonesia (latitude -6.1657, longitude 106.7952), using location-specific Typical Meteorological Year (TMY) data automatically retrieved from the HelioScope database, which integrates reliable global meteorological sources. This ensures that the estimated energy yield reflects Jakarta's actual climatic conditions, providing a realistic assessment of the system's technical performance.

A. Rooftop Solar Power Systems in Indonesia

In Indonesia, the production of rooftop solar power systems is directly affected by a range of policies developed to enhance the usage of renewable energy sources. There are also Presidential Regulation No. 22 2007 and Minister of Energy and Mineral Resources Regulation No. 13 2019, which compel the installation of rooftop solar power systems in government programs and housing domestic niches areas [19][20][21]. These regulations are taken to support a renewable energy target achievement of 23% by 2025 by reducing reliance on fossil-based energy sources such as coal and gas because they escalate energy costs and increase carbon emissions. As for residential and commercial consumers, economic studies have revealed that rooftop solar power systems could be cost effective, even yielding returns on investments. In addition, the government also offers measures such as the advertisement of 65% incentives on ministry of energy and mineral resources policy 49 of 2018 to induce more uptake of rooftop solar systems. However, regulations continue to evolve in efforts to enhance the use of solar power while also addressing the impacts or issues occurring in the field. This includes the Minister of Energy and Mineral Resources Regulation No. 26 of 2021, which regulates the Use of Electricity by Medium and Large Consumers, reinforcing government support for renewable energy by providing additional incentives for rooftop solar users. These regulations offer incentives for residential and commercial consumers to invest in solar power, which can reduce long-term electricity costs and support Indonesia's commitment to the Paris Agreement to lower greenhouse gas emissions. Nevertheless, challenges such as complex bureaucracy, lack of public awareness, and the strong influence of the coal industry remain obstacles to broader implementation. In 2024, the Minister of Energy and Mineral Resources Regulation No. 2 of 2024 was issued, stating that there would be no further incentives for excess energy produced by solar power systems entering the PLN grid. Although incentives for rooftop solar power users have been eliminated, investment in rooftop solar system installations is declining, especially for on-grid systems where battery components are not required. As a result, the number of rooftop solar power users is expected to continue to increase [22] [23]. Therefore, cooperation between the government, the private sector, and the community is essential to achieving renewable energy targets and addressing existing challenges, thus realizing a more sustainable energy future in Indonesia. As of January 2024, there are 8,574 rooftop solar power customers with a total installed capacity of 149.2 MWp, predominantly in the industrial sector at 82.72%, followed by the business sector at 21.78%, residential sector at 20.81%, social sector at 13.5%, government sector at 10.16%, and special services sector at 0.22%. The region with the highest number of customers is Banten, with 2,997 customers and a total installed capacity of 12.4 MWp. Although still far from the rooftop solar power implementation target, its growth shows a significant increase from just 609 customers in 2018 to 8,574 customers in January 2024. Table I illustrates important changes in the ESDM regulations for residential rooftop solar power.

TABLE I. IMPORTANT CHANGES IN ESDM REGULATIONS FOR RESIDENTIAL ROOFTOP SOLAR POWER SYSTEM

Year	Regulation	Maximum Capacity	Incentive
2018	Regulation of the Ministry of Energy and Mineral Resources No. 49	100% from Installed Capacity	65% from Utility Selling Price
2021	Regulation of the Ministry of Energy and Mineral Resources No. 26	100% from Installed Capacity	100% from Utility Selling Price
2024	Regulation of the Ministry of Energy and Mineral Resources No. 2	No Maximum Capacity	N/A

B. Types of Housing in Indonesia

This study conducts a technical and economic analysis of rooftop solar power systems (PLTS) in residential areas of Indonesia. One important aspect discussed is the type of house and the estimated roof area, which play a significant role in determining the optimal capacity of solar panels that can be installed. Table II provides an overview of various types of houses commonly found in Indonesia, along with estimates of the available roof area.

This information is used to calculate the potential installation capacity of PLTS for each type of house, as well as to estimate potential energy production and electricity cost savings. This data is crucial for understanding the scale of rooftop solar power implementation across different types of housing, from simple homes to those with larger roofs. In this study, the types of housing are limited to seven types: Type 21, Type 36, Type 45, Type 54, Type 60, Type 70, and Type 120.

TABLE II. TYPES OF HOUSES AND ESTIMATED ROOF AREA AND ELECTRICITY GRID CONNECTION

Housing Type	Land Area	House Area	Roof Area
Tipe 21	3x7 m^2, 5,25x4 m^2, 6x3,5m^2	21 m^2	21 m^2
Tipe 36	6x6 m^2, 9x4 m^2	60-72 m^2	36 m^2
Tipe 45	6x7,5 m^2	72-96 m^2	45 m^2
Tipe 54	9x6 m^2, 13,5x4 m^2, 6x12m^2	90-120 m^2	54 m^2
Tipe 60	6x10m^2	72-120 m^2	60 m^2
Tipe 70	7x10 m^2, 5x14 m^2, 6x12m^2	120-150 m^2	70 m^2
Tipe 120 >120	10x12 m^2, 8x15 m^2 >200m^2	>150 m^2 >200m^2	120 m^2 >200m^2

C. Design of Rooftop Solar Power Systems (PLTS)

To design a rooftop solar power system (PLTS), several factors must be considered. First, the available solar radiation and roof installation potential must be assessed [24][13]. Next, the type of solar panels and the capacity of the panels to be installed must be determined. The sizing of the photovoltaic (PV) system can be done through two methods: Load-Based Sizing and Area-Based Sizing.

1. **Load-Based Sizing**: This method calculates the size of the PV system based on energy needs and peak load. It involves analysing electricity consumption, considering energy efficiency, and accounting for solar radiation levels and system efficiency. The PV system size is determined by matching energy requirements with the available PV panel capacity.
2. **Area-Based Sizing**: This method determines the PV system size based on the available installation area, calculating the number of panels that can be installed in that space. Factors such as panel efficiency, orientation, and shading are also considered. Software such as HelioScope is often used for accurate simulations of panel layout and performance.

For rooftop PLTS systems in urban residential areas, the classification can be divided into four categories:

1. **100% On-Grid**: Where the electricity needs are fully supplied by PLN (the national electricity provider).
2. **On-Grid without Battery**: Where electricity consumption is met from both the PLTS system and PLN.
3. **On-Grid with Battery**: Where electricity can be supplied from the PLTS system, PLN, or battery storage.
4. **Off-Grid**: Where the system is not connected to PLN; however, the use of this system in urban areas is still relatively expensive and less efficient due to the intermittent and unstable nature of solar energy.

In the technical and economic analysis of rooftop PLTS systems, one of the key factors affecting the calculation of energy cost savings is the electricity tariff applied to household customers. Electricity tariffs in Indonesia vary depending on the type of customer and the power usage level. To understand the impact of installing rooftop PLTS on electricity cost savings, it is important to review the electricity tariff structure applied by PLN to households. Table 2 provides information regarding customer categories, installed power, and electricity tariffs per kWh. This data will serve as the basis for calculating energy savings and estimating the return on investment from installing rooftop PLTS in residential areas. This analysis is expected to provide a clear picture of the potential economic benefits for household customers switching to renewable energy through solar panel installation.

Electricity customers in Indonesia pay a component of Value Added Tax (VAT) and a public lighting tax (PPJ) as part of their electricity bill. For small/low voltage residential customers (R- 1/TR) with installed capacity up to 450 VA, the fixed charge is IDR 11,000. However, for customers from 900VA to more than 6600 VA, the load cost applies under RM1. Additionally, there are several important parameters used to assess whether the installed system is economical or not, as outlined below [25][26][27].

D. Economic Analysis

Three primary financial indicators are used in the analysis: Net Present Value (NPV), Payback Period (PP), and Levelized Cost of Energy (LCOE). The NPV is calculated to assess the profitability of the investment by discounting future cash flows to present value. The formula is expressed as:

TABLE III. HOUSEHOLD CUSTOMER TARIFFS IN INDONESIA

Tariff Code	Installed Capacity	Reguler		Prepaid
		Load Cost (IDR/kVA/ Bulan)	Usage Cost (IDR/kWh)	(IDR/kWh)
R-1/TR	s.d 450 VA	11000	169-495	415
R-1/TR	900 VA	RM1	275-495	1352
R-1/TR	1300 VA	RM1	1444,70	1444,70
R-1/TR	2200 VA	RM1	1444,70	1444,70
R-2/TR	3500VA-5500kVA	RM1	1699,53	1699,53
R-3/TR	6600 keatas	RM1	1699,53	1699,53

RM1= 40 (Operating hours) x Installed Capacity (kVA) x Usage Cost

$$\text{NPV} = \sum_{t=1}^{n} \frac{C_t - O_t}{(1+r)^t} - C_0 \quad (1)$$

where C_t is electricity cost saving in year t, O_t is the annual operation and maintenance cost, r is the discount rate, n is the project lifetime, and C_0 is the initial investment cost.

The Payback Period indicates the time required to recover the initial investment through electricity bill savings. It is calculated as:

$$\text{PP} = \frac{C_0}{Annual\ net\ savings} \quad (2)$$

LCOE measures the average cost per kilowatt-hour (kWh) of electricity generated over the system's lifetime. The formula is:

$$\text{LCOE} = \frac{\sum_{t=1}^{n} \frac{C_0 + O_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \quad (3)$$

where E_t is the electricity produced in year t.

The potential monthly savings can be estimated by calculating the difference between the household's monthly electricity consumption and the energy generated by the solar PV system, both measured in kilowatt-hours (kWh), and then multiplying this difference by the prevailing electricity rate (IDR/kWh). This approach offers a simplified method to assess the financial gains from implementing rooftop solar technology.

III. RESULTS AND DISCUSSION

In this study, several common types of houses in Indonesia are considered, namely types 21, 36, 45, 54, 60, 70, and 120. The simulation considers factors such as available roof area, tilt angle, daily solar irradiance, and system performance ratio. Parameters used in the simulation include an average solar irradiance of 4.8 kWh/m²/day, a system efficiency of 85%, a degradation rate of 0.5% per year, and a fixed tilt angle based on the location's optimal inclination. The analysis was carried out using HelioScope, a widely used web-based PV design and simulation software, which incorporates location-specific meteorological data (TMY) such as solar radiation, ambient temperature, and system losses. The simulation was performed for a representative location in Jakarta, Indonesia, with geographic coordinates of latitude -6.1657 and longitude 106.7952.

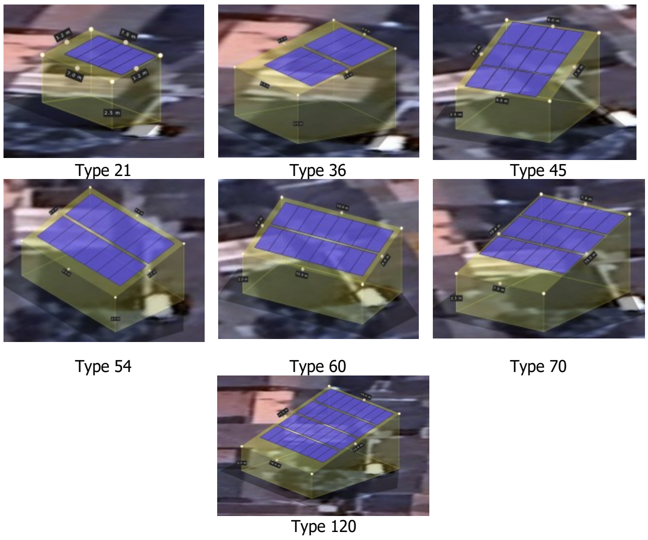

Figure 1. Results of Solar Panel Placement Simulation

This approach ensures that the estimated energy production for each house type reflects realistic environmental and technical conditions, tailored to the Indonesian context. Figure 1 presents the results of the solar panel placement simulation conducted for various types of residential rooftops in Indonesia. This simulation was performed to identify the optimal number and arrangement of photovoltaic (PV) panels on each house type, considering the available roof area and orientation. The placement results serve as the foundation for determining the total installed capacity (kWp) and estimating the potential monthly energy generation (kWh) for each residential category analysed in this study. This step is crucial to ensure that the proposed PV systems are technically feasible and aligned with the physical characteristics of typical Indonesian housing model.

For the simulation it is assumed to used JINKO - JKM M-60 solar panels with a capacity of 550Wp.The simulation results presented in Table IV highlight the technical performance and expected outcomes of rooftop solar power systems (PLTS) across various types of residential buildings. The number of solar panels that can be installed depends on the available roof area for each house type. For example, a type 21 house can accommodate 5 panels with a total installed capacity of 2.75 kWp, while a type 120 house can support up to 36 panels with a capacity of 19.8 kWp. As the installed capacity increases, the amount of electricity generated also rises from 261.3 kWh per month for type 21 to 1,671.6 kWh for type 120. The table clearly illustrates a direct relationship between house size and the performance of rooftop PV systems: larger homes offer more roof space, allowing for more panels, higher energy output, and improved potential to meet household energy needs.

TABLE IV. TECHNICAL RESULTS OF SIMULATION AND CALCULATION OF ROOFTOP SOLAR POWER SYSTEMS (PLTS) FOR RESIDENTIAL HOUSING.

Housing Type	Total PV (Psc)	Installed Capacity (kW)	Total Power Output/month (kWh)
Type 21	5	2.75	261.3
Type 36	8	4.4	417.9
Type 45	12	6.6	626.7
Type 54	14	7.7	731.7
Type 60	16	8.8	835.8
Type 70	18	9.9	940.2
Type 120	36	19.8	1671.6

This demonstrates the scalability of rooftop solar systems in residential applications, with greater benefits achieved in homes with larger rooftop areas.

Table V presents the economic analysis of rooftop PV systems for various types of residential houses in Indonesia. The initial investment cost was calculated based on an assumed investment of IDR 17,000,000 per kWp, while the discount rate was set at 8% and the project lifetime at 20 years, which align with commonly adopted values in Indonesia for rooftop PV project evaluations. Each housing type is represented by a different installed system capacity, ranging from 2.75 kWp for Type 21 houses to 19.80 kWp for Type 120 houses. The table provides detailed data, including installed capacity (kWp), initial investment cost (in IDR), estimated annual electricity production (kWh), Levelized Cost of Electricity (LCOE) in IDR/kWh, Net Present Value (NPV) in IDR, and estimated payback period in years. From the table, it can be observed that larger housing types tend to have higher PV system capacities, which are associated with increased investment costs and higher annual energy production. The LCOE shows a decreasing trend as the system capacity increases, indicating the benefit of economies of scale for larger rooftop PV systems. For instance, the LCOE for Type 21 is IDR 1,205/kWh, while it decreases to IDR 1,082/kWh for Type 120. The NPV analysis reveals that smaller capacity systems (Type 21, 36, and 45) are not yet financially feasible, as they result in negative NPV values. In contrast, larger systems begin to demonstrate positive financial returns. NPV of IDR 89,945,000. In terms of the payback period, a decreasing trend is observed as system capacity increases. Type 54 shows a modest positive NPV of IDR 1,245,000, while Type 120 yields the highest financial benefit with an Type 21 requires a payback period of 12.4 years, whereas Type 120 achieves a shorter payback period of only 7.8 years. This indicates that rooftop PV investments become more economically attractive for larger households with higher energy consumption. In summary, Table 4 provides a comprehensive overview of the relationship between housing types, rooftop PV capacity, energy performance, electricity generation cost, financial feasibility, and investment payback period for the residential sector in Indonesia. The results of this study demonstrate a significant improvement in the economic performance of residential rooftop PV systems compared to recent findings in Indonesia. Previous research by [10] indicated that the LCOE for rooftop PV systems in urban areas like Jakarta and Denpasar remains higher than the prevailing electricity tariffs, limiting attractiveness to homeowners. Their findings reported LCOE values exceeding IDR 1,300/kWh with payback periods for 2-kWp systems ranging from 10.3 to 12.5 years [10][11].

TABLE V. ECONOMICAL RESULTS OF SIMULATION AND CALCULATION OF ROOFTOP SOLAR POWER SYSTEMS (PLTS) FOR RESIDENTIAL HOUSING.

Housing Type	CAPEX (IDR million)	NPV (IDR million)	LCOE (IDR /kWh)	Payback Period (Years)	Monthly Saving (IDR)
Type 21	46.75	-9.71	1,205	12.4	323,378
Type 36	74.8	-11.014	1,205	11.5	603,692
Type 45	112.2	-3.892	1,142	10.8	905,538
Type 54	130.9	1.245	1,132	10.5	1,057,358
Type 60	149.6	12.876	1,115	9.7	1,420,000
Type 70	168.3	19.432	1,108	9.4	1,597,500
Type 120	336.6	89.945	1,082	7.8	2,840,000

In contrast, this study achieves a lower LCOE between IDR 1,082 and 1,205/kWh across different residential types, particularly demonstrating better economic viability for larger systems (Type 60 and above). Moreover, the payback periods in this study range from 7.8 to 12.4 years, which is either comparable to or shorter than those reported in prior works, especially for larger systems (Type 70 and 120), which achieve significantly faster returns on investment. Additionally, while [10] suggest that a 40% increase in net-metering compensation is necessary to achieve acceptable feasibility, this study shows that positive NPV outcomes can already be achieved under existing tariff schemes starting from Type 54, with the highest NPV reaching IDR 89.945 million for Type 120. These results suggest that the system configurations proposed in this study present a more economically viable alternative, especially for larger-scale residential installations, even without changes to current regulations. Furthermore, the superior monthly savings (up to IDR 2.84 million) highlight the financial attractiveness of rooftop PV adoption in larger homes compared to smaller 2-kWp systems referenced in earlier studies [12]. Therefore, this research contributes to the current body of knowledge by offering evidence that larger residential rooftop PV systems in Indonesia can already achieve better financial performance than previously reported under the current regulatory framework, without requiring additional policy incentives.

IV. Conclusion

This study comprehensively analysed the techno-economic performance of residential rooftop photovoltaic (PV) systems across various house types in Indonesia, using metrics such as Levelized Cost of Energy (LCOE), Net Present Value (NPV), and Payback Period (PBP). The findings indicate that the economic feasibility of rooftop PV systems improves significantly with the increase in installed capacity and household electricity consumption. Smaller residential types (Type 21 and Type 36) exhibited negative NPV values (-9.71 to -11.014 million IDR) and relatively high LCOE (1,205 IDR/kWh), with payback periods exceeding 11 years. These results suggest that small-scale rooftop PV installations remain economically unattractive under current electricity tariffs and incentive structures. Conversely, larger house types (Type 54 and above) showed markedly better performance. Notably, Type 120 with 19.8 kWp installed capacity achieved the lowest LCOE of 1,082 IDR/kWh, a positive NPV of 89.945 million IDR, and the shortest payback period of 7.8 years. These results align with previous studies highlighting that rooftop PV systems become increasingly feasible as scale and self-consumption levels rise. Additionally, the monthly savings for larger houses reach up to 2.84 million IDR, further strengthening the investment rationale for higher-capacity installations. In summary, the techno-economic analysis demonstrates that rooftop PV adoption in Indonesia is more economically viable for medium to large-scale residential buildings, whereas small-scale systems face significant economic challenges under the current regulatory framework.

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