Journal of Electrical Engineering and Computers (JEECOM)
Vol. 8, No. 2 (2026), DOI: 10.33650/jeecom.v8i2.17293
p-ISSN: 2715-0410; e-ISSN: 2715-6427

Technical and Economic Feasibility of a Rooftop Solar Photovoltaic System at Bank Nagari Lubuk Gadang Branch

Sepannur Bandri[1]*, Zuriman Anthony[1], Fauzan Ismail[1], Yusreni Warmi[1], Arfita Yuana Dewi[1], Andi Muhammad Nur Putra[1], Liliana[2]

[1]Department of Electrical Engineering, Faculty of Engineering, Institut Teknologi Padang, Padang, Indonesia.
[2]Department of Electrical Engineering, Faculty of Engineering, UIN SUSKA Riau, Riau, Indonesia.

Article Info

Article history:

Received September 13, 2026
Revised September 14, 2026
Accepted October 5, 2026

Keywords:

Photovoltaic
HOMER
Net Present Value
Payback Period
Off-Grid System

ABSTRACT

The increasing demand for electrical energy and operational costs encourage the use of renewable energy sources in commercial buildings. This study aims to analyze the technical and economic feasibility of implementing a photovoltaic system at PT Bank Nagari, Lubuk Gadang Branch, South Solok Regency. The study uses a quantitative approach with a technical-economic feasibility study design through an electrical load survey, analysis of installation area conditions, component design, simulation using HOMER, and investment evaluation with Net Present Value, Internal Rate of Return, and Payback Period. The results show energy consumption of 251,514 kWh per day on weekdays and 75,157 kWh per day on holidays, with a monthly consumption of 6,386,078 kWh. Based on these needs, a system with a capacity of 84 kWp is designed consisting of 210 modules with a power of 400 Wp, a battery bank with a capacity of 840 kWh, a 66 kW inverter, and 30 units of SCC MPPT. The HOMER simulation produced 105,442 kWh of electricity per year with excess electricity of 41,453 kWh per year or 39.3 percent. From the financial aspect, a positive NPV of Rp381,776,996, an IRR of 11.82 percent, and a payback period of 10.64 years were obtained. The results showed that the designed system has positive technical and economic prospects, but investment decisions still need to consider the company's MARR value, battery replacement costs, and the consistency of actual load data with simulation parameters. These findings indicate that the use of solar energy has the potential to support the reduction of electricity purchases from the grid, increase operational cost efficiency, and strengthen sustainable energy management strategies in commercial banking buildings effectively.

Corresponding Author:
Sepannur Bandri,
Department of Electrical Engineering, Faculty of Engineering, Institut Teknologi Padang, Indonesia.
E-mail: sepannur@itp.ac.id; Orcid ID : https://orcid.org/0000-0002-1432-8184

1. INTRODUCTION

The transition toward low-carbon electricity systems has increased the relevance of solar photovoltaic (PV) technology because it offers modular generation, low operational emissions, and increasingly competitive costs [1], [2], [3]. Indonesia has substantial solar-energy potential due to its tropical location and year-round irradiation [10], [11]. Expanding rooftop PV in buildings is also consistent with the Sustainable Development Goals (SDGs), particularly SDG 7 - Affordable and Clean Energy, and supports Indonesia's efforts to increase the use of renewable energy. However, resource potential alone does not ensure project feasibility because PV output is influenced by irradiation, temperature, shading, dust, orientation, installation characteristics, and long-term module degradation [5], [6], [13].

Commercial and office buildings are promising locations for rooftop PV because their highest electricity demand generally occurs during daytime hours, when solar generation is also available [17]-[19]. This characteristic is especially relevant to banking facilities, where air-conditioning systems, computers, networks, transaction equipment, lighting, security devices, and other support loads operate intensively during business hours. Nevertheless, the capacity of a rooftop PV system must be determined from the actual load profile, usable roof area, solar resources, conversion losses, inverter requirements, and energy-storage strategy rather than from installed power or roof area alone [18], [24], [26].

A technically adequate PV configuration is not automatically economically attractive. Investment feasibility depends on initial capital cost, operation and maintenance, component replacement, electricity tariffs, energy utilization, project life, and the selected financial benchmark [7]-[9]. Previous studies report widely varying payback periods: approximately 8.6 years for a household-scale configuration [21], nearly 17 years for a 32 kWp office system [19], and 4.22 years for a commercial-building system under different tariff and resource conditions [22]. These differences demonstrate that NPV, IRR, BCR, and Payback Period must be evaluated using site-specific technical and financial assumptions rather than transferred directly from other projects [20], [21].

Despite the growing number of PV feasibility studies in Indonesia, a specific research gap remains for banking buildings that combines validated office load data, an off-grid rooftop PV-battery configuration, HOMER-based energy simulation, and long-term investment analysis under local conditions. Existing studies have focused on households, mosques, government offices, and other commercial buildings [11], [16], [18], [19], [23]-[25], while evidence for branch-banking facilities remains limited. At Bank Nagari Lubuk Gadang Branch, this issue is relevant because electricity is a recurring operating cost and the branch's internal financial report shows that net profit decreased from IDR 19,205,258,011.00 in 2022 to IDR 13,824,496,408.00 in 2023, strengthening the need to assess energy-efficiency investments using actual operating conditions.

Accordingly, this study aims to assess the technical and economic feasibility of a rooftop solar photovoltaic system at Bank Nagari Lubuk Gadang Branch by: (1) validating the building's electricity-consumption profile against PLN billing data; (2) determining the required PV, battery, inverter, and MPPT/SCC capacities; (3) evaluating annual energy production, load supply, and excess electricity using HOMER; and (4) assessing investment feasibility using NPV, IRR, BCR, and Payback Period. The study is intended to provide a site-specific basis for deciding whether rooftop PV can reduce grid dependence and operating electricity costs while supporting the clean-energy objectives associated with SDG 7.

2. METHOD

2.1. Research Design and Location

This study uses a quantitative approach with a technical-economic feasibility study design to assess the use of a Solar Power Plant (PLTS) at PT Bank Nagari Lubuk Gadang Branch, Padang Aro, Nagari Lubuk Gadang, Sangir District, South Solok Regency. The analysis was conducted by integrating the characteristics of the building's electrical energy consumption, the physical condition of the installation area, the design of PLTS components, system simulation results, and investment feasibility. The research objects include office electrical loads, photovoltaic modules, batteries, inverters, solar charge controllers/MPPT, and investment and system operational costs.

2.2. Types, Sources and Techniques of Data Collection

The research data consists of primary and secondary data. Primary data was obtained through a direct survey of electrical equipment, number of units, installed power, duration of use, operating time patterns, and the condition and effective area of roofs that have the potential to be used for solar module installation. Secondary data includes PLN electricity bills, electricity tariffs, technical specifications of PV system components, solar radiation data used in the simulation device, procurement and installation costs, maintenance and component replacement costs, inflation rates or discount rates, and the economic life of the system. The load data from the survey was compared with the consumption on the PLN bill as a verification step so that the load profile used in the design is close to actual conditions.

2.3. Energy Needs Analysis and Solar Power Plant Design

Energy requirements are calculated from the accumulated consumption of each piece of equipment based on its power and usage duration. Load profiles are differentiated between weekdays and holidays due to different building operating patterns. Daily energy is calculated by summing the results of equipment power, number of units, and operating duration. Next, corrections are made for system losses, conversion efficiency, and demand factors before determining generating capacity. Generally, electrical energy requirements are expressed as:

$$E\_daily = \Sigma (P\_i \times n\_i \times t\_i) \quad (1)$$

Where E_daily is the daily energy (Wh/day), P_i is the equipment power (W), n_i is the number of units, and t_i is the usage time (hours/day). The PV module capacity is determined based on the corrected energy requirement and the effective irradiation time or peak sun hour. The number of modules is obtained by dividing the required array capacity by the nominal module power. The battery capacity is determined from the energy requirement to be stored, system voltage, autonomy period, battery efficiency, and Depth of Discharge (DOD) limit. The inverter is selected with a capacity that is at least capable of serving the peak load and considering the safety margin, while the MPPT/SCC capacity is determined from the total power and the planned module string configuration.

2.4. System Performance Simulation

The technical design of the solar power plant was then simulated using HOMER software to evaluate the energy balance between solar power plant production and load demand. Input parameters included load profiles, component capacities and specifications, solar resources, project lifespan, and economic parameters. The simulation results were used to estimate annual electricity production, usable energy to serve the load, excess energy, and system adequacy. The simulation results were also used as a comparison against manual calculations to determine whether the planned capacity was proportional to the building's energy needs.

2.5. Investment Feasibility Analysis

An economic analysis is performed after obtaining the technical configuration and system cost estimates. Cost components include initial investment, installation costs, operation and maintenance costs, and component replacement costs over the life of the project. Financial benefits primarily stem from savings in electricity costs previously paid to PLN. All cash flows are calculated over the project's economic life and analyzed using Net Present Value (NPV), Internal Rate of Return (IRR), Payback Period (PP), and Benefit Cost Ratio (BCR).

$$NPV = \Sigma [CF\_t / (1 + i) \hat{} t] - I\_0 \quad (2)$$

CF_t is the net cash flow in year t, i is the discount rate, t is the period, and I_0 is the initial investment. An investment is considered feasible if NPV > 0.

$$BCR = PW(Benefit) / PW(Cost) \quad (3)$$

An investment is considered feasible if the BCR ≥ 1. The IRR is compared to the discount rate or minimum attractive rate of return; the investment is feasible if the IRR is greater than the reference rate. The Payback Period is determined from the year when the cumulative cash flow changes from negative to zero or positive.

2.6. Analysis Stages and Decision Criteria

The research stages were carried out sequentially, namely: literature study and parameter determination; load survey and roof condition; preparation and validation of electricity consumption profiles; calculation of PV module capacity, battery, inverter, and MPPT/SCC; preparation of system configuration; simulation using HOMER; investment and cash flow estimation; and feasibility analysis with NPV, IRR, PP, and BCR. The feasibility conclusion was determined by considering two dimensions simultaneously, namely the system's ability to technically meet energy needs and the investment's ability to generate financial benefits within the project's lifetime. If the simulation results indicate too large a capacity or produce high excess energy, the configuration needs to be re-evaluated so that the design is more efficient and relevant to the actual load pattern of Bank Nagari Lubuk Gadang Branch.

3. RESULTS AND DISCUSSION

3.1. Electricity Consumption of PT Bank Nagari Lubuk Gadang Branch Office Within 24 Hours

Load measurements and inventories show a clear difference in consumption patterns between weekdays and holidays. On weekdays, most office equipment is active simultaneously during operating hours, while on holidays, the load is dominated by 24-hour equipment, such as pumps, air conditioners, ATMs, dispensers, and refrigerators. The following figure compares the electricity load on weekdays and holidays.

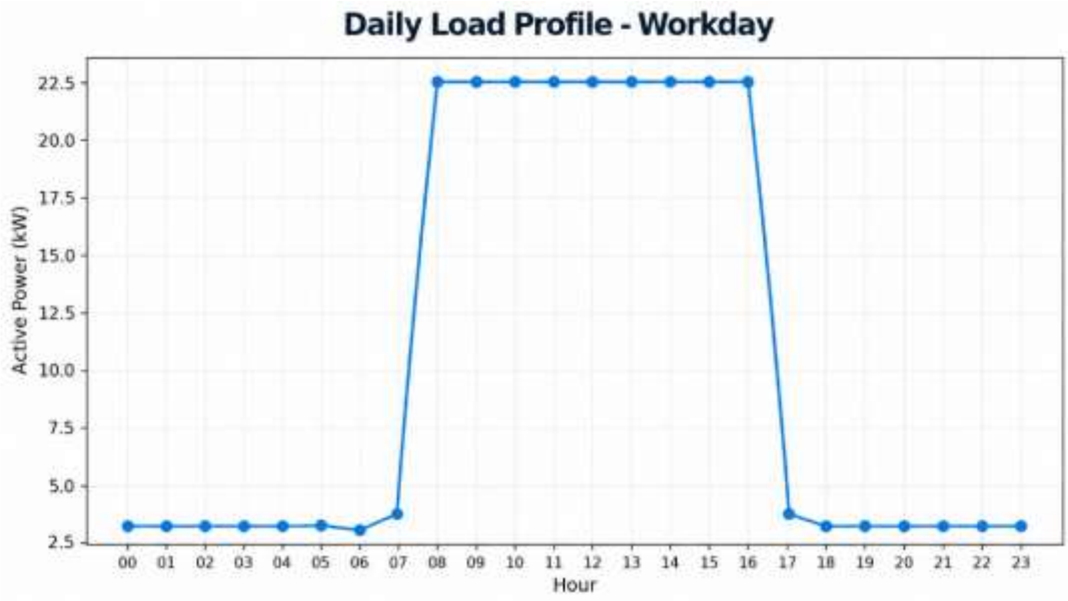

Figure 1. Hourly electric power profile on weekdays

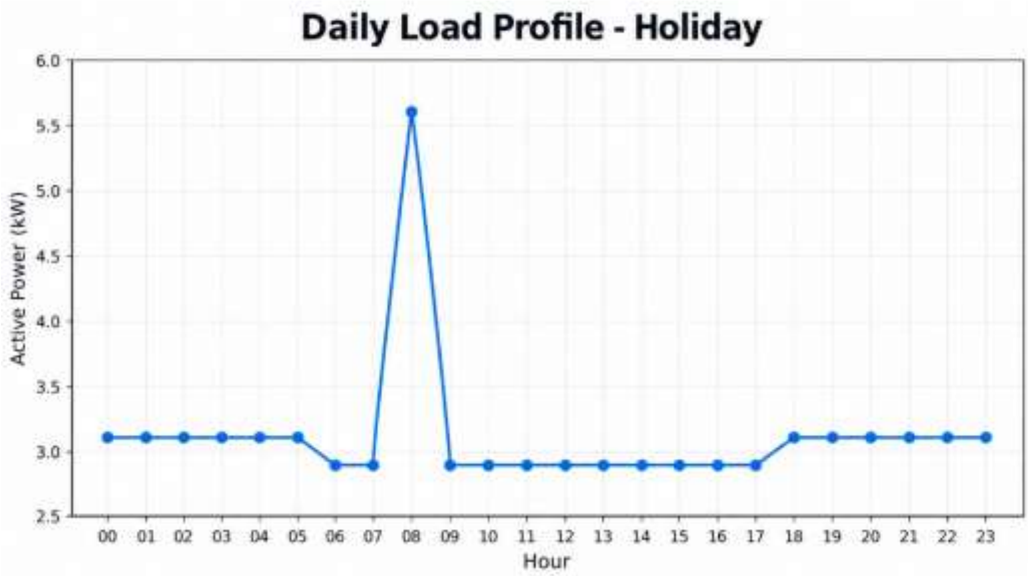

Figure 2. Hourly electric power profile on Saturday-Sunday

The load profile shows a strong difference between weekdays and holidays. On weekdays, consumption reaches 251,514 kWh/day with a peak load of around 22,645 kW between 8:00 AM and 5:00 PM, while on holidays consumption decreases to 75,157 kWh/day with a peak load of 5,640 kW. This pattern confirms that bank service activities, particularly the operation of air conditioning systems, UPSs, computers, lighting, printers, and supporting equipment, are the main drivers of energy demand. This characteristic is advantageous for the implementation of solar PV because the highest demand occurs during the day, the period when photovoltaic modules generally produce the most energy. This finding indicates that commercial buildings have good potential for rooftop PV utilization when their load profiles coincide with the solar production period. Solar PV systems in commercial buildings can reduce dependence on grid energy if their capacity is adjusted to actual usage patterns [8].

3.2. Electricity Consumption in One Month

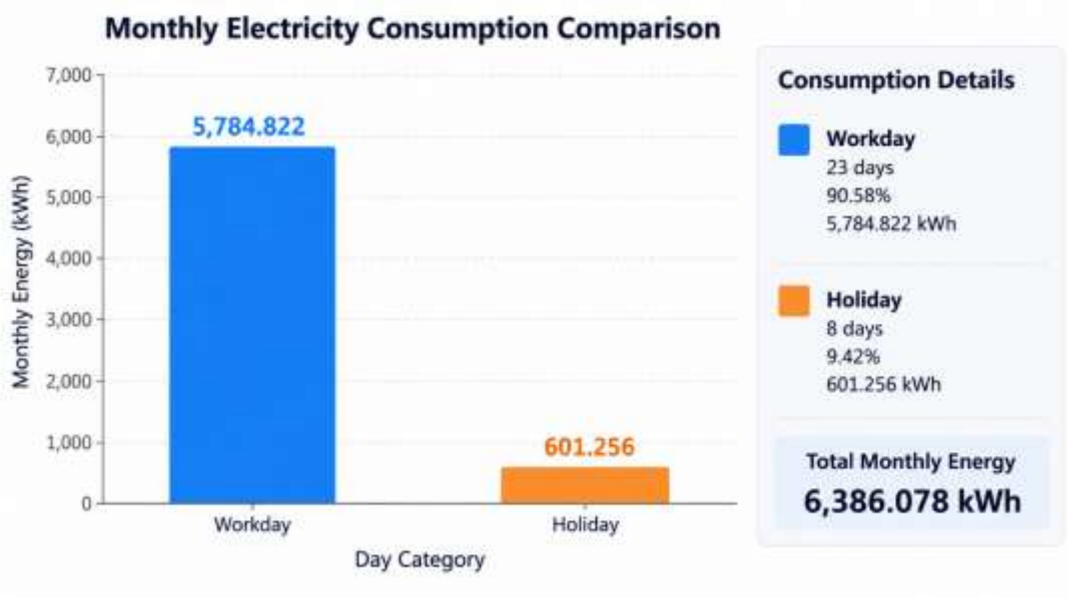

Figure 3. Comparison of Weekday and Holiday Energy Consumption

Accumulated consumption for 31 days of 6,386,078 kWh shows that 90.58% of energy is used on weekdays, while Saturday-Sunday only contributes 9.42%. This dominance indicates that determining the capacity of a solar power plant should not only be based on the total monthly energy, but also on the distribution of energy use time. Consumption patterns and system size are the main factors in PV optimization and energy storage. Putra et al. In addition, technical-economic analysis of PV in office buildings needs to use the characteristics of building energy needs as a basis for determining capacity so that the generated energy can be utilized effectively [12].

3.3. PLN Bills Electricity Bills and Survey Results Validation

Table 1. Comparison of estimated consumption and PLN bills

Data source	Consumption (kWh)	Tariff (Rp/kWh)	Energy costs (Rp)
Survey results	6,386	1,444.7	9,225,854
PLN Bill	6,342	1,444.7	9,162,287
Difference	44	-	63,567

A comparison of the survey results with PLN bills shows a difference of only 44 kWh or approximately 0.69%, namely 6,386 kWh based on load inventory and 6,342 kWh based on PLN data. The difference in energy costs is also relatively small, namely Rp63,567. This closeness indicates that the inventory method of equipment, power, number of units, and operating duration has sufficiently represented the condition of office electricity consumption. The reliability of energy demand data is an important basis in PV feasibility studies because errors in load estimation can result in inaccurate system sizes and economic indicators. Thus, the level of agreement between the survey and PLN bills strengthens the use of the research load profile as a basis for technical design [6].

3.4. Results of Calculation of Solar Panel Module Requirements

Table 2. PV module capacity determination results

Parameter	Mark
Weekday energy consumption	251,514 kWh/day
System losses	15%
Need/reserve factor	10%
Total correction factor	25%

ISSN: 2715-6427

Energy after correction	335,352 kWh/day
Effective sundial	4 hours/day
Required PV capacity	83,838 kWp
Module capacity	400 Wp
Number of modules	210 units
Installed capacity	84.0 kWp

The calculation yields an array requirement of 83,838 kWp and is rounded to an installed capacity of 84 kWp using 210 400 Wp modules. This determination has included system losses of 15% and a 10% demand/reserve factor, resulting in a corrected energy requirement of 335,352 kWh/day. The correction approach is necessary because the actual energy received by the load is not identical to the nominal capacity of the module. Temperature, radiation intensity, shading, dust, orientation, and installation characteristics can reduce PV output. Environmental conditions have a significant influence on efficiency and energy production. In the context of Indonesia's tropical climate, there is a potential difference between simulation and actual performance, so the use of loss factors and site validation are relevant in designing an 84 kWp capacity [18].

3.5. Battery, Inverter, and SCC MPPT Requirements

Table 3. Battery capacity determination results

Parameter	Mark
Daily energy after correction	335,352 kWh/day
Autonomy time	2 days
DOD/correction factor	1.25
Battery voltage	48 V
Battery capacity	250 Ah
Nominal energy per battery	12 kWh
Number of batteries	70 units
Nominal capacity of battery bank	840 kWh

Table 4. Inverter capacity in system configuration

Component	Amount	Capacity used in the configuration
Inverter	1 unit	66 kW

Table 5. Results of determining the SCC MPPT

Parameter	Mark
Capacity of one SCC MPPT	3,000 W
Module per MPPT	7 modules
PV power per MPPT	2,800 Wp
Total PV capacity	84,000 Wp
Number of SCC MPPT	30 units

The design uses 70 48 V 250 Ah batteries with a nominal battery bank capacity of approximately 840 kWh, one 66 kW inverter, and 30 3 kW SCC MPPTs. The large battery capacity is a consequence of the off-grid configuration and the assumed two-day autonomy time, as the system must still be able to provide energy when solar production decreases. Battery capacity directly affects the level of energy independence and the cost of the PV-battery system. The compatibility of the PV architecture, inverter, and power control system plays a crucial role in increasing conversion efficiency. Therefore, a configuration of 30 MPPTs each handling approximately 2.8 kWp provides structured power distribution, while the inverter capacity needs to be linked to the maximum load, starting load characteristics, and operating margins so that its selection can be technically justified [24].

3.6. Solar Power System Configuration

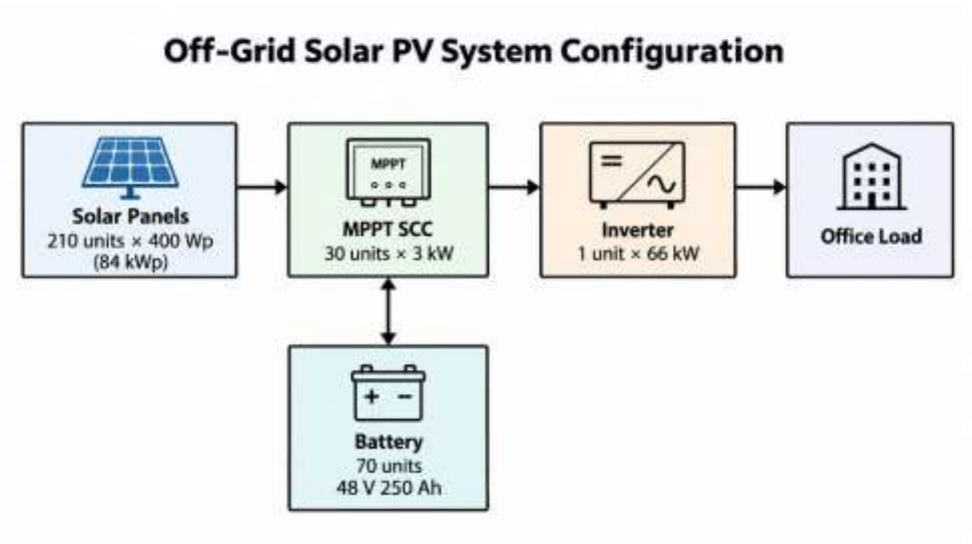

Figure 4. Off-grid solar power system configuration resulting from the design

The final configuration consisting of 84 kWp PV, 840 kWh battery bank, 30 SCC MPPT, and 66 kW inverter shows that the research prioritizes the system's ability to supply office needs independently. Off-grid systems provide advantages in terms of independence and continuity of supply, but at the same time increase investment due to the need for larger batteries and control devices. The PV system configuration needs to be adjusted to consumption patterns, solar resources, and cost structures to optimize economic benefits. Integrated technical and economic evaluations are needed in the PV design of commercial buildings. Therefore, the off-grid configuration at Bank Nagari can be considered feasible as an energy independence scenario, but comparison with on-grid or hybrid configurations in further research can help find alternatives with more efficient investment costs [10].

3.7. Net Present Value (NPV) Investment Feasibility Analysis

The financial analysis was conducted using investment costs, replacement/maintenance costs, benefits in the form of electricity bill savings, and cash flow over the project's lifetime. The main indicators available in the research results are Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period (PP).

Table 6. Net Present Value analysis results

Indicator	Mark
Initial investment based on cost details	Rp1,116,265,000
Present Worth of Cost	Rp1,938,265,000
Present Worth of Benefit	Rp2,320,041,996
NPV	Rp381,776,996
Criteria	NPV > 0
Results	Worthy

The Present Worth of Benefit value of Rp2,320,041,996 is higher than the Present Worth of Cost of Rp1,938,265,000, resulting in a positive NPV of Rp381,776,996. Based on the NPV > 0 criteria, this result indicates that the projected financial benefits over the life of the project are able to exceed the calculated costs. The feasibility of rooftop solar power plants in office buildings is greatly influenced by the initial investment, energy savings, electricity production, and project life. Reducing energy purchases from the grid is one of the main sources of benefits of rooftop PV. Thus, a positive NPV is an indicator that supports the financial feasibility of solar power plant investment at Bank Nagari, Lubuk Gadang Branch [15].

3.8. Internal Rate of Return (IRR) Investment Feasibility Analysis

Table 7. Results of Internal Rate of Return analysis

Indicator	Mark
Present Worth of Cost	Rp1,938,265,000
IRR	11.82%
Eligibility criteria	IRR > MARR/discount rate
Results based on IRR	Conditional: feasible if MARR < 11.82%
Research result	Worthy

The obtained IRR of 11.82% indicates the project's internal rate of return based on the cash flows used in the study. Budi et al. (2022) emphasized that PV feasibility based on IRR is influenced by financial parameters and must be compared with the minimum required rate of return. Ansori et al. (2023) also used financial indicators together so that investment decisions do not rely solely on a single measure [21].

Based on the data available in the manuscript, an IRR of 11.82% is not considered absolutely feasible because the company's MARR/discount rate has not been included. The correct interpretation is that an investment is feasible according to the IRR criteria if the MARR is less than 11.82%; if the MARR is equal to or greater than 11.82%, the IRR criteria are not met.

3.9. Payback Period and Investment Cash Flow

Table 8. Movement of investment returns up to the 11th year

The 20th year	Cash inflow	Remaining investment
1	Rp120,942,192	Rp2,065,448,808
2	Rp133,653,216	Rp1,931,795,592
3	Rp147,700,169	Rp1,784,095,422
4	Rp163,223,457	Rp1,620,871,965
5	Rp180,378,243	Rp1,440,493,722
6	Rp199,335,996	Rp1,241,157,727
7	Rp220,286,209	Rp1,020,871,517
8	Rp243,438,290	Rp777,433,228
9	Rp269,023,654	Rp508,409,574
10	Rp297,298,040	Rp211,111,534
11	Rp328,544,064	-Rp117,432,530

Table 9. Investment cash flow for 20 years

The 20th year	Cost	Benefits
1	-Rp1,116,265,000	Rp120,942,192
2	-Rp630,498	Rp133,653,216
3	-Rp646,324	Rp147,700,169
4	-Rp662,546	Rp163,223,457
5	-Rp679,176	Rp180,378,243
6	-Rp696,223	Rp199,335,996
7	-Rp482,817,148	Rp220,286,209
8	-Rp731,613	Rp243,438,290
9	-Rp749,976	Rp269,023,654

10	-Rp768,800	Rp297,298,040
11	-Rp788,097	Rp328,544,064
12	-Rp807,879	Rp363,074,045
13	-Rp828,156	Rp401,233,127
14	-Rp574,309,924	Rp443,402,729
15	-Rp870,251	Rp490,004,356
16	-Rp892,095	Rp541,503,813
17	-Rp914,486	Rp598,415,864
18	-Rp937,440	Rp661,309,371
19	-Rp960,970	Rp730,812,986
20	-Rp985,090	Rp807,621,431

The payback period of 10.64 years, or approximately 10 years and 8 months, indicates that the investment is recovered before the end of the 20-year project horizon. At the end of the 10th year, there is still a remaining investment of Rp211,111,534, while in the 11th year, the cumulative current has passed the break-even point. This value is within a diverse range compared to previous studies. Ansori et al. (2023) reported a payback period of approximately 8.6 years for a specific configuration, while Cinicy et al. (2023) obtained a payback period approaching 17 years for a rooftop solar power plant in an office building [19, 21]. Habib et al. (2024) obtained a shorter period under different cost, tariff, and solar resource conditions. This variation confirms that the payback period is highly sensitive to system price, capacity, electricity tariff, and PV energy utilization level [22].

The 20-year cash flow also shows significant costs at the start of the project, as well as in years 7 and 14, due to battery replacement. This is important because energy storage is one of the largest cost components in off-grid systems. Koester et al. (2022) emphasize the need to incorporate degradation and long-term condition of PV components into techno-economic assessments, while Poudyal et al. (2021) show that operation, maintenance, and component replacement costs can alter project feasibility outcomes. Therefore, including battery replacement costs in the cash flow makes the investment analysis more realistic than those that only consider the initial investment [6, 8].

3.10. System Simulation Results Using HOMER

Table 11. Summary of HOMER simulation results

Simulation result parameters	Mark	Proportion to production
Solar power plant electricity production	105,442 kWh/year	100%
HOMER scenario load consumption	60,386 kWh/year	57.3%
Excess electricity	41,453 kWh/year	39.3%

The HOMER simulation yielded a PV production of 105,442 kWh/year, a simulation scenario load of 60,386 kWh/year, and excess electricity of 41,453 kWh/year or 39.3%. The large excess energy indicates that the 84 kWp capacity has a higher production capacity than the energy utilized by the load in the HOMER scenario. Optimizing PV size can increase self-consumption while improving economic results and emphasizes the need for validation between simulation and actual conditions in tropical climates.

PLN's actual consumption of 6,342 kWh/month, if simply annualized, becomes approximately 76,104 kWh/year. Since this figure differs from the HOMER scenario load of 60,386 kWh/year, the value of 41,453 kWh/year or 39.3% excess electricity only applies to the current HOMER scenario. If the annual load is updated to 76,104 kWh/year, the HOMER simulation needs to be rerun so that the excess electricity value, PV contribution, and technical-economic indicators are obtained consistently [27].

4. CONCLUSION

Based on the research results, the proposed 84 kWp rooftop photovoltaic system at Bank Nagari Lubuk Gadang Branch is technically feasible and conditionally economically feasible. The electricity-consumption survey agreed closely with the PLN bill, with a deviation of only 0.69%, and the daytime-dominated load profile is compatible with solar generation. In the HOMER scenario, the system produces 105,442 kWh/year, serves a modeled load of 60,386 kWh/year, and generates 41,453 kWh/year (39.3%) of excess electricity. Financially, the project yields a positive NPV of Rp381,776,996 and a Payback Period of 10.64 years over a 20-year project horizon, while the IRR is 11.82%. Overall, the 84 kWp design is technically feasible, and the investment is financially feasible only if the company's MARR is below 11.82%; it does not satisfy the IRR criterion when MARR is equal to or above 11.82%. Before implementation, the HOMER simulation should be rerun using the actual annual load of approximately 76,104 kWh/year derived from the PLN bill, and the battery replacement assumptions for years 7 and 14 should be verified so that the final technical-economic indicators are internally consistent.

ACKNOWLEDGEMENTS

On this occasion, the author would like to express his deepest gratitude to colleagues at the Department of Electrical Engineering, Faculty of Engineering, Institut Teknologi Padang, who have provided great contributions in the form of suggestions, direction, and support so that the author can complete this work.

REFERENCES

[1] Marques Lameirinhas, RA, Torres, JPN, & de Melo Cunha, JP (2022). A photovoltaic technology review: History, fundamentals and applications. Energies, 15(5), 1823. https://doi.org/10.3390/en15051823
[2] Ghosh, S., & Yadav, R. (2021). Future of photovoltaic technologies: A comprehensive review. Sustainable Energy Technologies and Assessments, 47, 101410. https://doi.org/10.1016/j.seta.2021.101410
[3] Tawalbeh, M., Al-Othman, A., Kafiah, F., Abdelsalam, E., Almomani, F., & Alkasrawi, M. (2021). Environmental impacts of solar photovoltaic systems: A critical review of recent progress and future outlook. Science of the Total Environment, 759, 143528. https://doi.org/10.1016/j.scitotenv.2020.143528
[4] Vodapally, S. N., & Ali, M. H. (2023). A comprehensive review of solar photovoltaic (PV) technologies, architecture, and its applications to improve efficiency. Energies, 16(1), 319. https://doi.org/10.3390/en16010319
[5] Aslam, A., Ahmed, N., Qureshi, S.A., Assadi, M., & Ahmed, N. (2022). Advances in solar PV systems: A comprehensive review of PV performance, influencing factors, and mitigation techniques. Energies, 15(20), 7595. https://doi.org/10.3390/en15207595
[6] Koester, L., Lindig, S., Louwen, A., Astigarraga, A., Manzolini, G., & Moser, D. (2022). Review of photovoltaic module degradation, field inspection techniques and techno-economic assessment. Renewable and Sustainable Energy Reviews, 165, 112616. https://doi.org/10.1016/j.rser.2022.112616
[7] Zhang, Y., Ma, T., Campana, P. E., Yamaguchi, Y., & Dai, Y. (2020). A techno-economic sizing method for grid-connected household photovoltaic battery systems. Applied Energy, 269, 115106. https://doi.org/10.1016/j.apenergy.2020.115106
[8] Poudyal, R., Loskot, P., & Parajuli, R. (2021). Techno-economic feasibility analysis of a 3-kW PV system installation in Nepal. Renewables, 8, 5. https://doi.org/10.1186/s40807-021-00068-9
[9] Abdul-Ganiyu, S., Quansah, D.A., Ramde, E.W., Seidu, R., & Adaramola, M.S. (2021). Techno-economic analysis of solar photovoltaic (PV) and solar photovoltaic thermal (PVT) systems using exergy analysis. Sustainable Energy Technologies and Assessments, 47, 101520. https://doi.org/10.1016/j.seta.2021.101520
[10] Silalahi, D.F., Blakers, A., Stocks, M., Lu, B., Cheng, C., & Hayes, L. (2021). Indonesia's vast solar energy potential. Energies, 14(17), 5424. https://doi.org/10.3390/en14175424
[11] Tarigan, E. (2020). Rooftop PV system policy and implementation study for a household in Indonesia. International Journal of Energy Economics and Policy, 10(5), 110–115. https://doi.org/10.32479/ijeep.9539
[12] Hidayatno, A., Setiawan, AD, Wikananda Supartha, IM, Moeis, AO, Rahman, I., & Widiono, E. (2020). Investigating policies on improving household rooftop photovoltaics adoption in Indonesia. Renewable Energy, 156, 731–742. https://doi.org/10.1016/j.renene.2020.04.106
[13] Shaik, F., Lingala, S.S., & Veeraboina, P. (2023). Effect of various parameters on the performance of solar PV power plants: A review and the experimental study. Sustainable Energy Research, 10, 6. https://doi.org/10.1186/s40807-023-00076-x
[14] Santoso, RW, Dionova, BW, Eteruddin, H., Saputra, K., Rosyid, OA, Rizanulhaq, FM, & Abdullah, MI (2026). Performance and techno-economic analysis of a 1.82 kWp rooftop PV system in the tropical climate of Indonesia: A simulation vs. reality approach. National Journal of Electrical Engineering, 15(1). https://doi.org/10.25077/jnte.v15n1.1427.2026
[15] Setyawati, D. (2020). Analysis of perceptions towards the rooftop photovoltaic solar system policy in Indonesia. Energy Policy, 144, 111569. https://doi.org/10.1016/j.enpol.2020.111569
[16] Suparwoko, & Qamar, F.A. (2022). Techno-economic analysis of rooftop solar power plant implementation and policy on mosques: An Indonesian case study. Scientific Reports, 12, 4823. https://doi.org/10.1038/s41598-022-08968-6
[17] Ghaleb, B., & Asif, M. (2022). Application of solar PV in commercial buildings: Utilizability of rooftops. Energy and Buildings, 257, 111774. https://doi.org/10.1016/j.enbuild.2021.111774
[18] Putra, IWS, Kumara, INS, & Hartati, RS (2022). Techno-economic analysis of the implementation of a PV rooftop

system at the Denpasar Mayor's Office Building. Scientific Journal of Electrical Technology, 21(2), 185–194. https://doi.org/10.24843/MITE.2022.v21i02.P05

[19] Cinicy, OSR, Windarta, J., & Saptadi, S. (2023). Economic feasibility study of a 32 kWp rooftop solar power plant in the PT KPJB office building, PLTU Tanjung Jati B, Jepara Regency. Journal of New and Renewable Energy, 4(2), 97–107. https://doi.org/10.14710/jebt.2023.17574

[20] Budi, RFS, Sarjiya, & Hadi, SP (2022). The prospect of rooftop photovoltaic development considering global horizontal irradiation uncertainty and government policies: A case of Java Island, Indonesia. International Journal of Energy Economics and Policy, 12(4), 104–116. https://doi.org/10.32479/ijeep.13066

[21] Ansori, A., Arsana, IM, Siregar, IH, Adiwibowo, PH, & Haryuda, SI (2023). Techno-economic analysis of triangular rooftop solar PV model/PLN on-grid household scale in Indonesia. ASEAN Engineering Journal, 13(4), 127–132. https://doi.org/10.11113/aej.v13.19858

[22] Habib, S., Tamoor, M., Gulzar, MM, Chauhdary, ST, Ahmad, H., Alqahtani, M., & Khalid, M. (2024). Design, techno-economic evaluation, and experimental testing of grid connected rooftop solar photovoltaic systems for commercial buildings. Frontiers in Energy Research, 12, 1483755. https://doi.org/10.3389/fenrg.2024.1483755

[23] Widyanto, AN, Adhi, MAK, Husnayain, F., Utomo, AR, & Ardita, IM (2023). Techno-economic analysis of rooftop solar panel uprating on commercial buildings (Case study on Karawang Branch Office of XYZ Company). Scientific Bulletin of Undergraduate Electrical Engineering, 5(1), 86–97. https://doi.org/10.12928/biste.v5i1.7579

[24] Effendy, M., Nasar, M., Abduh, M., Suwignyo, Ad, A., Sm., L., & RA, F. (2024). Technical and economic feasibility study of rooftop solar power generation at Rayz Hotel, University of Muhammadiyah Malang. Techné: Jurnal Ilmiah Elektroteknika, 23(1), 95–106. https://doi.org/10.31358/techne.v23i1.455

[25] Putri, DNN, Rizanulhaq, FM, Sari, TK, Widjaja, MS, & Irianto, CG (2024). Techno-economics of rooftop solar power plants for residential customers in Indonesia. Jurnal Teknik Elektro, 16(2). https://doi.org/10.15294/jte.v16i2.14514

[26] Saprudin, AF, Yunus, M. Y., Ningtias, DWA, Hasanah, NK, & Diyono. (2026). Techno-economic optimization of rooftop photovoltaic systems using genetic algorithm for Government Building Kemenko 3 in Nusantara Capital City. INTEK: Jurnal Penelitian, 13(1). https://doi.org/10.31963/intek.v13i1.6351

[27] Adi, HP, & Arifin, Z. (2026). Techno-Economic Optimization of Existing Hybrid Power Generation System Development Using Multi Tools (Case Study: Sebira Island).*Pendas: Scientific Journal of Elementary Education*, 11(01), 166-179.https://doi.org/10.23969/jp.v11i01.43176