Jurnal ELECTRON, Vol. 4, No.2, November 2023, Hal. 78-88
e-ISSN 2622-6588 / p-ISSN : 2830-523X
Received: 18/09/2023, **Revised:** 16/10/2023, **Accepted:** 06/11/2023

Techno-economic Analysis and Optimization of Renewable Energy Forecasting at Universitas Jenderal Achmad Yani

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ABSTRACT

The availability of electrical energy ensures operational sustainability in everyday life, including the educational environment. The possibility of easier renewable energy installation encourages the goal of growing the installation to be affordable. Universitas Jenderal Achmad Yani is one of the campuses that has the capacity to use renewable energy and has a role in environmental awareness in accordance with the university's future vision. In light of this, a hybrid photovoltaic (PV), diesel, and battery plant design is presented as an alternative power plant to supplement conventional energy sources. However, it is critical to examine the long-term capital and profit estimations that must be considered. The hybrid plant is proposed in two configurations, grid-connected and off-grid. In this paper, modeling and simulation are performed using Net Present Cost (NPC) prices from the Ministry of Energy and Mineral Resources (MEMR) rooftop PV installation planning guidelines and inflation estimations from the Republic of Indonesia's Ministry of Finance. Furthermore, until the contribution of energy generated in the simulation is displayed, the production and consumption of electrical energy required for the selected building instances are generated. Hybrid plant modeling has been completed at Universitas Jenderal Achmad Yani's Faculty of Health Sciences and Technology (FHST) and Rectorate buildings. According to the simulation results, the NPC cost for the next 25 years is anticipated to be IDR 1,047,534,000, with a total electrical energy production of 729,807 kWh/year and a renewable energy contribution >91.4%. Furthermore, from a technological and economic standpoint, a grid-connected hybrid generation system is advocated

Keywords: Hybrid, Net Present Cost, Renewable Energy, Universitas Jenderal Achmad Yani

INTISARI

Ketersediaan energi listrik merupakan jaminan sebagai sumber keberlanjutan operasional di kehidupan sehari-hari salah satunya di lingkungan pendidikan. Potensi instalasi energi terbarukan yang semakin mudah mendorong tujuan peningkatan instalasi menjadi murah. Universitas Jenderal Achmad Yani salah satu kampus yang berpotensi memanfaatkan energi terbarukan dan memiliki peranan dalam wawasan lingkungan sehingga sesuai dengan visi universitas di masa yang akan datang. Latarbelakang tersebut suatu desain pembangkit hibrida meliputi photovoltaic (PV), Diesel, Baterai diusulkan sebagai pembangkit listrik alternatif sebagai penunjang sumber energi konvensional. Namun perlu dilihat estimasi modal dan keuntungan yang perlu dipertimbangkan dalam jangka panjang. Dalam makalah ini, suatu pembangkit hibrida menggunakan dua skenario yaitu terhubung grid dan tanpa terhubung grid. Pemodelan dan simulasi dibuat dengan harga Net Present Cost (NPC) berdasarkan panduan perencanaan instalasi PV atap Kementrian Energi dan Sumber Daya Mineral (ESDM) dan estimasi inflasi dari kementrian keuangan republik Indonesia. Selain itu produksi dan konsumsi energi listrik yang dibutuhkan untuk contoh gedung yang dipilih dihasilkan hingga kontribusi energi yang dihasilkan dalam simulasi tersebut dipaparkan. Pemodelan pembangkit Hibrida pada gedung Fakultas Ilmu dan Teknologi Kesehatan dan gedung Rektorat Universitas Jenderal Achmad Yani telah dilakukan. Hasil simulasi menunjukkan biaya NPC untuk 25 tahun mendatang diperkirakan Rp 1.047.534.000, dengan total produksi energi listrik 729.807 kWh/tahun dengan kontribusi energi terbarukan mencapai >91.4%. Lebih lanjut pandangan dari segi teknis dan ekonomis, secara efektif, dan efisien sistem pembangkit hibrida terhubung jaringan PT. PLN (Persero) direkomendasikan.

Kata kunci: *Energi Terbarukan, Hibrida, Net Present Cost, Universitas Jenderal Achmad Yani.*

I. INTRODUCTION

The current topic that is receiving the most discussion and attention in terms of energy needs is the shift to Renewable Energy (RE)[1][2]. Several developing countries are rushing to add RE installations as part of their promise to lessen their reliance on traditional electricity sources and cut emissions[3][4]. Minister of Energy and Mineral

e-ISSN 2622-6588 / p-ISSN : 2830-523X
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Resources (MEMR) Decree Number 143K/20/MEM/2019 Concerning the National Electricity Master Plan for the Period 2019-2038[5]. Based on this background, MEMR projects a 6.9% annual increase in national electricity demand[6]. Therefore, RE implementation activities in Indonesia can be applied in all fields, including industrial, commercial, communal and residential fields.

In addition to its electricity subscription to the PLN grid, Universitas Jenderal Achmad Yani is one of the campuses that has the option to exploit the potential of renewable energy kinds of photovoltaic (PV) with other components that support this energy source[7][8][9]. However, establishing a renewable energy component necessitates significant investment costs, the cost of which is unpredictable[10] . When installing a PV system, there are several factors to consider, including the capital cost of components, replacement prices, operation and maintenance costs, and other ancillary expenditures, like as installation services[11].

This paper, a design and techno-economic assessment of two new buildings on campus, Faculty of Health Sciences and Technology (FHST) and Rectorate buildings, is presented. The study's goals are to examine the demand for total electrical energy production, grid sales, and renewable energy portion. Analyzing the overall project cost in each suggested hybrid scheme over the next 25 years to determine the most optimal hybrid design based on electricity distribution, project development costs, and the amount of renewable energy contribution in the FHST and Rectorate buildings.

The systematic discussion of paper writing begins with the introduction, The introduction that will provide the background of research connected to the aims. The second section is the research method, which includes data collection methods, an explanation of the system block diagram of the proposed PV-based hybrid power plant scheme connected to and not connected to the grid, the research location, and the capacity of the hybrid generation system components. The third section concludes the conclusion section with the test results and essential analysis based on the simulation and model of the hybrid plant.

Table 1 describes some of the studies related to earlier research and to the analysis with a techno-economic focus. To complete the cost planning with the anticipated RE contribution, various options are required. Some independent study has been conducted at Universitas Jenderal Achmad Yani, however it must be supplemented with other sources at this time.

Table 1 shows the roadmap of previous research done at Universitas Jenderal Achmad Yani to model renewable energy, as well as research connected to the deployment of microgrids or hybrid plants, as well as techno-economic evaluations.

The problem formulation in this research related to tecno-economy analysis on hybrid power generation system (PV, Diesel, Battery) for both building (FHST and Rectorate) at Universitas Jenderal Achmad Yani is to determine the cost of each hybrid component, considerations in selecting and using hybrid power generation system equipment and creating a hybrid system with on-grid and off-grid scenarios. To accomplish some of these goals, the hybrid system must be simulated software to obtain an economic comparison and electrical energy output in each scenario.

II. BASIC THEORI

A. Potential Energy based on Location

The hybrid plant is planned to be placed in Jenderal Achmad Yani University's newest building with a concrete flat roof type, namely the Rectorate building, which is located at the coordinates -6.8893 latitude and 107.5245 longitude, and the FHST building, which is located at the coordinates -6.8858 latitude and 107.5261 longitude. Universitas Jenderal Achmad Yani has three distribution stations and one substation. The new buildings at Universitas Jenderal Achmad Yani that will be the topic of this investigation are solely new buildings on campus. This hybrid power plant is proposed to meet the existing load's electricity supply needs. Meteorological data is the major data source for renewable energy resource data. This goal is required in order to calculate the quantity of potential solar energy that can be captured and generated by PV.

Table 2 displays the Global Horizontal Irradiation (GHI), ambient temperature, and wind speed characteristics at a height of 10 meters at the location. This resource data comes from the National Aeronautics and Space Administration (NASA), and it may be found at the website power.larc.nasa.gov. This data covers the previous 11 years through 2021. The average GHI across a year is 6.61 kWh/m^2/day, with the maximum irradiation value occurring in January - February at 7.25 kWh/m^2/day.

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Table 1. Literature Reviews on Hybrid and Techno-economic Model

No	References	Location	Proposed Design
1	H.R. Iskandar, et al. 2019[8] and continues research in 2021[9]	Electrical Engineering Laboratory (EEL) Universitas Jenderal Achmad Yani, Cimahi. Indonesia	1. Proposed of rooftop PV system 32.1 kWp off-grid connected for laboratory. 2. Proposed optimization rooftop area increasing PV capacity until 47.2%, using 243 PV panels of 250Wp and energy potential can be harvest 2350 kWh/m^2.day. Total rooftop PV system 60.750 supported to the laboratory.
2	R. Castrillon-Mendoza, et al. 2020[12].	University Autónoma de Cali, Colombia.	The integration of grid-connected photovoltaic systems, which allows for the integration of zero energy buildings.
3	L. Xing, H. Xu, et al. 2020[13].	Residential household in Tehran, Iran.	A hybrid energy system, which includes a PV system, battery, a fuel cell (FC), a natural gas (NG) boiler, a thermal load controller (TLC), and a converter.
4	M. Sim, D. Suh, et al. 2021[14]	Campus in Korea.	Integrating RE systems using Multi-object Particle-swam Optimization.
5	F. Nazipov, S. Tokolat, et al. 2021 [15].	Nazarbayev University Campus, Kazakhstan.	Integration RE (PV system + Wind Turbin (WT)) combined with solar tracker system and geothermal pump total capacity 53 kW.
6	S. Gbadamosi, F. Ogunje, et al. 2022[16].	Educational Institution in Nigeria, Africa.	Variant scenario on-grid connected and offgrid using PV and battery.
7	T. Riayatsyah, T. Geumpana, et al. 2022[17].	Meunasah Papeun, Aceh Besar Regency, Aceh, Indonesia.	Grid-connected PV system and WT 1,213 kW using simple tarrif and RE Fraction up to 82% (energy contribution)
8	G. Gehlert, M. Wiegand, et al. 2022[18].	The Lecturing and Exhibition Building (LEB), Heide city, Germany.	Heat pump system using renewable energy (PV, WT + Battery) integration for LEB. Total generated power 23.3 kW.
9	M. Raman, P. Meena, et al. 2022[19].	Rural in India.	Net Present Cost (NPC) in microgrid configuration using PV and Diesel Generator (DG) and variant load until 25 years.
10	A. Xu, L. Awalin, et al. 2023[20]	Ponorogo Regency, East Java, Indonesia.	Various scenario of techno-economic on DG connected with PV, WT and battery model.
11	M. Alsheri, Y. Guo et al, 2023[21]	King Saud University Campus, Riyadh.	Microgrid design and techno-economic analysis for RE Penetration> 82%.
12	H. R. Iskandar et al. Proposed in 2023	FHST and Rectorate Universitas Jenderal Achmad Yani, Cimahi.	1. Proposing hybrid generation (rooftop PV system, DG, battery and converter) systems. 2. Tekno-ekonomi Anlysis for 25 years ago.

The highest irradiation value during the summer because the sun's rays are not frequently obstructed by clouds, while the irradiation value decreases during the rainy season because the sun's rays are obstructed by cloudy clouds. In one year, the average temperature is 21.48°C. According to Table 2, the greatest temperature was 22.09°C in November and the lowest temperature was 20.62°C in July.

The operational properties of PV panels will be influenced by the high temperature. The PV panel will perform best if it is tested in line with the Standard Test Condition (STC) at 25°C.

Received: 18/09/2023, **Revised:** 16/10/2023, **Accepted:** 06/11/2023

Table 2. Meteo-data and Resource of Energy

Month	Glob. Hor. Irradiance (kWh/m²)	Temp. (°C)	Wind Speed (m/sec.)
Jan	7.25	21.16	3.11
Feb	7.25	21.46	2.45
Mar	7.04	21.73	2.19
Apr	6.52	21.96	1.85
May	5.93	21.96	1.90
Jun	5.61	21.26	1.90
Jul	5.77	20.62	2.2
Aug	6.26	20.63	2.29
Sept	6.73	21.22	2.31
Oct	6.88	22.00	2.09
Nov	6.98	22.09	1.93
Des	7.09	21.66	2.25
Ave./year	6.61	21.48	2.23

Table 3. Existing Building Requirements

Building	Load Profile (kWh)	Energy Estimation Lost (Wh)	Tot. Energy Supplied (Wh)	Battery Capcity (Ah)
FHST	21.2	3166	4025	109,937.5
Rectorate	3.5	525	4025	18,225

B. Homer-based Hybrid Design Scheme

When PV energy generation is not operational, the grid network is chosen to cover energy shortfalls. Furthermore, for system stability, the grid must maintain a steady frequency in the face of variations in load and power supply. Furthermore, while the PV system is not in use, the electricity is provided entirely by the grid. The electrical system parameters must be improved in order to maximize investment and operational expenses. Electricity tariff power refers to Tariff Adjustment for Electricity July - September 2023, which is done out every three months if there is a change. Tariff categories are divided into 13. Because this hybrid system falls under the medium business demands category, the following power tariff must be included IDR 1,444.70 [22].

C. Economic Parameter Input

The cost of installing rooftop PV varies depending on the application. Several factors influence this, including the system's capacity, the technology/specification of the components used, the location/region of installation, which affects the transportation costs of PV components and rooftop PV installer vendors, as well as the installer vendor's service quality and the absence of after-sales service. As an example, the typical rooftop PV installation cost is IDR 15,000,000.00/kWp This pricing is based on the cost of its primary components, which are PV panels and inverters. In the Indonesian market, solar panels cost between IDR 9,500,000.00, and IDR 15,000,000.00/Wp, while inverters cost between IDR 1,900,000.00/Wp and IDR 5,000,000.00/Wp. Rooftop PV installation costs account for 47% of PV costs, 13% of inverter costs, and 40% of all other supplementary components and installation services. As a result, the average cost of installing rooftop PV is around IDR 25,000,000.00/kWp[23]. The cost of a 12 V battery module is estimated at $100/kWh (Raiford, 2020c), resulting in an SB cost of $170/kWh regardless of DOD. If adjusted into Rupiah, each $1 is equal to IDR 15,360.00, so we can multiply this value for parameter input in Homer software as a battery-specific analysis while using uniform prices for other PV system components as in some previous modeling [24].

For the price of this type of battery on the market, which is approximately IDR 1,500,000.00 to IDR 3,000,000.00, the percentage is taken from the following tables: 11 and 12 for capital cost, O&M, and Replacement. Replacement is also used for batteries because the maximum estimated useful life is only 10 years. O&M costs are operational pricing or expenditures linked with the business's day-to-day maintenance and technical administration. For one system, maintenance charges range from IDR 500,000.00 to IDR 1,500,000.00 every visit. So, assuming 50 visits during a 25-year PV design, it is twice a year, with a note based on the required procedures, or once every 6 months.

D. Renewable Energy Capacity

The power supplied by the campus substation is 2500 kVA, and there are now only three stations, thus the power at each station is 2500 kVA/250 (3 stations) kVA, so the power at each station is 3.33 kVA, or 80 kWh in 24 hours. Because the power supplied by PV is based on solar energy, the use of electricity is limited to 8 hours. Table 3 shows the overall peak monthly power consumption of the FTHS and rectorate buildings, therefore the assumption of total power supplied by each PV adjusts the entire existing demand.

For it to be calculated with the total PV that must be installed, the new system component has an anticipated energy loss of 15% of the total energy load that must be supplied.

III. RESEARCH METHOD

This whole study lasted approximately 7 months, from February 2023 to August 2023. The research activity schedule includes research goals and stages ranging from literature reviews to the compilation of research reports. The location is selected by changing the parameters such that it has enough land and avoids towering buildings and trees that will block or cover the panel, reducing its performance. Figure 1 depicts a study flowchart utilized as a stage in the HOMER-based simulation.

The first stage involves designing energy requirements based on PV sources for charging grid-connected hybrid system batteries. In order to obtain data on the potential of renewable energy, particularly solar power, as supporting data for system design, PV will be installed connected to three phases (grid connected) and modeled to estimate PV contributions to on-grid and off-grid systems. The next step is to simulate the system's load profile (kWh) in order to calculate the capacity of the PV panel (kWp) as an off-grid energy source. Determining capital cost, component replacement, and operation and maintenance (O&M) costs, as well as estimating the levelized cost of energy (LCOE) paid to the grid based on the minimum and maximum Net Present Cost (NPC). in accordance with the Indonesia Ministry of Energy and Mineral Resources (MEMR) rooftop solar PV development guidelines and planning for the next 25 years.

A. Grid Optimization

To achieve the most optimal and cost-effective system results, HOMER software must be configured to act as an exclusive derivative-free algorithm. The check on the function "allow system with multiple generators" is required for Homer to optimize the energy source system, and then the check "issue a warning if an off-grid system has" is required to present a warning in the results for systems that fulfill the specified criteria. The rightmost level of this optimization option displays the maximum system simulation or ten thousand times the system accuracy to minimize the error to 1%. The Net Present Cost (NPC) is set to 1%, which causes the optimization to be lengthier but more precise (see Table 4).

B. Economics Setting

Setting economics changes the value of the currency that will be generated in the HOMER application's system. For example, depending on how we set it up, the cost currency that comes out can be dollars, rupiahs, cents, and so on. In this situation, the Indonesian rupiah (IDR/Rp) is used.

Table 4. Grid Optimization Input

No.	Parameter	Input
1	Max. Simulation per Optimization	10
2	System Design and NPC Precision	0.01
3	Focus Factor	50.00
4	Max. Renewable Penetration	>55%
5	Batt. Autonomy of less than	2 Hours
6	Grid Power Price / kWh	IDR. 1,444.70
7	Grid Emissions ($C0_2$) / kWh	800 g

Table 5. Economics Parameter Input

No.	Parameter	Input
1	Nom. Discount Rate	5.98 %
2	Expected Inflation Rate	3.50 %
3	Project Lifetime	25 Years

Table 6. Constraints Parameter Input

No.	Parameter	Input
1	Min. Renewable Fraction	10 %
2	Solar Power Output	80 %

The configuration setting in economics project duration is 25 years, according to Table 5. The Homer application calculates the project life based on the compounded annual cost of each component while accounting for inflation and the Bank Indonesia benchmark interest rate. Over the last ten years, the average benchmark interest rate has reached a high of 5.98%, while inflation has averaged 3.5%. The discount rate is assumed to be 2.40%.

C. Constraints

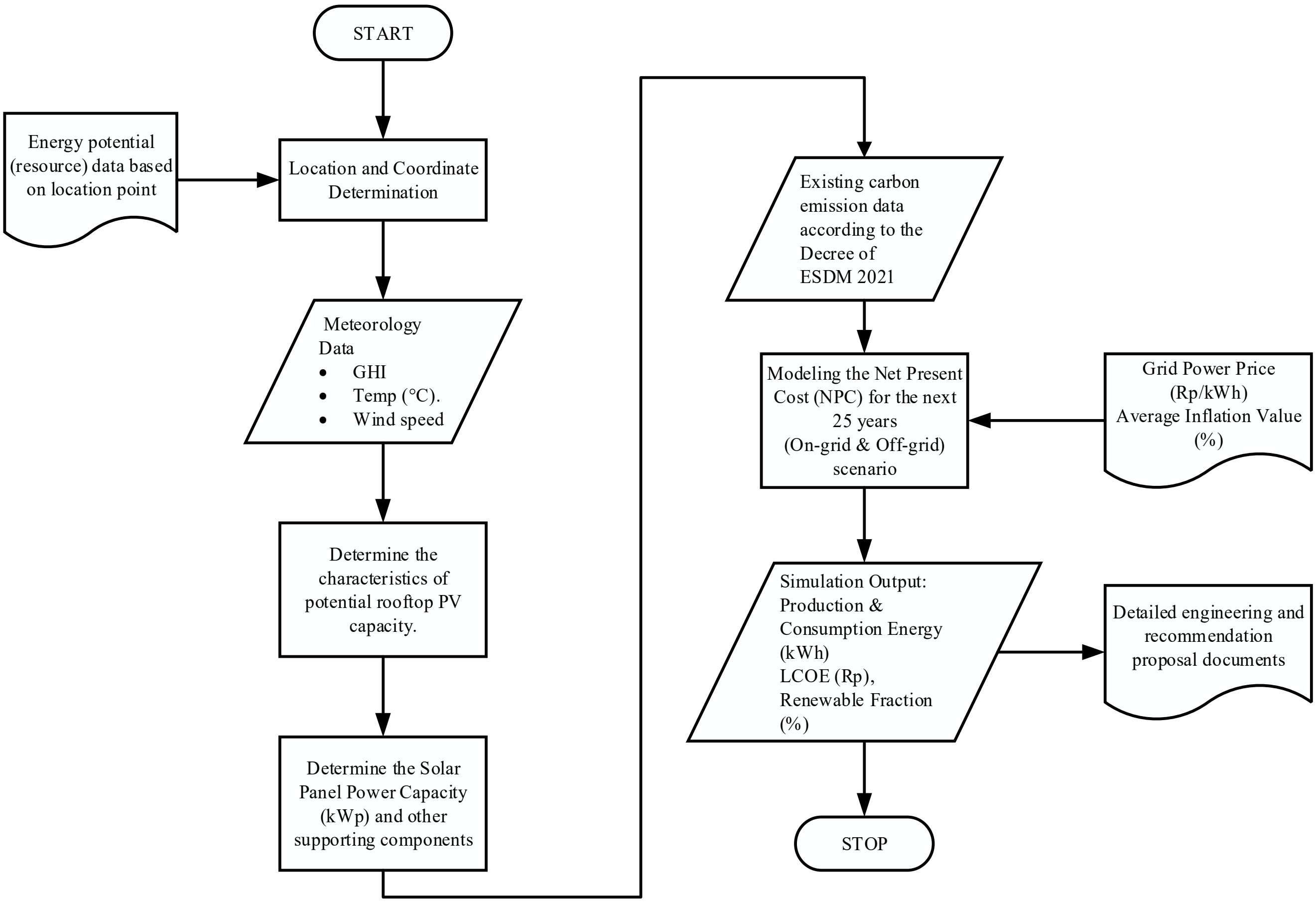

Figure 1. Simulation and Modeling Flowchart

The max. annual capacity shortage value is defined as the amount of daily energy shortage set at 0% based on the system setup. The min. renewable fraction is defined as the minimum proportion of renewable energy required to meet the electrical energy demand, which is set at 10%. Load in current step (%) as a percentage of additional load every hour, set to 10% to predict when there is an increase in load. Solar power output is defined as the amount of energy that can be released by the PV panel to compensate for an 80% reduction in solar cell energy (see Table 6).

IV. RESULT AND DISCUSSION

A. On-Grid Simulation Result

The on-grid scenario is a hybrid generating system designed to be connected to the grid (PLN), where the hybrid plant's electrical energy can be sold to the grid and can also supply electrical energy when the hybrid plant (PV + Battery) does not get enough power. On-grid scenario PV system as a source of electrical energy and batteries will store energy as a backup for the sustainability of energy from PV. The result of the power that can be generated by the FHST building is 351.8 kWp. The PV panels used to supply power to the FHST building are si-monocrystalline type PV panels. This data is used as simulation material with HOMER Pro. software to optimize the installation of RE devices that have a profitable investment value. In addition, this software also calculates the recommended capacity size to be installed in the system. The basic system output results are the system's beginning conditions that rely solely on the grid (PLN), as illustrated in table 7 below. According to the simulation, the new FHST building's annual electrical power usage is 128,407 kWh. As a result, the total amount of grid energy consumed is 128,407 kWh. Because the electrical energy is entirely supplied by the PLN grid, the base system has a renewable energy penetration of 0%. The system's electrical energy production performance shows that total energy produced is 729,807 kWh/year and

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e-ISSN 2622-6588 / p-ISSN : 2830-523X
Received: 18/09/2023, **Revised:** 16/10/2023, **Accepted:** 06/11/2023

renewable energy penetration is 91.4%, with 670,282 kWh/year produced by solar panels and 59,525 kWh/year purchased from the grid. With an annual load demand of 128,407 kWh. So, using the on-grid system scenario, electrical energy can be fulfilled and electrical power may be sold to the grid for 567,067 kWh/year. This system also generates 861 kWh of extra electricity per year.

The total amount of electricity that can be generated for the Rectorate building is 58.31 kWp. The Rectorate building, like the FTHS building, is proposed to use the same sort of PV panels. The annual electrical power usage is predicted to be 21,287 kWh. As a result, the total amount of grid energy consumed is 21,287 kWh. Because the electrical energy is completely from the grid, the base system of this building has a renewable energy penetration of 0%. According to the Homer software simulation results, the total energy produced is 122,210 kWh/year, and the renewable energy penetration is 91.5%, with PV generated energy of 112,348 kWh/year and grid purchase of 9,862 kWh/year. The scenario with the on-grid system of electrical energy can be satisfied with a load need of 21,287 kWh/year, and the electrical power that can be sold to the grid is 95,057 kWh/year. This system also generates 262 kWh of extra electricity every year.

B. Off-Grid Simulation Result

The off-grid scenario is a hybrid system that is not designed to be connected to the grid, in which the electrical energy generated by the PV system is pure and there is no grid supply. That is, the electrical energy created cannot be sold to the grid and is not dependent on the grid for supply.

The absence of the existing grid from the grid distinguishes the off-grid scenario from the prior scenario. As a result, the Distributed Generator (DG) is deployed and used as a stand-alone power source to meet all electrical load requirements. The diesel generator off-grid system is linked with renewable energy generators and batteries. Under extreme conditions where PV will lose 90% of its efficiency, the diesel generator can improve the system's frequency responsiveness. Based on the software simulation (FTHS) colomn, the power output on the system performance displayed in Figure 8 reveals that the total energy gain created is 176,448 kWh/year and that renewable energy penetration must be 100%, with solar panels producing 176,448 kWh/year. The load requirement of 128,407 kWh/year, the power in the off-grid system scenario can be covered by PV power production, but the off-grid system still has 37,694 kWh/year extra electricity.

This off-grid situation is depicted in Table 8 column Rectorate for the simulation results in the Rectorate building. The energy output is 25,848 kWh/year, and renewable energy penetration is 95.7%, with solar panels producing 24,923 kWh/year. The power in the off-grid system scenario can be covered by the production of electrical power from solar panels with a load need of 21,287 kWh/year, but the off-grid system still has excess electricity of 2,822 kWh/year. When compared to the off-grid situation, the on-grid option produces the most electrical energy. The total hybrid electrical energy output of the FHST building is 728,807 kWh/year, while the total hybrid electrical energy production of the Rectorate building is 122,210 kWh/year.

Based on additional study of the simulation data, it can be shown that the suggested hybrid system has nearly the same renewable penetration value despite the fact that the system generates different electricity. Because system load demand, energy sold, and energy purchased all influence the value of renewable penetration. However, the hybrid system has a load demand with a fixed nominal value for each scenario, therefore the value of purchased and sold power determines the value of renewable penetration. If the system is on-grid, a blackout or other electrical disturbance can cause fluctuating variations in the electrical power to be sold or purchased. The influence on the on-grid system that is connected to the grid is readily visible. In the case of an off-grid system, the nominal renewable penetration will be 100%, with electric power generation exceeding load consumption needs. However, the renewable penetration value drops to 95.7% in the off-grid system of the Rectorate building because the power produced by the off-grid system in the Rectorate building is close to the total load requirements needed by the off-grid system in the Rectorate building, forcing the system to use a generator as an additional electric power supply.

C. Techno-economic Simulation Result

The values of each parameter entered into the Homer software are shown in Tables 9 and 10. The capital cost value is applied to the O&M price using the references stated before. The parameter in Homer is used to adjust the equipment life. The number of components is calculated based on the nameplate.

Table 7. Electricity Output of On-grid Scenario

Building	Photovoltaic (kWh/Year)	Load Demand Consumption (kWh/Year)	Grid Sales (kWh/Year)	Tot. Consumption (kWh/Year)	Excess Electricity (kWh/Year)	RE Penetration (%)
FHST	670,282	128,407	567,067	695.474	861	91.4
Rectorate	112.348	21.287	95.057	116,344	262	91.5

Table 8. Electricity Output of Off-grid Scenario

Building	Photovoltaic (kWh/Year)	Load Demand Consumption (kWh/Year)	Grid Sales (kWh/Year)	Tot. Consumption (kWh/Year)	Excess Electricity (kWh/Year)	RE Penetration (%)
FHST	176,448	128,407	0	128,407	37,694	100
Rectorate	24,923	21.287	0	21,287	2,822	95.7

Table 9. Homer Input Cost Parameters

No	Component	Capital Cost (Million Rp)		Replacement (Million Rp)		O&M (Million Rp)	
		FHST	Rectorate	FHST	Rectorate	FHST	Rectorate
1	Photovoltaic	5,280	885	0	0	352	59
2	Battery	644	112	431	75	0	0
3	Diesel Generator	304	68,7	203	48,1	3,472/Op. yr	9,2/Op. yr
4	Inverter	880	146	686	109	0	0

Table 10. Homer Input Quantity Parameters

No	Component	Quantity (pcs)		Capacity		Life Design	
		FHST	Rectorate	FHST	Rectorate	FHST	Rectorate
1	Photovoltaic	670	108	352 kWp	59 kWp	25 Year	25 Year
2	Battery	92	16	4,2 MWh	4,2 MWh	15 Year	15 Year
3	Diesel Generator	1	1	400 kW	100 kW	90,000 Hours	15,000 Hours
4	Inverter	440	73	440 kW	73 kW	15 Year	15 Year

Capital costs up to O&M were computed or assumed for the simulation parameters using data from the 2020 Energy Storage Grand Challenge Cost and Performance Assessment. It should be noted that the capital cost data supplied corresponds to $/kWh of accessible energy at 50% DOD for a lead-acid BESS consisting of a single cell, which is more expensive but has a longer life cycle.

According to Table 11, the economic value of the hybrid system in the FHST building has an NPC value of IDR 3,458,857,000.00 In the off-grid situation, the highest value is IDR 6,125,565,000.00 Furthermore, the on-grid scenario is the most affordable at IDR 1,047,534,000.00 Based on this, the on-grid option is the most profitable for the project over the next 25 years. When compared to the annual running costs of

e-ISSN 2622-6588 / p-ISSN : 2830-523X
Received: 18/09/2023, **Revised:** 16/10/2023, **Accepted:** 06/11/2023

Table 11. Techno-economic Hybrid Simulation Result of FHST Building

Assessment Criteria	NPC (Billion Rp)	Op. Cost (Million Rp)	COE (Rp)	Emission (kg/Year)	RE Penetration (%)
Based System (PLN)	3.5	185	1,444,70	81,153	9
On-grid Scenario	1.0	369	80.78	37,620	91.4
Off-grid Scenario	6.1	125	2,558.53	25.4	100

Table 12. Techno-economic Hybrid Simulation Result of Rectorate Building

Assessment Criteria	NPC (Million Rp)	Op. Cost (Million Rp)	COE (Rp)	Emission (kg/Year)	RE Penetration (%)
Based System (PLN)	573	30.7	1,444,70	13,453	0
On-grid Scenario	175	62.1	80.68	5,233	91.5
Off-grid Scenario	973	25.0	2,361.56	883	95.7

the on-grid base system of IDR 185,509,600 in the on-grid scenario of IDR 369,232,900 in the off-grid scenario of IDR 125,815,200 in the off-grid scenario. Based on this, the annual cost of the off-grid scenario is lower than the annual cost of the on-grid option. The lowest Cost of Energy (COE) cost in the on-grid scenario is IDR 80.78/kWh, IDR 2,558.53/kWh in the off-grid scenario, and IDR 1,444.70/kWh in the base system.

The on-grid scenario has the lowest cost, lowering prices by 95% to IDR 80.78/ kWh. With 0% renewable energy penetration, the grid (basic system) scenario emits 81,153 kg of CO_2/year. The on-grid scenario emits 37,620 kg of CO_2/ year, representing a 46% reduction with 91.3% increased renewable energy penetration, whereas the off-grid scenario emits 25.4 kg/year, representing a 98% reduction with 100% renewable energy penetration. Based on this, these two scenarios have the potential to reduce CO_2 emissions by >40% while increasing renewable energy penetration by > 90%.

According to Table 12, the NPC value or project cost for 25 years in the base system (grid) of the Rectorate building hybrid system is IDR 573,395,600.00, while the maximum value in the off-grid scenario is IDR 937,292,900.00. Furthermore, the on-grid scenario is the most affordable at IDR 175,024,100.00. The yearly operational cost of the on-grid base system is IDR 30,753,040.00/year, IDR 62,073,980.00/year in the on-grid scenario, and IDR 25,061,070.00/year in the off-grid scenario. Based on this, the annual cost of the off-grid scenario is lower than the annual cost of the on-grid option. The on-grid scenario's lowest COE cost is IDR 80.68-. The off-grid scenario costs IDR 2,361.56 per kWh, while the standard system costs IDR 1,444.70 per kWh. Based on this, the on-grid scenario has the lowest cost, lowering expenditures by 95% to IDR 80.68 per kWh. With 0% renewable energy penetration, the grid (basic system) scenario emits 13,453 kg of CO2 per year.

The on-grid scenario produces 6,233 kg of CO2 emissions per year, representing a 46% reduction with a 91.5% increase in renewable energy penetration. The off-grid scenario produces 883 kg of CO2 emissions per year, representing an 86% reduction with a 100% increase in renewable energy penetration. Based on this, these two scenarios can reduce CO2 emissions by more than 40% while increasing renewable energy penetration by more than 90%. The economic modeling findings suggest that the on-grid system's NPC value has declined significantly. The initial system capital cost of the on-grid system is IDR 982,355,770.00, with a total grid cost of IDR 2,294,878,459.76. Because the system is linked to the grid, grid sales and excess electricity generated can be sold to the grid. The entire sales of electric power in the on-grid system were IDR 1,985,064,919.27, lowering the on-grid system's NPC value to IDR 175,024,100.00.

e-ISSN 2622-6588 / p-ISSN : 2830-523X
Received: 18/09/2023, **Revised:** 16/10/2023, **Accepted:** 06/11/2023

The economic data of the proposed hybrid system for Universitas Jenderal Achmad Yani FHST and Rectorate buildings has been modelled. Each scenario that has been run shows that the on-grid system has the lowest NPC, Operation Cost, and COE expenses when compared to other situations.

V. CONCLUSION

Based on the investigation, the author concludes that the hybrid system in the FHST building has an annual load need of 128,407 kWh. With an on-grid total power generation of 729,807 kWh/year, grid sales of 567,067 kWh/year, and renewable energy penetration of 91.4%. The overall electric power production in the off-grid system is 176,448 kWh/year, and renewable energy penetration is 100%. The hybrid system in the Rectorate building has a load requirement of 21,287 kWh per year. With an on-grid total power generation of 122,210 kWh/year, grid sales of 95,057 kWh/year, and renewable energy penetration of 91.5%. The off-grid system produces 25,848 kWh/year and has a renewable energy penetration of 95.7%. Because the off-grid system generates electrical power without the assistance of the grid, the off-grid system does not have grid sales. Because it is connected to the grid, this hybrid system designed in the FHST and Rectorate buildings is based on the optimization of electricity distribution, integration of renewable and non-renewable energy, electric power output per year, and grid sales results. When compared to other systems, the on-grid scenario is the most optimal.

ACKNOWLEDGMENTS

Thanks to the research and community service institution through SKEP No/194/Unjani/VI/2023 for the research funds for the internal grant scheme in 2023.

REFERENCES

[1] IRENA, *International Renewable Energy Agency*, 2020th ed. Abu Dhabi: IRENA, 2020.

[2] International Renewable Energy Agency, "Renewable Energy Statistics 2022," International Renewable Energy Agency, Abu Dhabi, 2022. [Online]. Available: www.irena.org.

[3] International Renewable Energy Agency, *Indonesia Energy Transition Outlook 2022*, 2022nd ed. Abu Dhabi: International Renewable Energy Agency, 2022.

[4] F. Tanneberger *et al.*, "Towards net zero CO2 in 2050: An emission reduction pathway for organic soils in Germany," *Mires Peat*, vol. 27, no. 05, pp. 1–17, Jan. 2021, doi: 10.19189/MAP.2020.SNPG.STA.1951.

[5] Kementrian Energi dan Sumber Daya Mineral, "Rencana Umum Ketenagalistrikan Nasional 2019 - 2038." Kementrian Energi dan Sumber Daya Mineral, Jakarta, pp. 1–441, 2019, [Online]. Available: https://jdih.esdm.go.id/storage/document/Kepmen-esdm-143-Thn 2019 RUKN 2019.pdf.

[6] Undang Undang RI, "Undang-Undang No 16 Tahun 2016 Tentang Pengesahan Paris Agreement To The United Nations Framework Convention on Climate Change," p. 71, 2016.

[7] H. R. Iskandar, Y. B. Zainal, and S. Sambasri, "Study and Analysis of Shading Effects on Photovoltaic Application System," *1 st Int. Conf. Ind. Electr. Electron. (ICIEE) Int. Board Progr. Comm.*, vol. 218, no. 02004, pp. 1–8, 2018, doi: https://doi.org/10.1051/matecconf/201821802004.

[8] H. R. Iskandar, E. Darmawan, Y. B. Zainal, G. Angga Setia, N. Winanti, and F. Haz, "Design of Solar Power Plant for Electrical Engineering Department Laboratory," in *Proceedings of the 2nd International Conference on High Voltage Engineering and Power Systems: Towards Sustainable and Reliable Power Delivery, ICHVEPS 2019*, Oct. 2019, pp. 145–150, doi: 10.1109/ICHVEPS47643.2019.9011041.

[9] H. R. Iskandar, N. Heryana, N. Winanti, G. A. Setia, R. Ridwanulloh, and M. R. Alfarizi, "Optimal Design of Rooftop PV Systems for Electrical Engineering Department Laboratory," in *2021 3rd International Conference on High Voltage Engineering and Power Systems, ICHVEPS 2021*, 2021, pp. 349–354, doi: 10.1109/ICHVEPS53178.2021.9601097.

[10] V. B. Hau, M. Husein, I. Y. Chung, D. J. Won, W. Torre, and T. Nguyen, "Analyzing the Impact of Renewable Energy Incentives and Parameter Uncertainties on Financial Feasibility of a Campus Microgrid," *Energies*, vol. 11, no. 9, pp. 1–24, 2018, doi: 10.3390/en11092446.

[11] M. Der Yang, Y. P. Chen, Y. H. Lin, Y. F. Ho,

e-ISSN 2622-6588 / p-ISSN : 2830-523X
Received: 18/09/2023, **Revised:** 16/10/2023, **Accepted:** 06/11/2023

and J. Y. Lin, "Multiobjective Optimization using Nondominated Sorting Genetic Algorithm-II for Allocation of Energy Conservation and Renewable Energy Facilities in a Campus," *Energy Build.*, vol. 122, pp. 120–130, 2016, doi: 10.1016/j.enbuild.2016.04.027.

[12] R. Castrillón-Mendoza, P. A. Manrique-Castillo, J. M. Rey-Hernández, F. J. Rey-Martínez, and G. González-Palomino, "PV Energy Performance in a Sustainable Campus," *Electron.*, vol. 9, no. 11, pp. 1–24, 2020, doi: 10.3390/electronics9111874.

[13] L. N. Xing, H. L. Xu, A. K. Sani, M. A. Hossain, and S. M. Muyeen, "Techno-economic and environmental assessment of the hybrid energy system considering electric and thermal loads," *Electron.*, vol. 10, no. 24, 2021, doi: 10.3390/electronics10243136.

[14] M. Sim, D. Suh, and M. O. Otto, "Multi-objective Particle Swarm Optimization-based Decision Support Model for Integrating Renewable Energy Systems in a Korean Campus Building," *Sustain.*, vol. 13, no. 15, pp. 1–18, 2021, doi: 10.3390/su13158660.

[15] F. Nazipov, S. Tokbolat, D. Khussainova, M. Mustafa, and A. Almahadin, "Integration of Renewable Energy Technologies in University Campuses: a Case Study," in *IOP Conference Series: Materials Science and Engineering*, 2021, vol. 1044, no. 1, pp. 1–6, doi: 10.1088/1757-899x/1044/1/012015.

[16] S. L. Gbadamosi, F. S. Ogunje, S. T. Wara, and N. I. Nwulu, "Techno-Economic Evaluation of a Hybrid Energy System for an Educational Institution: A Case Study," *Energies*, vol. 15, no. 15, pp. 1–12, 2022, doi: 10.3390/en15155606.

[17] T. M. I. Riayatsyah, T. A. Geumpana, I. M. Rizwanul Fattah, S. Rizal, and T. M. Indra Mahlia, "Techno-Economic Analysis and Optimisation of Campus Grid-Connected Hybrid Renewable Energy System Using HOMER Grid," *Sustain.*, vol. 14, no. 13, pp. 1–18, 2022, doi: 10.3390/su14137735.

[18] G. Gehlert, M. Wiegand, M. Lymar, and S. Huusmann, "Simultaneity in Renewable Building Energy Supply—A Case Study on a Lecturing and Exhibition Building on a University Campus Located in the Cfb Climate Zone," *Sustain.*, vol. 14, no. 19, pp. 1–18, 2022, doi: 10.3390/su141912538.

[19] M. Raman, P. Meena, V. Champa, V. Prema, and P. R. Mishra, "Techno-economic Assessment of Microgrid in Rural India Considering Incremental load Growth Over Years," *AIMS Energy*, vol. 10, no. 4, pp. 900–921, 2022, doi: 10.3934/energy.2022041.

[20] A. Xu, L. J. Awalin, A. Al-Khaykan, H. F. Fard, I. Alhamrouni, and M. Salem, "Techno-Economic and Environmental Study of Optimum Hybrid Renewable Systems, including PV/Wind/Gen/Battery, with Various Components to Find the Best Renewable Combination for Ponorogo Regency, East Java, Indonesia," *Sustain.*, vol. 15, no. 3, pp. 1–15, 2023, doi: 10.3390/su15031802.

[21] M. A. H. Alshehri, Y. Guo, and G. Lei, "Renewable-Energy-Based Microgrid Design and Feasibility Analysis for King Saud University Campus, Riyadh," *Sustain.*, vol. 15, no. 13, pp. 1–24, 2023, doi: 10.3390/su151310708.

[22] PT. PLN (Persero), "Penetapan Penyesuaian Tarif Tenaga Listrik (Tarrif Adjusment)." PT. PLN (Persero), Jakarta, p. 1, 2023, [Online]. Available: https://web.pln.co.id/pelanggan/tarif-tenaga-listrik/tariff-adjustment.

[23] A. Rachmi, B. Prakoso, Hanny Berchmans, I. Devi Sara, and Winne, "Panduan Perencanaan dan Pemanfaatan PLTS atap di Indonesia," *PLTS Atap*. ICED (Indonesia Clean Energy Development), p. 94, 2020, [Online]. Available: https://drive.esdm.go.id/wl/?id=XOegh8pXO9FMjebl4x0joDD6hIZe94Fm.

[24] V. Viswanathan, K. Mongird, R. Franks, X. Li, V. Sprenkle, and R. Baxter, "Grid energy storage technology cost and performance assessment 2020," 2020. [Online]. Available: https://www.energy.gov/energy-storage-grandchallenge/downloads/2020-grid-energy-storage-technology-cost-and-performance.