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Solar Electricity Energy: Utilization of Renewable Energy Sources to Realize a Sustainable Campus at UIN Raden Fatah Palembang

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Abstract. Universities play an essential role in achieving Indonesia's 2060 carbon-neutral target. Emissions in the campus are mainly sourced from its electrical energy, transportation, and water use, along with other wastes. Electrical energy from solar is renewable energy, free from pollutants and noise pollution. This paper examines the sustainable energy performance of solar energy at the Universitas Islam Negeri Raden Fatah Palembang (UINRFP) and its development efforts. From August 2022 to March 2023, a solar power plant (SPP) operation with a capacity of 7.74 kWp has generated 6,281.5 kWh of electricity (28.55 kWh/day). Using a radiation factor of 0.8 and an equivalent sun hour of 4.61 (3-5 hours/day), the rooftop capacity of all buildings on Jakabaring Campus is 2,000 kWp, the potential of SPP electricity of UINRFP will exceed 39.3% compared to the 2022 electricity demand. If the capacity is, half the electricity generated from renewable energy meets 70% of the demand. Gradually UINRFP continues to develop its energy sources towards sustainable energy. The development of other research-scale renewable energy with hybrid solar energy and wind power for the aesthetic lighting function on the rectorate building has the potential to generate 290 kWh/year. In addition, micro-hydro energy sources from campus canals (water volume ±9,400 m^3) and biomass are potential renewable energy sources at UINRFP for a sustainable campus in the future and contributing to reducing the impact of climate change.

Keyword:

Solar Energy, SPP, Solar-Wind Energy Hybrid, Sustainable Energy, Micro-Hydro, Biomass

1. Introduction

The construction of the Universitas Islam Negeri Raden Fatah Palembang (UINRFP) campus is carried out sustainably, always based on mutually acceptable academic values and universal and global academic values, and integrated with the fundamental importance of Islamic education, namely Tawazzun (balance), Tasamuh (tolerance), Obadiah (worship), Ahsan (excellence), wah Hashanah (exemplary), and Riyadh (leadership). The value of a universal and global academic balance between individual and social interests and between science and charity [1].

Efforts to realize the fundamental values through establishing UINRFP's vision: "To become a university with international standards, with a national perspective and Islamic character in 2040". A world-class university is achieved through international recognition and cooperation in the field of sustainability, which is in synergy with the tri dharma of higher education—furthermore, implementing the SDGs and realizing a green and environmentally friendly campus based on global sustainable standards, including the UI GreenMetric World University Rankings (UIGMWUR).

The implementation and performance of a sustainable green campus is a policy to be implemented by all academics in the UINRFP campus area. Activities to create a green campus include water-soil-land conservation, flora-fauna conservation, energy efficiency and conservation, water resource management and efficiency, green transportation, green building, waste management, greenhouse gases (GHG) emission reduction, as well as education and research based on sustainability- environmental friendliness and climate change adaptation. Regarding efficiency and energy conservation, the UINRFP campus is trying to substitute non-renewable sources for renewable ones by developing solar power plants (SPP), hybrid solar-wind power, energy potential from biomass, and micro-hydro. Energy efficiency and conservation policies in the campus area are contained in the Chancellor's Decree Number 1790 of 2022 concerning energy-saving policies on the UINRFP campus.

The need for electricity and energy on campus is quite large, directly proportional to the number of students and academic staff and the number of supporting infrastructure. Therefore it is necessary to convert from potential resources owned to renewable energy. The energy development potential will come from solar panels, water-swamp resources, and biomass (remaining vegetation and domestic waste). Efforts to convert electricity to renewable energy sources are the campus' contribution to reducing greenhouse gas (GHG) emissions from using electricity by PT Perusahaan Listrik Negara (PLN). At the same time, this effort is the contribution and implementation of the campus in realizing the achievement of the SDGs (Sustainable Development Goals) targets. The various efforts above and the development of existing potential can make the campus environmentally friendly with low carbon emissions that support a low carbon economy and Indonesia's carbon-neutral performance in 2060 [2, 3].

The importance of adaptation to climate change and to increase the reduction of carbon emissions requires conversion from non-renewable to renewable energy according to the potential of the campus. Therefore, this paper will examine the performance of sustainable energy from the Sun at Universitas Islam Negeri Raden Fatah Palembang (UINRFP) and development efforts in supporting the achievement of a green and sustainable campus.

2. Implementation of Clean and Sustainable Energy at UINRFP

2.1. The solar power plant characterization and performance

A solar power plant (SPP) has been built on the UINRFP campus since 2022. The first renewable energy operation on campus has a capacity of 7.74 kWp. Solar panels are devices that can convert sunlight energy into electrical energy. SPP solar panels with photovoltaic (PV) technology directly convert solar radiation (photon energy) into electrical energy.

PV is composed of materials made from semiconductors such as silicon titanium oxide. The PV type used is monocrystalline because it has high efficiency and higher crystalline silicon (c-Si) material purity compared to the polycrystalline type. Solar panels can be an alternative to generating electricity independently (off the grid) or with other energy sources (on the grid).

SPP produces electricity from solar energy, which is obtained free of charge. Indonesia is on the equator, so it is very rich in solar energy sources with an average solar radiation intensity of around 4.8 kWh/m^2/day (http://www.litbang.esdm.go.id) (4.5 kWh/m^2/day according to Bachtiar, 2006 [4]). The location of UINRFP's solar panels is still around the equator (03^{o}00'35.96"; 104^{o}46'22.60") (Figure 1), so it has excellent strategic value and SPP productivity. SPP is installed on the roof of the Central Administration Building (Rectorate) of the Jakabaring Campus (rooftop type) as an effort to empower space and usability in land use [5, 6].

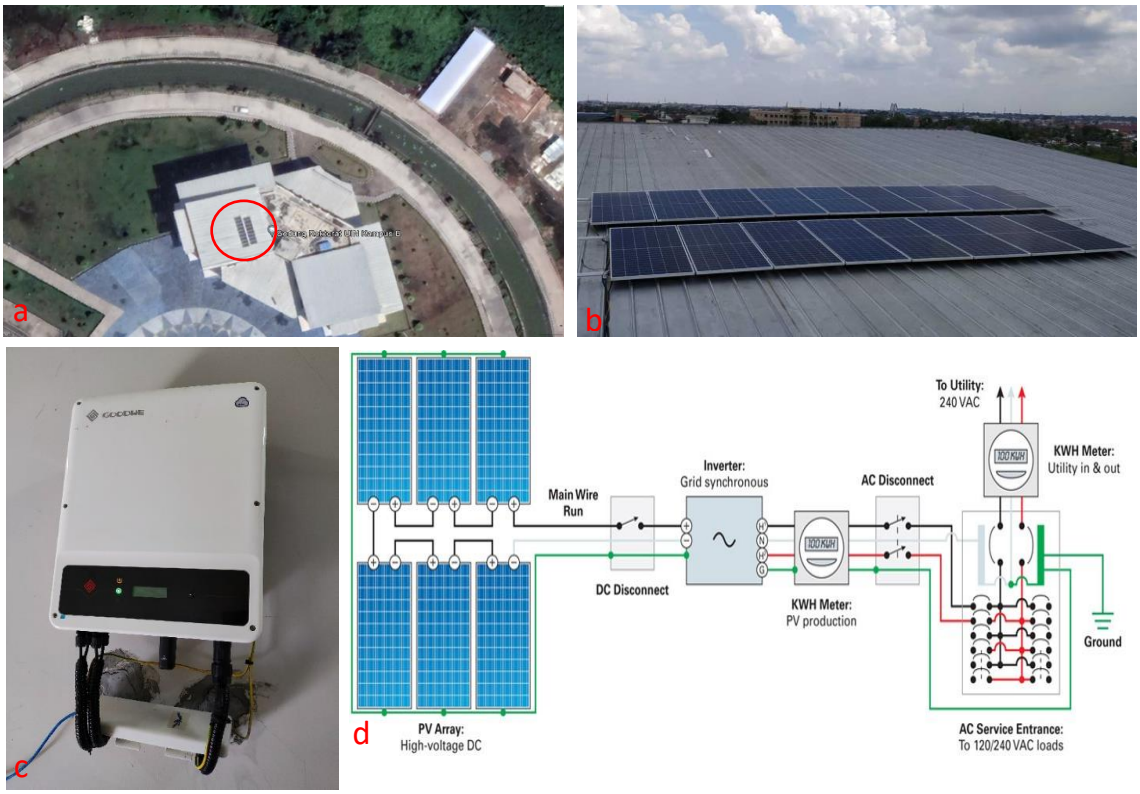

Figure 1. (a) The location of the rooftop PV in the red circle, (b) Installed solar panels, (c) Inverter system, (d) Diagram of the rooftop SPP system

The on-grid system was chosen because the PV capacity is still relatively small, without battery units so it is more economical, the electricity produced is directly used, as well as substituting the use of PLN electricity. This system is supported by an inverter system which is equipped with voltage and frequency synchronization units, real-time production

monitoring, so that electricity production when it reaches working voltage can be directly distributed to the load network, and management-monitoring of generators can be done real-time anytime anywhere. The weakness of this SPP system is that it is only productive during the day when there is sunlight.

SPP consists of 17 solar panels, each with a capacity of 0.455 kWp (total 7,735 Wp) of monocrystalline type. It has been operational for 8 months (August 2022 to March 2023) with a dynamic radiation capacity that has generated 6,281.5 kWh of electricity (220 days) or an average of 28.55 kWh/day with an average electricity value per month of Rp. 1.13 million (Table 1). SPP has an equivalent sun hour value of 4.61, this value is quite good and almost reaches the maximum (theoretical 3-5 hours/day). The equivalent sun hour value is obtained based on the performance of solar panels and their integration with the climatic conditions of the Jakabaring Campus area. The natural conditions and campus environment support the development of SPP's renewable electricity production. Therefore in the future it will continue to be increased, so that it will significantly reduce electricity consumption from non-renewable PLN, as well as reduce GHG emissions. The non-renewable energy conversion program to renewable energy continues to be pursued based on SPP, and uses other resources such as biomass and micro-hydro.

Table 1. UINRFP SPP Productivity

Month	Electricity generated (kWh/month)	Value (Rp.)	Number of days	Productivity (kWh/day)
August '22 [a]	484.1	699,040.4	15	32,27
September	913.6	1,319,238.4	30	30.45
October	892.7	1,289,058.8	31	28.80
November	894.7	1,291,946.8	30	29.82
December	819.1	1,182,780.4	31	26.42
January '23	838.0	1,210,072.0	31	27.03
February	772.5	1,115,490.0	28	27.59
March [b]	666.8	962,859.2	24	27.78
Amount	6281.5	9,070,486.0	220	28.55

[a] Starting operations August 16, 2022
[b] Until March 24, 2023

The relationship between air temperature is directly proportional to the electricity produced (Figure 2). The average daytime air temperature (06.00-18.00) can be an indicator and positively correlate with SPP electricity production. However, PV has a certain tolerance to air temperature (temperature increase to a particular value), followed by a rise in electricity produced. From Figure 2, the average air temperature is 33.47^{o}C (30 November 2022), has electricity production > compared to the average temperature of 34.26^{o}C (42.1 > 40.8 kWh). PV performance is based on the level of solar radiation and can be confirmed by the air temperature. In addition, air temperature also has a direct effect on PV performance. Thus, solar radiation or air temperature are the main factors in SPP productivity with PV technology. The effect of temperature on PV performance is in line with previous studies, that the factors that affect the performance of solar panels are solar radiation, temperature, and wind speed. The increase in temperature causes the open circuit voltage (Voc) to decrease, and the power

generated by the solar panels decreases. The rise in temperature in solar panels also affects the electrical efficiency of a solar panel [7, 8].

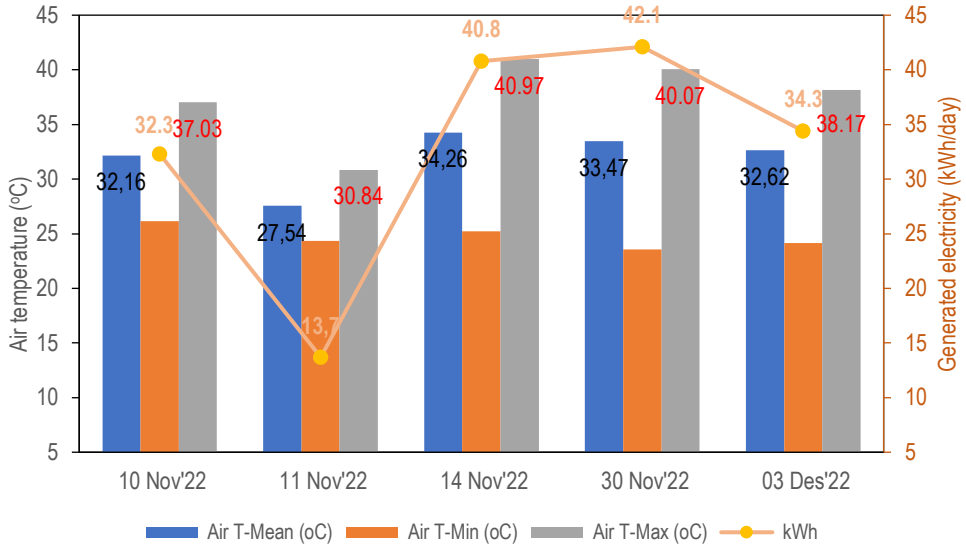

Figure 2. The relationship between electricity production from SPP and air temperature in the Jakabaring Campus area

2.2. Renewable energy management system at SPP

SPP uses an integrated inverter system (Goodwe SDT G2 [3-Ph] 8kW), which allows monitoring of production performance and use of electricity load from SPP. This system consists of a solar charge controller (SCC) type MPPT (maximum power point tracking), an inverter with a synchronous grid, and an IoT system with an Android application. It was equipped with a web-based application (https://semsportal.com/) to monitor SPP performance in real-time (Figure 3). This system becomes a smart meter that is integrated into the SPP system. This system is the basis for the management and development of SPP at UINRFP, including using data and information in conducting various studies related to SPP, renewable energy, and other related fields or themes.

2.3. SPP development

The UINRFP campus area is 125.28 Ha, covering three regions, namely the Sudirman Campus (6.5 Ha), the Jakabaring Campus (15 Ha), and the Payakabung Campus (103.78 Ha) [9], SPP 7.74 kWp and a solar-wind power hybrid pilot small-scale (290 kWh/year) (Figure 4) is located in the Jakabaring Campus Rectorate Building. This area has good potential for renewable energy development. Among other types of solar power plants, they have highly feasible natural conditions through the SPP rooftop type [10]. SPP development in 9 main buildings, each with four floors, in a relatively open environment. Massive tree planting is used to conserve soil water and flora fauna.

The performance of the first SPP was excellent, and gradually it continues to be developed with various schemes with internal and external resources. A study and analysis have been conducted on developing a rooftop SPP at the Jakabaring Campus in 9 building units with a maximum capacity of 2000 kW (2 MWp). This capacity is enormous and can meet all the electricity needs of the Jakabaring campus, even more than 39.3% compared to 2022 electricity consumption, if the development of SPP with half the capacity can meet 70% of

electricity needs (Table 2).

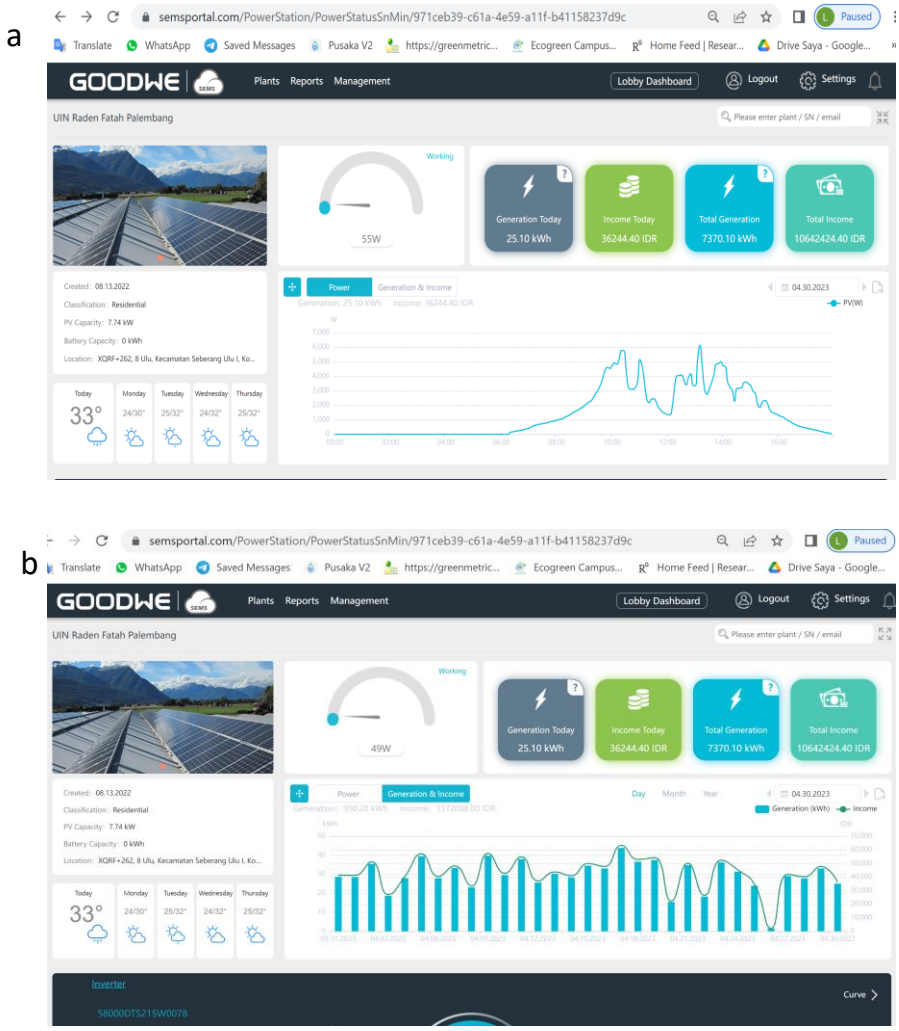

Figure 3. Website-based SPP monitoring system, (a) April 30, 2023 performance, (b) April 2023 performance

Figure 4. Pilot hybrid solar-wind power, (a) schematic, (b) wind turbine

Table 2. SPP development plan for the Jakabaring Campus area

Development potential	Generated electricity (kWh/day) [a]	Generated electricity (kWh/year) [b]	Meet campus needs (%)
2000 kWp	7376	2692240	139.32
1000 kWp	3688	1346120	69.66

[a] Based on a radiation factor of 0.8 and an equivalent sun hour of 4.61

[b] Jakabaring Campus electricity consumption in 2022 = 1932400 kWh

SPP is the hope and development plan at UINRFP in contributing to reducing greenhouse gas emissions and implementing a green campus and concrete action in accelerating the achievement of Indonesia's 2060 net zero emissions and or carbon neutral [11]. SPP is also a solution for reducing campus dependence on non-energy sources. Renewables are converted to renewable energy. Through the campus rooftop SPP development, the ratio of renewable to non-renewable energy utilization will increase (> 25% of total demand). Therefore, to increase the ratio of renewable energy, the development of renewable energy must be carried out together with other renewable energy resources owned in the UINRFP campus area.

The development of renewable energy sources is, of course, carried out in stages and systematically. Development is carried out with internal/independent funding capabilities and external sources from other parties. This development was carried out with the consideration of budget capability and priority level in the implementation of realizing sustainability and environmental friendliness, as well as with the integration of productivity on the UINRFP campus.

On the pilot scale, hybrid solar-wind power panels are also being developed. Trials were carried out with a capacity of 200 Wp (solar panel) and 2kW (wind turbine) with an electricity production of ±290 kWh/year. Wind turbines are not yet optimal in their development because they are related to wind resources, appropriate systems/methods, and appropriate infrastructure [12]. Hybrid solar power and pilot-scale wind power are used for utilization for lighting and aesthetics above the Jakabaring Campus rectorate building.

2.4. Potential renewable energy sources on the UINRFP campus

The Jakabaring Campus was built on swampland but with the concept of adaptation so that the function of the swamp remains sustainable and the land becomes efficient and valuable as a university area. The entire building uses piles that support the building without the accumulation of swamps. Soil is consolidated and allows swamp land to exist, with various functions such as water conservation and management, flora-fauna conservation, food/nutrition source for living things, environmental pollution prevention, etc. Drainage channels (canals) were built around the campus building and several retention lakes to accommodate rainfall water discharge and surface water flow (Figure 5).

The existence of a canal with an area of 9400 m^2 (water volume ±9400 m^3) has many benefits besides its function as water management (water management), a home for aquatic biota; it also has potential as a renewable energy resource. Hydropower-based renewable energy is the potential to develop MHP (micro-hydro power plant) [13].

Another renewable energy source from campuses is biomass, which comes from plant residues, domestic waste (wastewater from toilets and sewage), food waste, and canteen

wastewater [14, 15]. Maximum effort is needed to innovate and develop this type of renewable energy. It needs to be carried out in stages on a laboratory, pilot, and field scale (scale-up). Even though the output is small, with the right application-according to the material conditions of the source of local organic compounds, suitability for the application of biotechnology, and adaptation to local (endogenous) microorganisms, it will be able to produce optimum renewable energy. Among other things, through the development of biomass conversion biotechnology, such as an anaerobic digester (AD), biogas will be produced; and pyrolysis will produce bio-oil, syngas, and bio-char [16].

Figure 5. Water canals surrounding the campus area and retention lake at the Jakabaring Campus

3. Conclusion

UINRFP continues to innovate and implement in realizing a green campus that is sustainable and environmentally friendly, contributes to achieving the SDGs target, and is Indonesia's 2060 carbon-neutral target. A sustainable green campus is a mandate according to the university's vision towards a global university in 2040. The university's first SPP has a capacity of 7.74 kWp, excellent productivity, an average of 28.55 kWh/day, and an equivalent sun hour of 4.61. This SPP continues to be developed to equal 70% of meeting the needs of the Jakabaring Campus (1 MWp). The implementation and development of other renewable energy sources is a hybrid solar-wind power research pilot, micro-hydro, and biomass potential from the campus area and its surroundings. The above performance is part of UINRFP's goal of realizing a green campus by converting non-renewable energy to renewable energy. This effort is also the university's contribution to reducing GHG emissions and climate change's impact through integration and synergy with the tri dharma of higher education.

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