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Dynamic System Modeling of Renewable Energy Diversification at ITS Surabaya as a Sustainable University Management Effort

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***Abstrak*—Diversification is an effort to diversify various energy sources through reducing the use of fossil energy sources and substituting them with other energy sources including RE in order to optimize energy supply. Meanwhile, energy conservation is a systematic, planned and integrated effort to conserve existing energy resources and increase the efficiency of their use. Energy has a very significant role in human life in all sectors. Where energy demand in the commercial sector such as offices and services is still largely dominated by electricity around 60% -70%. Where the management is still largely managed by the State Electricity Company (PLN). The electricity consumption of the ITS Surabaya campus in 2019 around 9,586,857.72 kWh / year is still supported by PLN with a total expenditure of more than 9 billion. Considering the Indonesian government's program on the Target of Diversification of RUEN at least 23% in 2025 and 31% in 2050 and one of the 2030 Agenda for Sustainable Development Goals (SDGs) globally namely clean and affordable energy, the ITS Surabaya management effort is to achieve diversification of energy sources 50% renewable as stated in the 2015-2020 RENSTRA Target. The effort to diversify this renewable energy is by building a 16 KWP On Grid Solar Power Plant in the Research Center Building, which has produced around 26,290.92 kWh / year during the 2019 period.**

***Kata Kunci*—Dynamic System, Diversification RE, Electricity Needs and Fullfillment, Solar Power Plants, Payback Period, Sustainable Energy.**

I. INTRODUCTION

SUSTAINABLE energy management is an important part of the overall campus sustainable management consideration. A university as an educational institution and producer of intellectual human resources, is expected to be able to create and encourage the development of innovation projects that support the independence of institutions through a combination of institutional resources and appropriate technology in them.

The reduced production of fossil energy, especially petroleum, encourages the Government of Indonesia to make energy efficiency and diversification by increasing the role of New and Renewable Energy (RE) in maintaining national energy security and independence as stipulated in Government Regulation No. 79 of 2014 concerning National Energy Policy (KEN) in stipulate a progressive increase in the Renewable Energy Mix, with the target of the National Energy General Plan (RUEN) in the primary energy mix reaching at least 23% in 2025 and at least 31% in 2050 [1-5]. With the projected supply of RE in the energy mix that produces electricity or direct use in 2025 and 2050 can be seen in Figure 1. Electricity is a necessity and livelihood of many people, is one of the products of fossil energy that is increasingly rare and expensive. Based on 2018 data from the Ministry of Energy and Mineral Resources (KESDM) of Indonesia, the demand for energy in the commercial sector such as offices and services is still largely dominated by electricity, which is around 60% -70%. Where the increase in electricity demand in the commercial sector is predicted to increase about 7 times by 2050, with an average growth rate of electricity demand around 6% - 7% per year during the 2018-2050 period [3].

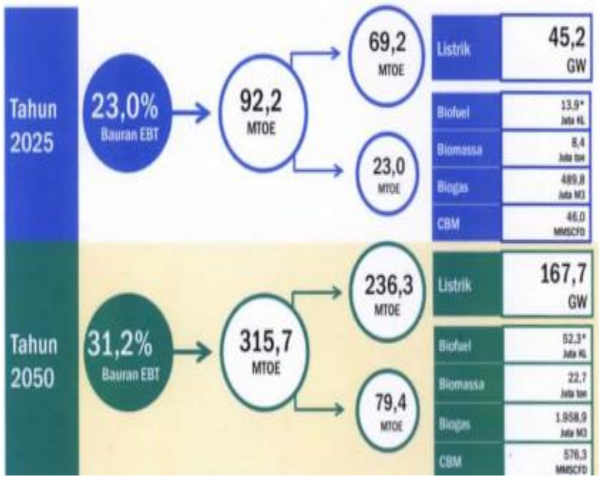

Figure 1. Primary Energy Supply - EBT in 2025 and 2050.

Indonesia as an archipelago that is crossed by the equator has abundant natural resources that can be utilized maximally as the best alternative energy source, namely the utilization of solar energy as a new and renewable energy source (EBT). Solar energy sources are scattered throughout the territory of Indonesia, so that the potential for PLTS to be developed or utilized by installing solar rooftop panels. According to Solarex (1996), Indonesia as a tropical country has high solar energy potential with an average irradiation of 4.5 kWh/m2/day - 5.0 kWh/m2/day, which means that for 1 Kw photovoltaic (PV) or 1 kWp solar panels have potential to produce 3.4 kWh to 5 kWh of electrical energy in one day [6-8]. The level of irradiation and the potential of solar energy in territory of Indonesia be explained in Figure 2 and Figure 3.

ITS Surabaya Campus is one of the largest campuses in the East Java region which has an area of around 180 hectares with a total building area of around 150,000 m2 [9]. ITS Surabaya has 10 faculties with 38 departments and is

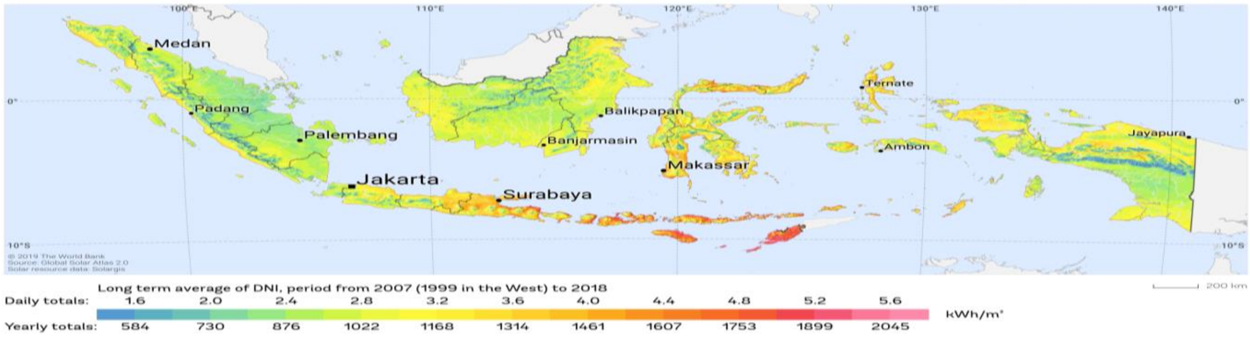

Figure 2. Direct Normal Irradiation in Indonesia.

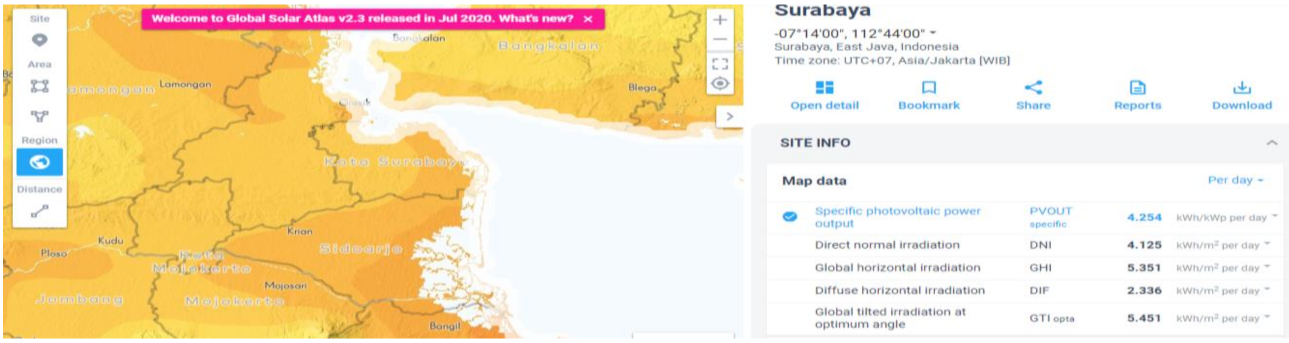

Figure 3. Photovoltaic Power Potential in Surabaya Region.

equipped with facilities including: student advisory center, language and cultural center, library, sports center, ITS house, student dormitory, mosque, health care center, and printing and publishing. With a total active academic population of around 21,714 people in 2018/2019 [10-12]. Then for electricity needs as part of its management operations, the ITS Surabaya campus has two electricity substations from the State Electricity Company (PLN) which supplies electricity to all buildings on campus called the Campus Power House and the Rector Power House. According to the Chair of ITS-Smart Eco Campus, Dra Dian Saptarini M.Sc in a seminar in 2018 said that every year ITS Surabaya spends around Rp. 7,000,000,000 for electricity payments in operations, and increased to around Rp. 9,000,000,000 in 2019 [13].

At present, Surabaya ITS Campus has started an effort in energy diversification by building one of ITS On-Grid PLTS located in the Research Center Building with a capacity of 16 WP. Based on Global Solar Atlas data, the Surabaya city area (-07 ° 14'00 ", 112 ° 44'00") where this research was conducted, as Figure 3. has the potential for electrical energy (kWh) that can be generated by installing 1 kWp solar panel (Photovoltaic Module) can produce daily energy around 4.25 kWh per day, with irradiation rates per day between 4.13 kWh / m2 to 5.35 kWh / m2 [8].

Based on the 2019 ITS Year-End Performance Report related to 3 Strategic Initiatives, it is stated that there are 20 Performance Indicators that serve as benchmarks for measuring the achievement of strategic objectives, where 6 indicators have reached the target of 100% or more, and 5 several indicators has not reached 50% of the target value, one of which is the Ratio of RE-Based Electricity Energy (kWh) per Total Electrical Energy Usage [14].

Diversification is an effort to diversify energy use through reducing the use of fossil energy sources and substituting them with other energy sources including RE. Meanwhile, energy conservation is a systematic, planned and integrated effort to conserve energy resources and increase the efficiency of their use.

The selection of the ITS Surabaya campus as a place of research was carried out with consideration of: (1). ITS Surabaya is one of the well-known and largest campuses in the East Java region that has a SMART ECO CAMPUS program that has been launched since 2011, is a more comprehensive eco-campus development by managing the environment, managing solid and liquid waste in an integrated manner, adding forest areas campus and park as well as streamlining the use of energy and clean water, bird, mammal and plant conservation activities, eco-urban farming and empowering campus internal transportation (campus bicycles and campus buses) [15]; (2). The efforts of the Surabaya ITS Campus in supporting the development of renewable energy in accordance with the 2015-2020 ITS RENSTRA as a National Medium-Term Development Plan for 2015-2019 with the aim of developing science and technology with policies directed at increasing research results [16]; (3). Support one of the 2030 Agenda for Sustainable Development Goals (SDGs) globally and nationally about clean and affordable energy, in reaching the concept of sustainable energy management [17-18]. (4). The target of the government of the Republic of Indonesia on the National Energy General Plan (RUEN) in an effort to increase the role of the energy mix by renewable energy sources (EBT) through the energy diversification program as an efficient step in the use of electricity, so as to be able to support sustainable university management [2].

II. METHOD

This research took place at the Sukolilo ITS Campus in

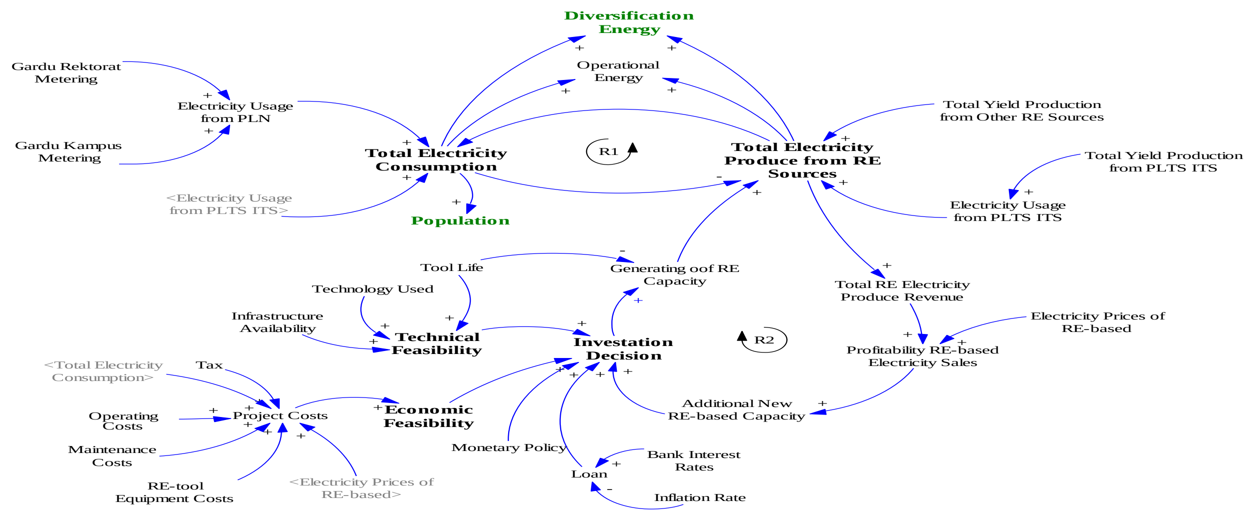

Figure 4. Causal Loop Diagram Operasional Energy in ITS Surabaya.

Table 1.
Mean comparison (E1) and Error comparison (E2) for electricity consumption in ITS Surabaya

Variabel	Average (Volt Ampere/VA)		Mean Comparison	Standard Deviation (VA)		Error Variance
	Data	Simulation	E1 ≤ 5%	Data	Simulation	E2 ≤ 30%
Rektorat Powerhouse	4,706,079.33	4,629,610.30	2%	80,6785.71	705,157.25	13%
Kampus Powerhouse	4,857,590.21	4,958,481.30	2%	775,795.60	819,349.99	6%
PLTS ITS	26,290.92	25,797.67	2%	2190,91	2,149.81	10%
Total Electricity Consumption per year	9,589,960.46	9,613,889.27	2%	1,584,772.22	1,526,657.04	1%

Surabaya, East Java. The quantitative approach is used by analyzing historical data obtained by observation and study of literature. The Dynamic System Framework was chosen to facilitate the identification of internal and external variables that have a significant impact on the problem to be discussed, and simulated its scenarios. So that it is expected to get a reference to the results desired by management in the next policy making process.

According to Sterman (2000), Dynamic System modeling that is modeled is a system problem [19]. The steps involved in dynamic system simulation are as follows: (1). Problem Identification and Purpose; (2). Literature Study and Identification of Significant Variables; (3). Inventory Data; (4). Development of Simulation and Model Formulation; (5). Model Verification and Validation; (6). Model Simulation; (7). Scenario; (8). Model Analysis and Interpretation.

A. Problem Identification and Research Purpose

The background of this research is the problem of energy management in ITS Surabaya Campus, especially electrical energy. By raising focus on efforts to diversify internal renewable energy, in the context of *efficient* use of fossil electricity with the diversification of internal RE sources and green energy *conservation* in support of sustainable university management. The formulation of the problem is used to determine the factors that are a problem in energy diversification with technical-economic considerations. With the aim to be used in making scenarios and alternative problem solving where the results will be used as a strategic consideration for ITS Surabaya management. Based on the development of the government policy situation in an effort to increase the role of renewable energy sources, and the efforts of the Surabaya ITS Campus in supporting sustainable energy, the research questions are:

1. What is the total electricity usage per year in the ITS Surabaya Campus ?
2. What is the electricity demand per capita in the ITS Surabaya Campus?
3. What is the potential for electrical energy that can be generated by Solar Power Plants (PLTS) ITS Surabaya?
4. Calculation of Payback Period for existing PLTS investments?
5. Scenarios for efforts to diversify internal energy from RE sources in the form of solar power plants (PLTS), if (a). Current Conditions (BAU); (b). Adjusting the RUEN Targets in the Energy Mix progressively, at least 23% in 2025 and at least 31% in 2050; (b). Adjusting ITS 2015-2020 RENSTRA Surabaya, around 50% ?

B. Literature Study and Identification of Significant Variables

After that, the literature study is done by studying the internal history of the report data, information data from previous studies and also other sources of information. The aim is to determine key performance indicators and significant variables in the real system that will be used in simulation modeling. The identification of these variables aims to facilitate the preparation of the next stage, namely the

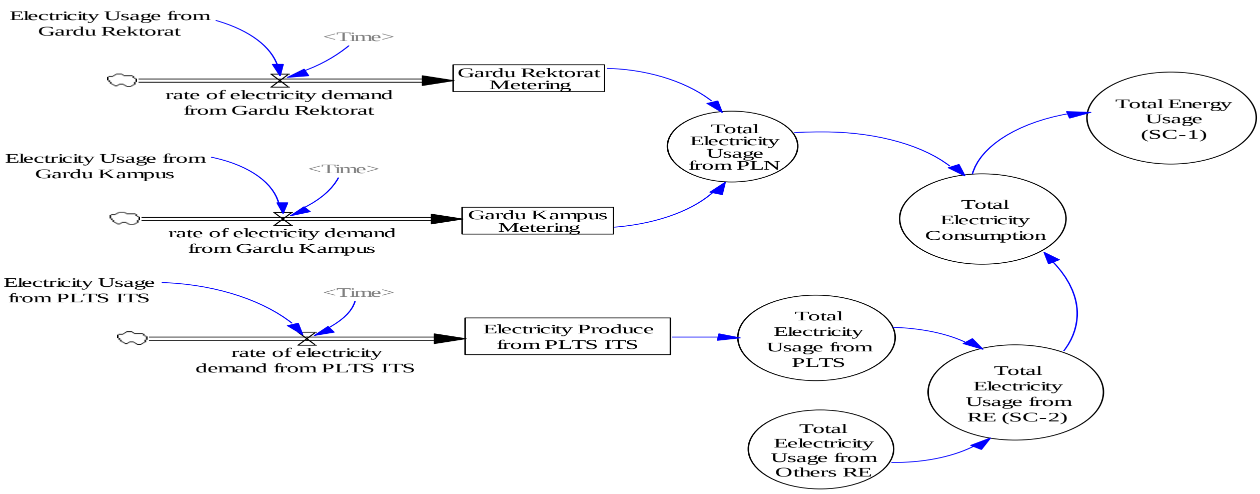

Figure 5. Stock Flow Diagram Total Energy Consumption.

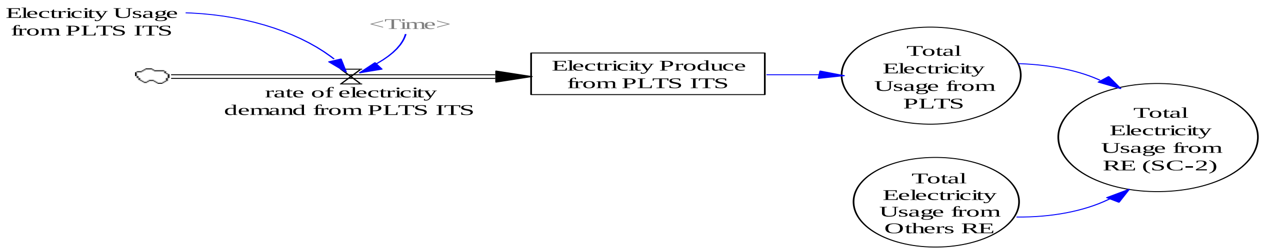

Figure 6. Stock Flow Diagram Total Electricity Usage from RE in ITS Surabaya Campus.

making of causal loop diagrams (CLD).

C. Data Inventories

A quantitative approach was used in this study. Primary data inventory is carried out by interviewing and collecting historical data derived from reports in the relevant sections of the ITS Surabaya Campus; and secondary data from previous research literature, articles or related online data source information.

D. Development of Simulation and Model Formulation

The development of simulation models in this study uses ventana simulation (vensim) tools as a tool to model the electrical operational system at ITS Surabaya. Based on the problem described above, the next step is to develop a model with a causal loop diagram (CLD) based on the representation of a real system, by visualizing how the variables and parameters are related to a system.

The CLD development phase is followed by the development of a stock and flow diagram (SFD). The development of SFD remains based on the CLD that was developed in the previous stage. With SFD, the conceptual system is more towards a model that can be simulated. SFD becomes an important stage because it represents the modeling of the actual system to be simulated according to the Dynamic System Method. SFD development steps, variables and parameters obtained can be improved again.

So that diagrams can be translated into models that can be simulated, each component in SFD is given a certain equation. Each component is determined by what form of equation is appropriate, so the SFD which already has a calculation equation is ready to execute the simulation.

The formulas used to connect between components of the model in the problem of energy diversification with consideration of technical-economic analysis, are :

1) Electricity Consumption

Electricity Consumption per Capita (kWh/capita) [18];[20]: used to determine the average electricity consumption per capita per year. The capita population referred to is the ITS Surabaya academic population consisting of lecturers, students and educators. Obtained by dividing the total electricity use (TPEL) by the total population (JP).

$$KLpk = \frac{TPEL}{JP} \quad (1)$$

2) Energy mix or Energy Diversification

Energy mix or *Energy Diversification* [18][20-21] : Used to find out how much the proportion of renewable energy use to total energy. Obtained by dividing the total renewable energy consumption (KRBT) with the total electricity consumption (KEF).

$$BET = \frac{KRBT}{KEF} \times 100\% \quad (2)$$

3) The Payback Period

The *Payback Period* method is used to calculate the amount of time needed to return the invested capital at the beginning[7][22]. So that the benefits of the costs incurred in the process of developing solar power plants with the results of the sale of energy obtained from the production capacity produced, can be an appraisal of the feasibility of a renewable

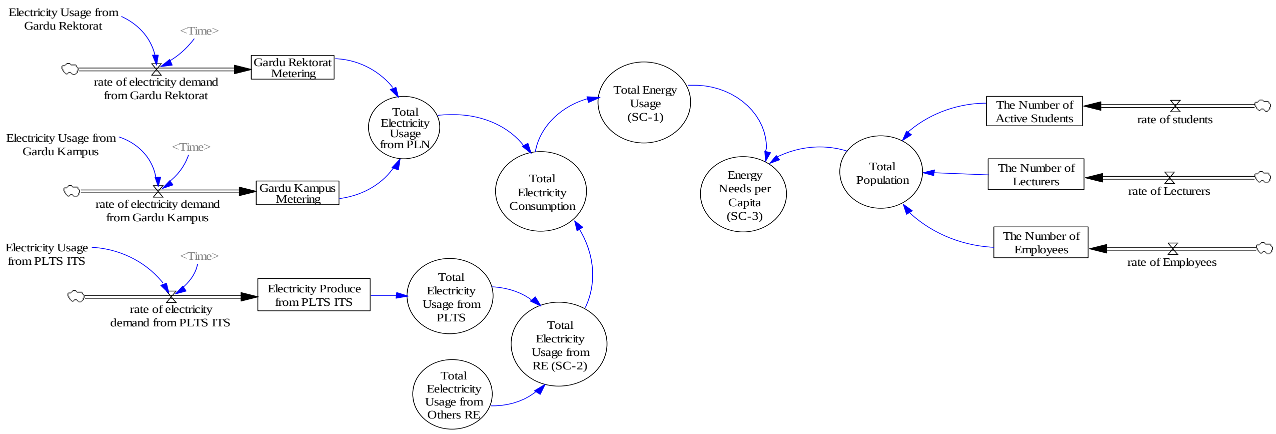

Figure 7. Stock Flow Diagram Energy Needs per Capita in ITS Surabaya Campus.

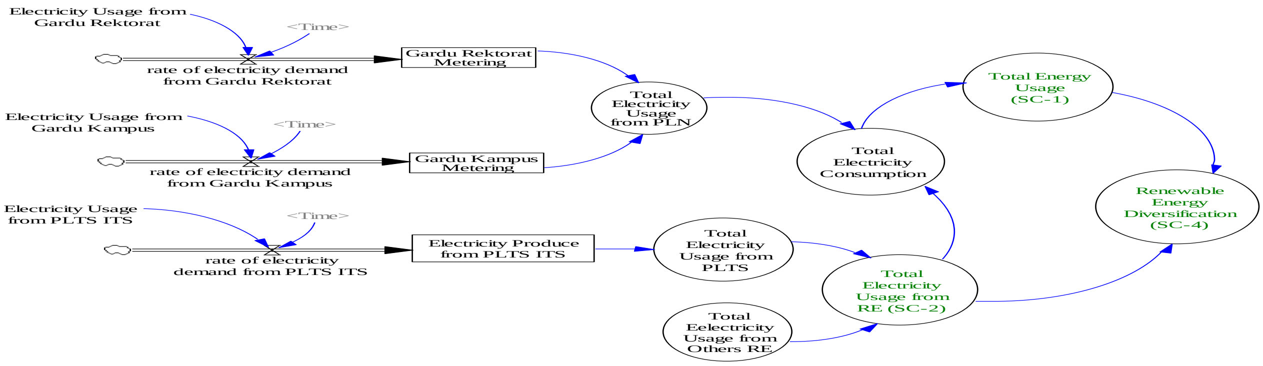

Figure 8. Stock Flow Diagram Energy Diversification in ITS Surabaya Campus.

energy project can be realized or projected the return value of its capital.

$$Payback\ Period = \frac{net\ cash\ investment}{KEnet\ cash\ incomeF} \times 1\ year \qquad (3)$$

4) Output power

Output power generated from PLTS (kWh / year) [19][20][23]: used to calculate the potential electrical energy generated by PLTS. Where is the multiplication between the area of the solar panel (A), the average of solar insulation (S), the length of solar radiation (t), the efficiency of the solar panel (η).

$$P_G = A_G \times S \times t \times \eta \qquad (4)$$

E. Model Verification and Validation

To ensure the model developed has validity, validation of the initial simulation results must be carried out, which aims to ensure that the model has described the actual conditions. Barlas (1996) states that there are two stages of model validation, namely the first validation by means of the average comparison test statistic or mean comparison and the second validation by the comparison test of amplitude variation or % error variance [24].

$$Mean\ Comparison\ (E_1) = \frac{|\ Simulation\ average\ value\ (\bar{S}) - Data\ average\ value\ (\bar{A})|}{Data\ average\ value\ (\bar{A})} \qquad (5)$$

$$Error\ Variance\ (E_2) = \frac{|\ Simulation\ stdev\ average\ (\overline{S_S}) - Data\ stdev\ average\ (\overline{S_a})|}{Data\ stdev\ average\ (\overline{S_a})} \qquad (6)$$

F. Models Simulation

If the equation phase of determining equations has been completed then the simulation process is then performed using applications that support the Dynamic System Method. A stock and flow diagram that already has an equilibrium calculation is ready for the simulation execution. The simulation phase needs to input secondary data to fill each component variable. These data are historical data that present the current condition of the system. The simulation phase is carried out to obtain the results of long-term system projections going forward using existing historical data input.

G. Scenarios

The results of the system simulation are developed with a predetermined model scenario and translated into a conceptual model that is SFD along with the equations of model calculations and predetermined parameter scenario data. After that, the simulation for the scenario model is executed. Model scenario is a representation of increasing system performance. Barlas (1989) provides two alternative scenarios for model development that can be used in dynamic systems, namely parameter scenarios (by changing variable values) and structure scenarios (by adding new variables) [25].

H. Models Intepretation (Analysis and Assessment)

This process is drawing conclusions from the results of the simulation model output. Techno-economic analysis will be used in consideration of campus scale renewable energy development strategies, then the results can be used as policy

Tabel 2.
BAU Scenario without the addition of a new RE power source

BAU Scenario	Result Analysis		
	2019	2025	2050
Total Electricity Usage (kWh/year)	9,613,148.64	12.554.132,82	22.442.176,43
Ratio RE Fulfillment to Total Electricity Usage (kWh/year)	0.27%	0.21%	0.12%
Energy Needs per Capita (kWh/capita/year)	442.72	578.16	1,033.53

Tabel 3.
Assumption of techno-economic feasibility

No.	Technical Needs	Costs
1	Investment costs PLTS On Grid 16 Wp	Rp. 500.000.000,-
2	Solar Panel Investassi PV V	75% from Total Invesment
3	Component Investment	25% from Total Invesment

strategy recommendations in the development of PLTS or other RE power plants in support of sustainable energy.

III. RESULT AND DISCUSSION

A. Causal Loop Diagram Energy Operational in ITS Surabaya

The electricity usage of the ITS Surabaya Campus is calculated based on the use of electricity derived from PLN electricity and renewable energy electricity generated by the On-Grid PLTS ITS located in the Research Center Building. The calculation of the use of PLN electricity is calculated based on the electricity meter records in the Rector's Gate and the Campus Post Meanwhile, the total electricity generated by PLTS On-Grid ITS is also used as an operational use of energy on the Surabaya ITS Campus.

Based on the identification of the variable development of an electric energy operational system model at ITS Surabaya Campus in an effort to diversify energy, it can be mapped in a causal circle diagram which can be seen in Figure 4.

B. Validity and Realibility

The development of renewable energy diversification models in simulations can be said to be valid and represent the system if the calculations meet the requirements for the average comparison (E1) and error variance (E2). Based on historical data between 2015 and 2019, simulation validation is obtained as shown in Table 1., where the results obtained are valid and reliable.

C. Model Scenario

1) Total Energy Model in ITS Surabaya

This model is calculated based on the existing energy needs at the ITS Surabaya campus, namely from the total use of electrical energy derived from PLN electricity and electricity produced by PLTS. For PLN electricity, it is calculated based on the metering found in the two power houses, namely the Rector of the Power House and the Campus Power House (Figure 5., while the source of electrical energy from RE, for the time being still comes from 16 KWP On Grid PLTS (Figure 6).

2) Energy per Capita Model in ITS Surabaya

The per capita energy demand model (formula (1) is calculated based on the total energy used divided by the number of ITS Surabaya active academic civilians based on being on the ITS Surabaya campus (Figure 7).

3) Energy per Capita Model in ITS Surabaya

The energy diversification model (Figure 8.) from the RE source is calculated based on the total electricity usage generated by the RE stock compared to the total overall energy use (formula (2).

D. Techno-Economic Aspect Analysis and Assessment

Based on previous research A. Arishinta of energy use in the ITS Surabaya campus environment, the analysis of the simulation results is as follows [26]. From historical data in 2019, it is known that the total electricity usage for management operations is around 9,613,148.64 kWh or 26,337.39 kWh / day, with a growth rate of around 3% per year. And the amount of electricity production from RE sources, namely PLTS On Grid 16 KWP is around 26,290.92 kWh / year or 72.03 kWh / day. So that for the effort to diversify electricity with RE currently only around 0.27% has been met. With an active academic community population per 2019 school year, there are 21,714 people consisting of staff lecturers and students. So the BAU scenario if only utilizing the 16 KWP On Grid PLTS that currently exists until 2050, without the addition of new RE sources, the results can be analyzed as follows (Table 2.).

Analysis of the techno-economic aspects of investment in Photovoltaic Power Plants is calculated in detail from the financial valuation of the investment cash flow. The Payback Period (PP) method is used to calculate the amount of time needed to return the money invested. Profit and cost analysis required in deciding whether a project / activity is feasible or not realized. The depreciation value associated with economic life in the Photovoltaic Power Plant System is divided into two categories, namely: 25 years for solar panels, and 5 years for component equipment. Several assumptions are used to calculate an economic feasibility, explained in Table 3.

Tabel 4.
Payback Period Calculation (BAU Scenario)

No.	Scenario	Result Analysis	
		Income Value (Rp./year)	Long Term Period Needs to Investment Return (year)
1	Optimistic	Rp. 19,323,826.20,-	25.87
2	Most Likely	Rp. 38,568,779.64,-	12.96
3	Pesimist	Rp. 19,323,826.20,-	27.69

Table 5.
RUEN and RENSTRA Target Calculation for Renewable Diversification

No.	Scenario RE Diversification (% per year)	Result Analysis		
		Total Electricity from RE Produced to Fulfilled Energy Needs (kWh/day)	Invesment Value Prediction (Rp.)	Income Value Prediction (Rp./year)
2	RUEN = 23%	7,910.82 (± 7.91 MWh)	Rp. 24,990,000,000,-	Rp. 2,122,276,153.22,-
3	RUEN = 31%	19,060.48 (± 19.10 MWh)	Rp. 29,064,790,935,-	Rp. 8,247,499,838.43,-
4	RENSTRA ITS = 50% (2025)	17,197.44 (± 17.20 MWh)	Rp. 54,315,000,000,-	Rp. 4,613,643,811.35,-

For the Payback Period Scenario, taking into account the initial investment value of 16 KWP On-grid PLTS of Rp. 500,000,000, with an economic age of 25 years, and a bank rate estimated at 7% per year, it can be calculated the value of income from the sale of electricity generated from PLTS, where the amount of annual income derived from the sale of electricity prices to PLN during the year walk. Assuming the price of electricity according to internal management data is Rp. 735, - per kWH. Then the Payback Period calculation results can be seen in Table 4.

Assuming the cost of installing solar panels per 1 KWP around Rp. 15,000,000 [27] and the price of EBT electricity around Rp. 735/kWh according to ITS Surabaya internal data. So for scenarios based on the RUEN Target of 23% in 2025 and 31% in 2050, also the RENSTA Target 50% in 2025 scenario which means there must be an effort to add new sources of electrical energy from RE by adjusting their respective targets, then the calculation of efforts to diversify electric energy from RE sources are as follows (Table 5.).

IV. CONCLUSION

Building new renewable energy sources for university scale, especially PLTS requires good planning because investment in the electricity industry is not cheap and demands long-term benefits. Economically, the amount of investment needed will be one of the obstacles in determining the scale of infrastructure development priorities in the development and governance of campus management. Technically, PLTS construction also requires periodic maintenance and supporting internal resources. It is expected that in the future, with consideration of a mature strategy, the management will be able to create energy independence by reducing the use of electricity from fossil energy and increasing the diversity of electricity sources from RE. With the RE diversification effort, it is expected that in the long term, in addition to being able to reduce the use of fossil energy electricity, it will also be able to reduce the effects of Greenhouse Gases due to CO2 emissions resulting from the use of fossil energy. Optimization of the effectiveness of RE source development will be achieved, if: measured; relevant and timely management of the RE source. While optimizing the efficiency of RE development will be achieved, if: the ease and accuracy of data is available in full so that the results can be used with existing measurement standards. Good energy management can also be a distinct advantage as a form of energy efficiency and conservation. So as to increase campus internal economic growth through a combination of available resources and appropriate technology that supports the independence of the institution in managing the sustainability of the university.

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