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Human Development Concept and Electrical System Simulation Using System Dynamics Model for Papua Province, Indonesia

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ABSTRACT

Development of human society (social), economic development, and environmental preservation are the three pillars of sustainable development. They must be implemented simultaneously and balanced. Two paradigms can be used to implement sustainable development, namely the economic development paradigm and the human development paradigm. This paper proposes a novel concept of human development in the Papua –Indonesia Province using a system thinking approach. This paper also proposes a novel modeling and simulation electrical system using a system dynamics method to fulfill human development demand. As an object of modeling and simulation, an electrical system in several regencies and municipality used. The simulation model results from the novel concept of human development in this study are projections of electricity demand and installed capacity of the 2016-2050 power plants in the BaU, moderate, and optimistic scenarios. Increased electricity demand and the installed capacity of the power plants are a function of the human development index and development acceleration. The average increase in electricity demand is 3.8583; 5.0652; 8.1779 and 7.1122 percent per year for the BaU scenario, 0.5088; 0.3404; 1.1578 and 0.6726 percent per year for the moderate scenario, and 0.5100; 0.3422; 1.1694 and 0.6760 percent per year for optimistic scenario. The average increase in installed capacity of the power plant is 3.9880; 5.2110; 8.4366 and 7.3141 percent per year for the BaU scenario, 4.1159; 5,4391; 8.7747 and 7.6709 percent per year for the moderate scenario, and 4.470; 5,611; 9.1128 and 7.8392 percent per year for the optimistic scenario.

Keywords: Human Development, System Thinking, System Dynamics, Papua-Indonesia
JEL Classifications: L94, O15, Q47, R58

1. INTRODUCTION

Papua Province is one of the provinces in Indonesia endowed with various natural resources. The various natural resources include flora and fauna, natural and energy resources, a high diversity of local cultures, as well as beautiful and historic places for the development of the tourism industry. The Papua Province also has geopolitical and geostrategic advantages because located between Asia and Australia continents and the Pacific Ocean.

Besides being endowed with various natural resources, Papua Province also faces development challenges that are not easy. The development challenges include various geographical conditions and uneven population distribution.

Another development challenge is the high level of local cultural diversity and the disparity in the level of civilization among local tribes. Fluctuating political, security and law issues, development paradigms and development planning approaches, and good governance in the transition processes also challenges to development that must be faced.

The administrative region of the Papua Province includes 28 regencies and one municipality with an area of 316,553.05 km^2. Papua Province has an average population density of 10 people per square kilometers in 2015. While the national average population density of 134 people per square kilometers (BPS Provinsi Papua, 2016; BPS, 2017). The population in the Papua Province consists of various ethnic groups: (1) Indigenous Papuans called Orang Asli Papua (OAP) who originate from the Melanesian race group (Sekretariat Negara RI, 2001), (2) residents from various regions in Indonesia, and (3) residents from outside Indonesia.

Development of human society (social), economic development, and environmental preservation are three pillars of sustainable development. They must be considered in balance and simultaneous, both in the process and in its impact, because they are interconnected and interdependent. Sustainable development that depends on social justice, the modern economy, and ecology is a convergent movement that continually requires further improvements. Cultural and political work is subsequent in the social pillar (Flint, 2013. p. 25-54).

Sustainable development can be implemented using two paradigms, namely: The economic development paradigm, and the human development paradigm (Bellù, 2011. p. 3-5).

Economic growth has used as a basis for planning development in many countries (including in Papua Province, Indonesia) until now, which among others are to make projections of energy and electricity demand and in making targets for increasing the human development index (HDI).

This paper proposes a novel concept of human development in the Papua Province and its impact on electricity demand and supply. Increasing of the HDI, population growth, electrification ratio, and development acceleration are driving factors that growth in electricity demand.

This study is aimed to explore the electrical system model that is more accommodating to regional characteristics and the local cultures to support the modernization process than for practical implementation purposes.

Electricity to meet public demand in the Papua Province is mostly coming from the State Electricity Company (Perusahaan Listrik Negara, PLN) Region Papua and West Papua. Most of the PLN's electricity systems are still isolated and scattered systems.

In this study, PLN electricity consumers consist of six customer sectors, namely: Social sector, household sector, business sector, industrial sector, public sector, and public street lighting.

Modeling and simulation use electrical systems in Biak-Numfor Regency, Jayapura Municipality, Jayawijaya Regency, and Merauke Regency those located as in Figure 1.

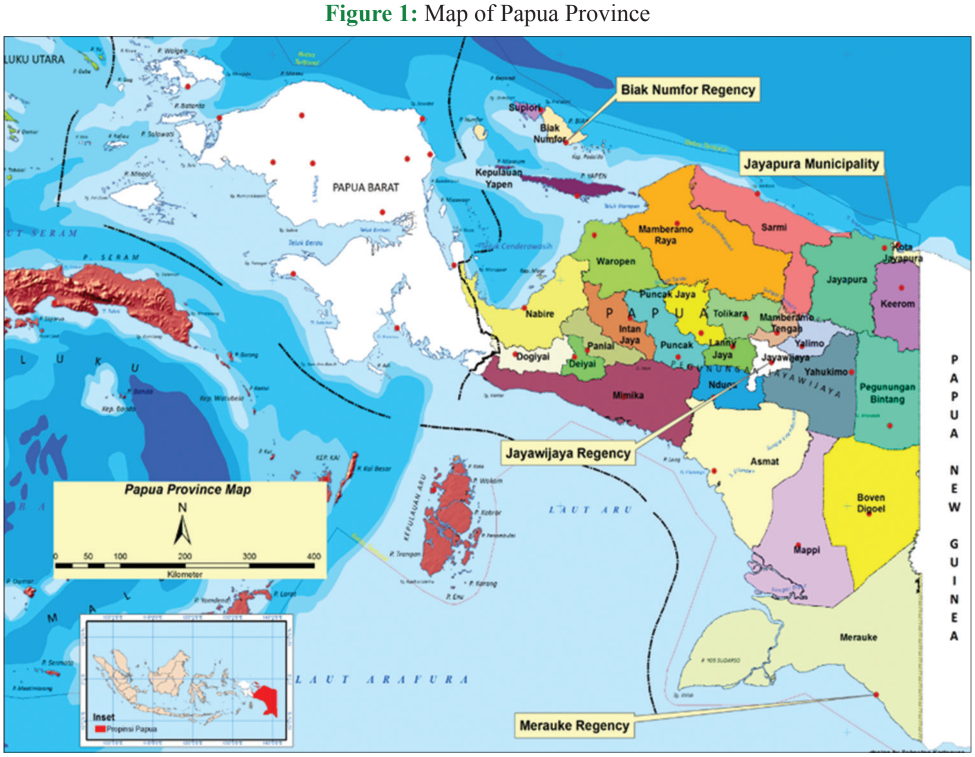
The Powersim studio tool is used for modeling and simulating this electrical system.

2. LITERATURE REVIEW

2.1. Human Development and HDI

The concept of economic development pays the most attention to economic growth, whereas the concept of human development pays attention to expanding people's choices to live full of freedom and dignity. Human development means positive growth and changes in the level of welfare that must occur in all aspects of people's lives. All aspects of people's lives include economic, social, political, cultural and environmental. Thus the center and goals of human development are in humans and their welfare (BPS, 2014. p. 7).

Figure 1: Map of Papua Province



Source: Modified from Lefaan and Dalimi (July 2018)

Human development to expand people's choices has two aspects. The aspects are fundamental aspects and more contextual aspects. The fundamental aspects include the choice to gain a healthy life and longevity, education, and skills to be able to access the resources needed to obtain a decent standard of living.

Once these three fundamental aspects of human development achieved, there will be opportunities for the community to reach more contextual choices. More contextual aspects include choices for the community to be able to participate in political life, community, and environmental preservation, gain guarantees of security and human rights, gender equality, economy, and social freedom to be able to access the resources needed to obtain a decent standard of living (UNDP, 2015; BPS, 2014). The fundamental aspects and the more contextual aspects bridged with the educational component in fundamental aspects (Supriyoko, 2003; Modouw, 2013. p. 38-46, 204-272).

The three fundamental aspects of human development can be proxied using the HDI which has a scale of 0-1, or 0-100 (Maqin and Sidharta, 2017; BPS, 2014).

2.2. Economic Growth, Energy Consumption, and Human Development

The relationship between energy consumption and economic growth towards human development has known through various results of previous studies, which among others were carried out by Kanagawa and Nakata (2008), Mazur (2011), Quedraogo (2013), Niu et al. (2013), Marqin and Sidharta (2017).

Increasing of HDI is a logarithmic function of increasing energy consumption and electricity consumption (Pasternak, 2000; Wu et al., 2010; Arto et al., 2016). Whereas, increasing average electricity demand per household is an exponential function of increasing HDI (Lefaan and Dalimi, July 2018).

2.3. System Dynamics Model

In solving big problems, the reductionist approach does this by breaking down the problems into smaller ones and completing them one by one. Instead, the approach systems thinking solves complex problems holistically, are interrelated so that they require trade-offs.

Systems thinking is not only a way of thinking that is based on mere symptoms and sequence of events but also represent the mindset and philosophy of thinking about all systems. Systems thinking developed in the 1950s was the basis of system dynamics (SD) modeling (Thorsteinsson, 2015; Haraldssons, 2000. p. 9).

SD is a computer modeling and simulation technique for understanding the behavior of complex systems that change over time (Lefaan and Dalimi, October 2018). SD developed by Jay Forester in Massachusetts Institute of Technology (MIT) in the 1960s (Haraldssons, 2000. p. 9).

Some essential tools in SD are delays, feedback, causal loop diagrams (CLD), and stock and flow diagrams (SFD). Delays create dynamics in the system because it provides an inertial system and generates oscillations. Delays are often responsible for trade-offs between the short-term and long-term effects of the policies implemented. Feedbacks have two forms those are positive feedback (reinforcing R) or negative feedback (balancing B).

CLD is an essential tool for projecting system dynamics. CLD states causal relationships and feedback structures of complex systems.

SFD are an essential tool besides CLD. Stock is an accumulation of flow over time, and that gives the system inertia and memory (Thorsteinsson, 2015; Lefaan and Dalimi, October 2018).

3. HUMAN DEVELOPMENT CONCEPT AND ELECTRICAL SYSTEM DEVELOPMENT IN PAPUA PROVINCE

There are five determinant factors that influence the success of sustainable development in each regency and municipality in the Papua Province, namely: (1) Geographical conditions, and population distribution,(2) local cultural diversity and level of civilization, (3) political, security and law, (4) development paradigm and development planning model, and (5) good governance.

The geographic conditions of the region in Papua Province vary greatly, ranging from areas that are easily accessible to areas that are very difficult to access by development (Mansoben, 1995. p. 25-34), a small and unevenly scattered population also causes the development gap between regencies and municipality.

The population in the Papua Province according to the results of the census conducted by the 2010 Central Bureau of Statistics (Badan Pusat Statistik, BPS) amounted to 2,833,381 people, consisting of OAP 2,121,4136 people and non-OAP totaling 711,945 people. The entire OAP consists of 329 tribal codes (BPS Papua Province, 2011. p. 63; Bappeda, 2013. p. 20, 22).

A small proportion of OAPs (10.3%) lives in urban areas to the suburbs areas (urban communities), while the majority (89.7%) live in suburbs areas to rural areas (kampung communities), and in rural areas to remote/isolated areas (gatherer and hunter communities), (Bappeda, 2013. p. 20; Modouw, 2013. p. 23, 51-52).

The most prominent and influential political issue in the security and law conditions in Papua Province is secession, political contestation among local elites seizes local political power, natural resources, and economic resources, and the split (pemekaran) of new regencies/provinces (Widjojo and Kossay, 2011; Rusdiarti and Pamungkas, 2017; Lefaan, 2013. p. 127-202; Suryawan, 2017).

The accelerated development imposed since the issuance of the Papua Special Autonomy Law in 2001 attracted many immigrants to Papua Province. The immigrants fill open employment opportunities, because they are generally better educated, have better skills and networks than OAP, so they control the economic sector and become one of the reasons for the marginalization of OAP (Lefaan, 2013. p. 104-119).

Good governance is also still in the process of transitioning to more advanced ones; this is related to the orientation of cultural values, the quality of human resources, and the quality of institutional performance (Hardjasoemantri, 2003; Madhu, 2011; Kemitraan, 2012; Kemitraan, 2013; Kemitraan, 2014).

How to determine the right direction, acceleration, and development strategies in each regency and municipality are the crucial problems faced in Papua Province.

If the acceleration of development is too high, marginalization to traditional OAP communities will increase, the threat to damage to their ecological zones will also increase (Suryawan, 2018. p. 153-181). Over-accelerated development can also lead to premature conditions for OAP. Premature conditions cause life expectancy to decrease, or if it stays long, it will experience many weaknesses (Modouw, 2013. p. 22-23).

But on the contrary, if the acceleration of development is too low, then some traditional OAP communities will endure more suffering in conditions of isolation, underdevelopment, and confined by discriminatory customs (Djoht, 2003. p. 13-26).

Thus the direction and acceleration of development need to be regulated with the right strategy so that the penetration of modernization to the level of traditional OAP communities can be comparable to the transformation of their level of adaptability to modernization.

In this context, the development of the electrical system does not only function as economic infrastructure, but can also be sought to become one of the policy instruments to determine the right direction, acceleration and development strategies. Therefore in the development planning approach, the empirical planning model based on the results of research and development is more suitable to be applied in the Papua Province than the technocratic planning model (TKP III LAN, 2010; Purwoko, 2017).

This paper proposes three priority development sectors as leverage points to find out the solution of the complex problems of development in Papua Province (Resosudarmo et al., 2014. p. 456-457). The three leverage points are infrastructure development, both economic infrastructure and social infrastructure (Torrisi, 2009. p. 14-19), human development, both the fundamental aspects and more contextual aspects (UNDP, 2015; Nayak, 2008); and development of the local economy potential. The development of local economic potential includes the populist economy and creative economy.

The populist economy consists of microenterprise, small enterprise and medium enterprise, cooperative institutions, and custom economy institutions (Purwoko, 2017).

The creative economy is the new economic sector (excluded the three well-known economic sectors) that combines information, technology, and intellectual abilities and creative ideas of humans in producing new products and services. The creative economy generated by the cultural and creative industries (SAVA, 2014; UNESCO and UNDP, 2013. p. 23).

The three priority sectors are then implemented simultaneously and balanced, with emphasis on the stages on the road map as follows:

1. Infrastructure development 2015 to 2020 (Bappenas, 2015. p. 39-101);
2. Human development, fundamental aspects 2020 to 2025.

More contextual aspects then implemented in the cultural transformation form that consists of the transformation process of theoretical values 2025-2030; the transformation process of social values, religious values, and aesthetic values 2030-2035; and the transformation process of political values 2035-2040 (Mansoben, 1995. p. 41-307; Koentjaraninggrat, 2009. p. 93-107; Ismawati, 2012. p. 100-106; Abdullah, 2002. p. 260-270; Suryawan, 2017. p. 27-107; Bappenas, 2005. p. 7-14; Kemdikbud, 2013. p. 1-70);

3. Development of the populist economy and creative economy 2015 to 2045 (Bappenas, 2015.p .65-66, and 71).

In 2040 it is expected that the success of the transformation process of political values will foster four pillars of new power, namely: (1) Political power, (2) intellectual power, (3) cultural power, and (4) moral power (Suryawan, 2017).

The four pillars of this new power will be a solid foundation for the formation of a new economic structure (economic transformation) which includes the populist economy and creative economy, corporate economy, and the country's economy as a unified supply chain of products and services.

The causal relationship between determinant factors, human development, and electrical system development is in Figure 2.

If the success of sustainable development increases, the conditions of the five determinant factors are also getting better. Conversely, if the conditions of the five determinant factors are getting better, then the success rate of sustainable development is also increased (reinforcing effect). The success of sustainable development also has a relationship that reinforces each other (reinforcing effect) with HDI and economic growth.

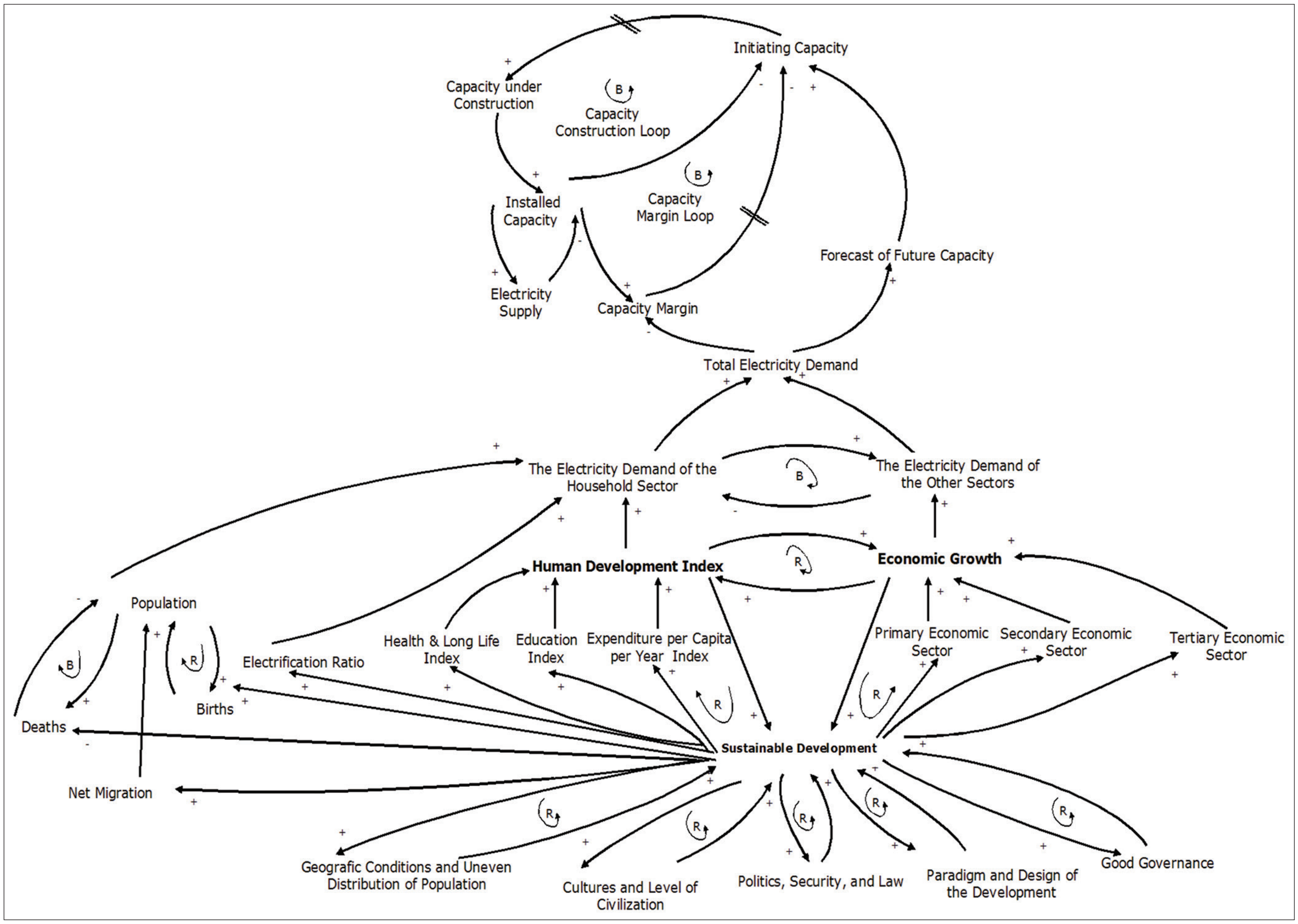
HDI and economic growth have a reinforcing effect, an increase in HDI has an effect on increasing economic growth, and on the contrary economic growth also has an effect on increasing the HDI value.

The total electricity demand is equal to the household sector demand divided by the percentage of household sector demand in the electricity demand mix. Total electricity demand is the sum of the household sector demand and other sectors demand.

In percentage terms, electricity demand for human development has a mutually debilitating relationship with the percentage of electricity demand for economic development (balancing effect). The fraction of household sector electricity demand and the fraction of other sectors electricity demand in the electricity demand mix indicates the development acceleration in a regency or municipality.

The capacity construction loop has the effect of balancing the initiating capacity. With increasing installed capacity, the rate of initiating capacity is decreased by the capacity construction loop.

Figure 2: A causal loop diagram of human development and the electrical system development



Source: Processed from Flint (2013), Lefaan and Dalimi (October 2018), Ramirez et al. (1997), and Mattew et al. (2015)

The capacity margin loop also has a balancing effect on the capacity forecast demand; this means that the demand forecast capacity increases with increasing total electricity demand, but decreases with increasing capacity margin loops.

The CLD between the HDI and the electricity system transformed into the SFD as in Figure 3.

4. MODELING AND SIMULATION OF ELECTRICAL SYSTEMS IN PAPUA PROVINCE

4.1. System Dynamics Model

The system dynamics model in Figure 3 consists of four sub-models, namely: HDI, population growth, electricity demand, and electricity supply.

1 HDI sub-model, population growth, and electricity demand

The HDI sub-model consists of three indices, namely: Health and life expectancy index (HLL_I), education index (ED_I), and adjusted expenditure per capita per year index (AECY_I).

a. Health and life expectancy index (HLL_I)

$$HLL\_I=IF(HLL<HLL\_Max,\ (HLL-HLL\_Min)/(HLL\_Max-HLL\_Min),1) \quad (1)$$

$$HLL\_rate = HLL\_growth \times HLL \quad (2)$$

b. Expecting years of schooling (EYS)

$$EYS = IF(EYSF<EYSF\_Max,\ (EYSF-EYSF\_Min)/(EYSF\_Max-EYSF\_Min),1) \quad (3)$$

$$EYSF\_rate = EYSF\_growth \times EYSF \quad (4)$$

c. Mean years of schooling (MYS)

$$MYS = IF(MYSF<MYSF\_Max,\ (MYSF-MYSF\_Min)/(MYSF\_Max-MYSF\_Min),1) \quad (5)$$

$$MYSF\_rate = MYSF\_growth \times MYSF \quad (6)$$

Education index (ED_I)

$$ED\_I = (EYS + MYS)/2 \quad (7)$$

d. Adjusted expenditure per capita per year index (AECY_I)

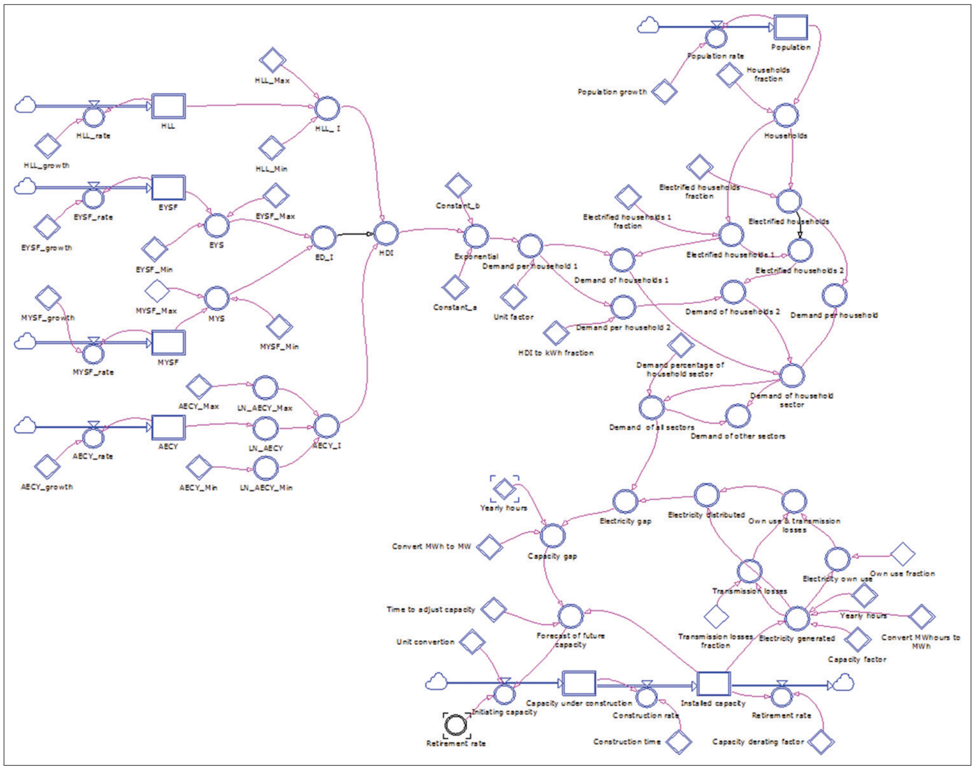
$$AECY\_I=IF(LN\_AECY<LN\_AECY\_Max,\ (LN\_AECY-LN\_AECY\_Min)/(LN\_AECY\_Max-LN\_AECY\_Min),1) \quad (8)$$

$$AECY\_rate = AECY\_growth \times AECY \quad (9)$$

e. Human development index (HDI, value 0-100)

$$HDI = 100\,x\,\sqrt[3]{HLL\_I\,x\,ED\_I\,x\,AECY\_I} \quad (10)$$

Figure 3: System dynamics model of electrical systems in Papua Province



Source: Processed from Lefaan and Dalimi (October, 2018), Babajide et al. (2018), Ford (1997), and Musango (2012. p. 129-132, 250-253)

f. *Exponential* = $a \times EXP(b \times HDI)$ (11)

The mathematical equation for the population growth sub-model up to the sub-model of household electricity demand refers to (Lefaan and Dalimi, October 2018).

The data for the HDI sub-model up to the sub-model of household electricity demand refers to (Lefaan and Dalimi, October 2018).

2. Electricity supply sub-model

$$\text{Electricity generated} = \text{Capacity factor} \times \text{Yearly hours} \times \text{Installed capacity} \times \text{Converts MWhours to MWh} \quad (12)$$

Installed capacity in 2015 (8.38, 42.83, 3.35, 12.10) in MW units. Three years of construction time. Capacity factors (0.60, 0.73, 0.58, 0.6843) (Source: Proceed from PLN and BPS data). Reserve power margin based on the installed capacity of the power plant is 35-40% (PLN, 2019. p. 2-10).

4.2. Model Simulation Scenario

Electricity demand and the installed capacity of the 2016-2050 power plant are projected to use three scenarios, namely the BaU scenario, moderate and optimistic scenarios.

HDI and development acceleration are used as driving factors for increasing electricity demand and installed capacity of power plants as in Tables 1 and 2.

5. RESULTS AND DISCUSSION

Simulation results include increased HDI, growth in electricity demand, and installed capacity of power plants as in Figures 4-6 and Tables 3-5.

5.1. HDI

In the BaU scenario, the results of HDI projections in Biak Regency, Jayapura Municipality, Jayawijaya Regency, and Merauke Regency have increased by an average of 0.3589; 0.2614; 0.3919; and 0.4443 points per year. This increase is equivalent to 0.5048; 0.3324; 1.1196; and 0.6533 percent per year.

In the moderate scenario HDI increases by an average of 0.3617; 0.3404; 0.4052; and 0.6726 points per year, or equivalent to 0.5088; 0.3404; 1.1578; and 0.6726 percent per year.

In the HDI optimistic scenario the average increase is 0.3626; 0.2691; 0.4093; and 0.6760 points per year, or equal to 0.5100; 0.3422; 1.1694; and 0.6760 percent per year.

The HDI in the moderate scenario increases by an average of 0.0040; 0.0063; 0.0383; and 0.0193 percent per year of HDI in the BaU scenario. Whereas, the HDI in the optimistic scenario increase s by an average of 0.0012; 0.0014; 0.0115; and 0.0034 percent per year from the HDI in the moderate scenario.

5.2. Electricity Demand

Electricity demand in the BaU scenario increases an average of 3.534; 19.137; 2.8623; and 9.695 MWh per year. This increase is equivalent to 3.8583; 5.0652; 8.1779; and 7.1122 percent per year.

Table 1: Growth of each component of the HDI

Regency/Municipality	HLL (%/year)	EYFS (%/year)	MYSF (%/year)	AECY (%/year)	Scenario
Biak-Numfor	0.1280	1.0993	1.2937	0.5002	BaU
Jayapura	0.0669	0.8283	0.7473	0.5364	
Jayawijaya	0.2406	1.2926	2.8568	1.3260	
Merauke	0.1920	0.9902	1.6843	0.4822	
Biak-Numfor	0.1331	1.1433	1.3454	0.5202	Moderate*
Jayapura	0.0696	0.8614	0.7772	0.5579	
Jayawijaya	0.2502	1.3443	2.9711	1.3790	
Merauke	0.1997	1.0298	1.7517	0.5015	
Biak-Numfor	0.1371	1.1776	1.3858	0.5358	Optimistic**
Jayapura	0.0717	0.8873	0.8005	0.5746	
Jayawijaya	0.2577	1.3846	3.0602	1.4204	
Merauke	0.2057	1.0607	1.8042	0.5165	

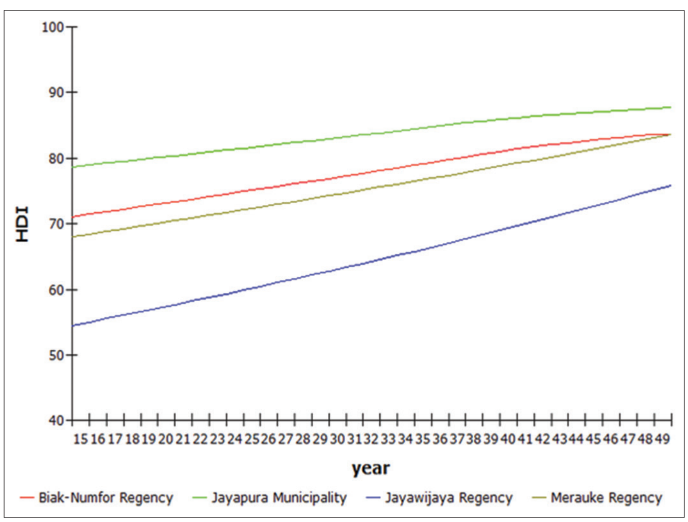
Source: Proceed from Lefaan and Dalimi (October 2018). *In 2025 it increases 4 percent from the BaU scenario. **In 2035 it increases 3 percent from the moderate scenario

Table 2: Development acceleration

Regency/Municipality	Percentage of the household sector demand to the total sector's demand (%)		
	BaU	Moderate*	Optimistic**
Biak-Numfor	58.74	56.74	52.74
Jayapura	49.21	47.21	43.21
Jayawijaya	65.88	63.88	59.88
Merauke	67.15	65.15	61.15

Source: Proceed from BPS data (Lefaan and Dalimi, July 2018). *In 2025 it decreases 2 percent from the BaU scenario. **In 2035 it decrease 4 percent from the moderate scenario

Figure 4: Increasing human development index with BaU scenario



Electricity demand in the moderate scenario increases an average is 3.551; 19.617; 2.9447; and 10.014 MWh per year, equivalent to 3.8764; 5.1923; 8.4135; and 7.3459 percent per year.

Electricity demand in the optimistic scenario increases an average of 3.556; 19.750; 2.9709; and 10.071 MWh per year, or equivalent to 3.8821; 5.2276; 8.4883; and 7.3879 percent per year.

Electricity demand in the moderate scenario increases an average of 0.0181; 0.1270; 0.2357; and 0.2337 percent per year of electricity demand in the BaU scenario.

Figure 5: Increasing electricity demand with the BaU scenario

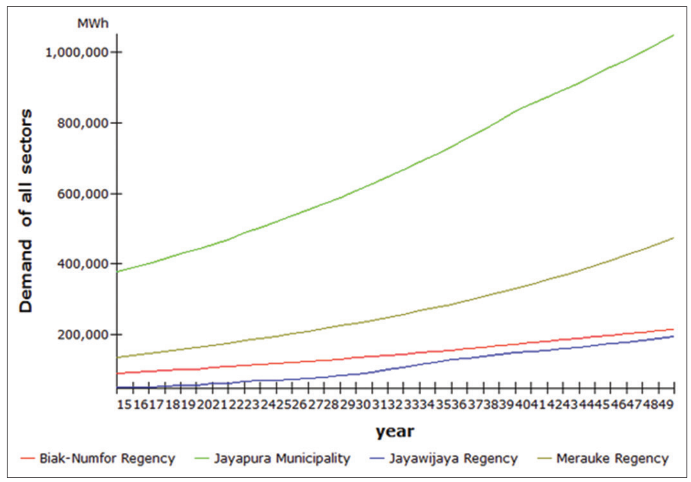
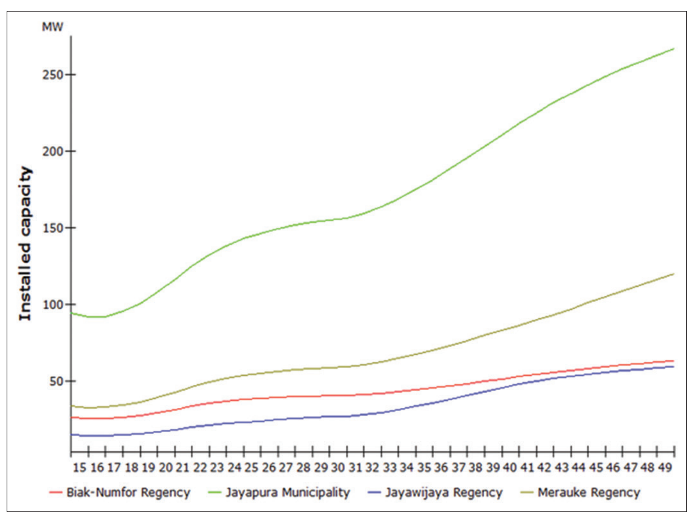


Figure 6: Installed capacity increases of the power plants in the BaU scenario



Electricity demand in the optimistic scenario increases an average of 0.0057; 0.0353; 0.0748; and 0.0420 percent per year of electricity demand in the moderate scenario.

The average elasticity of electricity demand for HDI in the BaU scenario is 7.6434; 15.2386; 7.3044; and 10.8872 percent per year.

Table 3: Results of HDI projections with BaU, moderate, and optimistic scenarios

Year	Regency/Municipality				Scenario
	Biak-Numfor	Jayapura	Jayawijaya	Merauke	
2015	71.09	78.65	54.51	68.01	BaU
2025	74.91	81.50	59.88	72.12	
2035	78.91	84.44	65.80	76.48	
2045	82.62	86.88	72.34	81.12	
2050	83.65	87.80	75.87	83.56	
2015	71.09	78.65	54.51	68.01	Moderate
2025	74.91	81.50	59.88	72.12	
2035	79.08	84.56	66.05	76.66	
2045	82.84	87.05	72.89	81.51	
2050	83.75	88.01	76.60	84.02	
2015	71.09	78.65	54.51	68.01	Optimistic
2025	74.91	81.50	59.88	72.12	
2035	79.08	84.56	66.05	76.66	
2045	82.89	87.09	73.03	81.61	
2050	83.78	88.07	76.82	84.10	

HDI: Human development index

Table 4: Results of electricity demand projections with BaU, moderate, and optimistic scenarios

Year	Regency/Municipality				Unit	Scenario
	Biak-Numfor	Jayapura	Jayawijaya	Merauke		
2015	91,605	377,803	50,485	136,314	MWh	BaU
2025	119,275	519,639	72,477	195,882		
2035	153,038	709,588	122,505	276,952		
2045	194,853	933,957	169,919	395,717		
2050	215,310	1,047,586	194,986	475,637		
2015	91,605	377,803	50,485	136,314	MWh	Moderate
2025	123,479	541,653	74,746	201,895		
2035	159,094	746,769	127,257	288,024		
2045	202,862	985,607	178,071	415,730		
2050	223,500	1,109,284	205,385	501,731		
2015	91,605	377,803	50,485	136,314	MWh	Optimistic
2025	123,479	541,653	74,746	201,895		
2035	171,160	815,954	135,758	306,865		
2045	218,730	1,081,637	191,161	446,242		
2050	240,754	1,220,183	221,291	537,853		

Table 5: Results of installed capacity of the power plants projections in Bau, moderate, and optimistic scenarios

Year	Regency/Municipality				Unit	Scenario
	Biak-Numfor	Jayapura	Jayawijaya	Merauke		
2015	26.58	94.69	15.04	33.79	MW	BaU
2025	38.15	143.10	23.41	54.01		
2035	44.54	175.13	33.72	67.70		
2045	58.35	243.52	54.94	101.24		
2050	63.68	267.39	59.45	120.29		
2015	26.58	94.69	15.04	33.79	MW	Moderate
2025	38.24	145.47	23.68	54.49		
2035	45.45	189.57	35.26	70.42		
2045	60.25	260.67	56.41	104.91		
2050	65.63	294.05	61.70	127.66		
2015	26.58	94.69	15.04	33.79	MW	Optimistic
2025	38.24	145.47	23.68	54.49		
2035	46.00	190.85	35.35	70.61		
2045	64.36	274.61	59.50	109.89		
2050	72.54	320.12	69.64	139.65		

The average elasticity of electricity demand to the HDI in the moderate scenario is 7.6186; 15.2540; 7.2665; and 10.9219 percent per year.

The average elasticity of electricity demand to the HDI in the optimistic scenario is 7.6118; 15.2763; 7.2589; and 10.9296 percent per year.

5.3.The installed Capacity of the Power Plants

The installed capacity of the power plants in the BaU scenario increases an average of 1.06; 4.93; 2.95; and 2.47 MW per year. This increase is equivalent to 3.9880; 5.2110; 8.4366; and 7.3141 percent per year.

The installed capacity of the power plants in the moderate scenario increases an average of 1.09; 5.15; 3.07; and 2.59 MW per year, or equivalent to 4.1159; 5.4391; 8.7747; and 7.6709 percent per year.

The installed capacity of the power plants in the optimistic scenario increases an average of 1.18; 5.31; 3.19; and 2.65 MW per year, or equivalent to 4.4470; 5.6111; 9.1128; and 7.8392 percent per year.

The installed capacity of the power plants in the moderate scenario increases an average of 0.1279; 0.2281; 0.3381; and 0.3568 percent per year of installed capacity of the power plants in the BaU scenario.

The installed capacity of the power plants in the optimistic scenario increases an average of 0.3311; 0.1720; 0.3381; and 0.6183 percent per year of installed capacity of the power plants in the moderate scenario.

6. CONCLUSIONS

This paper proposes a novel concept of human development in Papua Province, then applied in the electrical system modeling and simulation.

Electricity demand and installed capacity power plants of 2016-2050 projected as functions of the HDI and development acceleration using the BaU, moderate, and optimistic scenarios.

In the BaU scenario, the average HDI increase is 0.5048; 0.3324; 1.1196 and 0.6533 percent per year. This increase in HDI resulted in an increase in average electricity demand of 3.8583; 5.0652; 8.1779 and 7.1122 percent per year. This increase in HDI also resulted in an increase in average installed capacity of the power plants of 3.9880; 5.2110; 8.4366 and 7.3141 percent per year.

In the moderate scenario, the average HDI increase is 0.5088; 0.3404; 1.1578 and 0.6726 percent per year, and an increase in development acceleration of 2 percent per year from the BaU scenario. This increase in HDI and development acceleration resulted in an increase in average electricity demand of 3.8764; 5.1923; 8.4135 and 7.3459 percent per year. This increase in HDI and development acceleration also resulted in an increase in average installed capacity of the power plants of 4.1159; 5.4391; 8.7747 and 7.6709 percent per year.

In the optimistic scenario, the average HDI increase is 0.5100; 0.3422; 1.1694 and 0.6760 percent per year, and an increase in development acceleration of 4 percent per year from the moderate scenario. This increase in HDI and development acceleration resulted in an increase in average electricity demand of 3.8821; 5.2276; 8.4883 and 7.3879 percent per year. This increase in HDI and development acceleration also resulted in an increase in average installed capacity of the power plants of 4.470; 5.611; 9.1128 and 7.8392 percent per year.

The projection of electricity demand and supplies using the HDI approach is more holistic compared to using the economic growth approach.

The projection of electricity demand and supplies using the HDI approach includes two aspects once of the three aspects that are the pillars of sustainable development. Both of these aspects are the social and economic aspects. Health and longevity and education represent the social aspects, while the average per capita expenditure per year represents the economic aspect of the HDI. While the projection of electricity demand and supplies using the economic growth approach only covers one aspect, namely an increase in average income per capita.

With the economic development paradigm, electricity demand and the target of increasing HDI are a function of economic growth (development acceleration). With the human development paradigm, electricity demand and economic growth targets (development acceleration) are functions of increasing HDI.

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