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Analysis of Electrical Energy Needs and Supply Strategies in North Sulawesi Province

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Abstract: Electrical energy is an important requirement in the development of an area. North Sulawesi Province is one of the areas with rapid development. This is due to the establishment of a special industrial economic zone located in Bitung City. Special economic zones are a form of the Government of Indonesia's efforts to realize the vision of Indonesia Gold 2045. Thus, a new energy demand and supply prediction scenario is needed to overcome this. This study uses the End-Use method with two scenarios of demand and supply. The energy analysis software used is LEAP. The research data used consists of customer data, electricity consumption, North Sulawesi GRDP, list of installed power plants, plans for additional power plants. All data were obtained from various related agencies, including PT PLN, Department of Energy and Mineral Resources, BAPPEDA, BPS North Sulawesi. The results of the projection calculations for the Business as Usual (BaU) and Indonesia Emas 2045 demand scenarios have increased for all sectors. In the household sector the average growth was 6.00% and for business, public, and industry it was 3.00, 4.00 and 25.00%. The average growth for the projected energy demand for the Indonesia Gold 2045 scenario in all sectors is the same, which is 5.00%. In the BaU supply scenario, it is still dominated by PLTD, PLTU, PLTA, and PLTP, while in the Indonesia Gold 2045 scenario, PLTA has increased.

Keywords: Energy Projection; North Sulawesi; End-Use Method; LEAP; BaU

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Introduction

Electrical energy is one of the most important needs for human life. This is because almost all human activities today require electrical energy. In Law Number 30 of 2007 and Law Number 30 of 2009 the Government of Indonesia has regulated the use of natural resources for electrical energy needs (Presiden Republik Indonesia, 2007; 2009). The availability of good electrical energy is one indicator of the progress of a region. North Sulawesi Province has a special economic zone for industry located in Bitung City. The special economic zone of Bitung City was created to develop the area's fishing industry and make the port of Bitung City a trade route for Asia in eastern Indonesia.

In 2085 Indonesia has a goal of becoming an independent country that is influential in the Asia Pacific region. This goal is one of the dreams of Indonesia 2015 – 2085 which was written by the President of Indonesia, Ir. Joko Widodo, at the inauguration of the Indonesian Capsule Monument in Merauke on December 30, 2015. In realizing Indonesia's dream, the Indonesian government issued the Golden Indonesia Vision 2045. There are four pillars of the 2045 Golden Indonesia Vision, namely human resource development, mastery of science and technology, sustainable economic development, equitable development as well as national resilience and governance. One of the factors for sustainable economic development to run well is the need for electrical energy that is well met.

North Sulawesi is a province located in the northern part of the island of Sulawesi. North Sulawesi Province is located at 00 15' – 05 34' North Latitude and 123 07' –

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127 10' East Longitude. The geographical location of North Sulawesi Province has the potential to become a center for trade and regional economic growth in the eastern part of Indonesia. In an effort to optimize this potential, the central government has designated two areas in North Sulawesi as a Special Economic Zone (SEZ). This determination is regulated in Government Regulation no. 32/2014 – May 2014 (Promoda et al., 2016) and Government Regulation no. 84/2019 – December 2019 (Lengkong at al., 2018). The determination of the two SEZ areas will have an impact on the use of electrical energy in North Sulawesi. Housing and economic development in several areas in North Sulawesi are also experiencing developments which will have an impact on the demand and supply of electrical energy in the future. Thus, it is necessary to have the availability of sustainable electrical energy as regulated by the Law on energy and electricity.

In 2020 the use of electrical energy in North Sulawesi Province experienced a contraction in several sectors. The use of electrical energy for the household sector is 931.93 GWh or an increase of 9.0% compared to 2019. In the business sector, the use of electrical energy is 395.85 GWh. This value decreased by 9.5% from 2019. The decline in the use of electrical energy also occurred in the public sector. The total use of public sector electrical energy in 2020 is 164.60 GWh. This value decreased by 2.3% from 2019. For the Industrial sector, the total use of electrical energy in 2020 was 369.90 GWh. This value has increased by 15.3% from 2019. This fluctuation in the use of electrical energy is caused by the ongoing pandemic. The impact of this pandemic also affects economic activities and regional development. According to the Central Statistics Agency, Indonesia's economic growth rate in the first quarter (January-March) only grew by 2.97% or slower than the growth rate in the fourth quarter of 2019 of 4.97%, and in the second quarter of 2020 Indonesia's economic growth rate was minus 5. 32% (Wuryandani, 2020).

Based on the description above, a research study is needed to project the demand for electrical energy and the availability of electrical energy in North Sulawesi Province for the future. In the projection of electrical energy demand, the End-Use method and LEAP software are used. Low Emissions Analysis Platform (LEAP) is a software for predicting energy demand for the future with a set Scenario and period.

Low Emissions Analysis Platform (LEAP) is an energy software used for energy projection analysis. LEAP was developed by the Stockholm Environment Institute with the aim of being an energy demand analysis tool. In the old version, LEAP stands for Long-range Energy Alternative Planning System. This name change does not affect the main function of using LEAP as an energy planning tool. The LEAP software also has functions to calculate greenhouse gas emissions and energy costs (Massaga et al, 2019). In LEAP, energy demand analysis is used by dividing scenarios (Chayawatto et al, 2011). LEAP consists of four main modules, namely the key assumptions, demand, transformation, and resources modules (Bonay, 2019). To project LEAP energy demand using the End-Use method.

Figure 1. LEAP software

The Key Assumptions module is a part of LEAP that is used to store parameters (Imani, 2018). This parameter will be used in the calculation of the projection in the Demand module. Examples of parameters used are the amount of electrical energy consumption, the number of customers, and the number of residents. The Demand module is a module used to calculate energy demand (Roehana, 2019). The demand module consists of households, businesses, industry and the public. In this section LEAP calculates projections using the End-Use method. The result of this calculation is called the final energy demand.

The transformation module is used to calculate the energy supply. Energy supply in the transformation module for calculating energy demand fulfillment is calculated automatically (Wijaya and Ridwan, 2009). Energy supply consists of primary and secondary energy. Primary energy includes natural gas, oil, and coal, while secondary energy includes electricity, LPG, coal briquettes (Roehana, 2019). The resources module consists of a primary and a secondary which is designed by default. Branches in this module will appear by themselves according to the types of energy modeled in the transformation module (Wijaya and Ridwan, 2009).

$$D_{b,s,t} = TA_{b,s,t}.EI_{b,s,t} \quad \text{..... (1)}$$

EI = EC / Activity Level ..... (2)

$$TA_{b,s,t} = A_{b',s,t}{}^{x}\ A_{b'',s,t}{}^{x}\ A_{b''',s,t}{}^{x} \quad \text{..... (3)}$$

Description:

b = Branch
b' = Parent of branch b
b'' = Parent of branch
b''' = Parent of branch
s = Energy planning scenario
t = Base year of planning to final year

D = planning
TA = Energy demand (kWh)
EI = Total activity of electric customers (customers)
EC = Energy intensity (kWh/Customer)
A = Energy consumption (kWh)

In LEAP there is a tree diagram to form a structure in the calculation of energy projections. The tree diagram consists of different types of branches whose functions depend on each module. LEAP works in a structured manner so that determining the location of each branch is very demanding on the results of the projection. The main branches contained in LEAP are divided into category branches, technology branches, key assumptions branches, fuel branches, and environmental emissions branches (Heaps, 2020). Equation (1) is used to calculate the final energy demand. The method in calculating the final energy demand is the result of multiplying the energy activity with the energy intensity. The energy intensity can be obtained using equation (2). Equation (3) is the equation for calculating the total activity.

The parent branch is the main branch in the calculation of the total technology activity. The total technology activity is the product of the activity levels in all technology branches that will affect the demand branch. Examples of parent branches in this study are household, business, public, and industry and branch b are electricity

Method

The data used for this research are secondary data obtained from the Central Statistics Agency, Department of Energy and Mineral Resources, PT PLN, Bappeda of North Sulawesi. The data used include population data, GRDP data, electrical energy consumption data, and energy intensity. Energy intensity data was obtained through calculations using Excel software.

Data processing for this research uses two software, namely LEAP and Excel. The data that has been obtained are grouped into four sectors, namely the household, business, public, and industrial sectors. Calculation of energy demand projection using the End-Use method. This method calculates energy demand based on customer activity. The amount of electrical energy consumption with the End-Use method can be obtained through the following equation.

$Energy$ Consumption = $\sum^{i=n} Q_i \, I_i$ ..... (4)

Description,
Q_i = energy service activity i
I_i = intensity of energy use for
i = energy service I (kWh/customer)

Energy intensity describes the amount of energy use due to energy service activities (Bonay, 2019). A large value of energy intensity causes the efficient use of energy to decrease and vice versa if the value of energy efficiency is small, the more efficient the use of energy. Energy intensity is influenced by several factors, including income per capita, energy prices, growth, and energy imports. The equation to find the energy intensity value is as follows.

$$Energy\ Intensity = \frac{Electrical\ Energy\ Consumption\ (kWh)}{Number\ of\ Costomers} \quad \text{.... (5)}$$

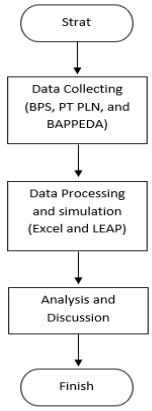

Figure 2. Research Flowchart

Result and Discussion

Historical Data Analysis and Discussion

Table 1. Historical Data on Energy Demand (PT PLN) (Electrical energy consumption data (GWh))

Year	Household	Business	Public	Industry
2016	749.38	353.45	141.61	156.08
2017	772.56	399.18	151.64	221.50
2018	812.46	428.11	162.28	274.04
2019	854.68	437.20	168.40	320.89
2020	931.93	395.85	164.60	369.90

Electrical energy consumption in North Sulawesi Province in the range of 2016 to 2020 is shown in Table 1. Electrical energy consumption data is obtained from secondary data from PT PLN. Electrical energy consumption in the industrial sector experienced the highest increase compared to other sectors. The average growth of electrical energy demand for the industrial sector is 24.50%. In the household sector, the average growth in the use of electrical energy is 5.62%. In the public and business sectors, the average growth in the use of electrical energy is 3.90% and 3.21%, respectively. Based on the average growth in the use of electrical energy, the business sector is the sector with the lowest growth.

The average growth of electricity customers in North Sulawesi Province in the 2016 - 2020 range is the largest in the public sector with an average growth of

5.91%. The lowest growth was in the business sector with an average growth of 3.81

Table 3. Historical Customer Data (PT PLN) (Number of Customers Data)

Year	Household	Business	Public	Industry
2016	561.44	23.32	17.01	379.00
2017	587.89	24.76	18.12	398.00
2018	618.01	25.76	19.37	410.00
2019	646.30	26.42	20.38	439.00
2020	676.46	27.08	21.40	453.00

In 2020 the population of North Sulawesi Province is 2,621,900 inhabitants. This value increased by 1.83% from 2016. The total population in the range of 2016 to 2020 can be seen in Table 3. In the same year the largest GRDP value of North Sulawesi Province was in the household sector, which was Rp. 88,126,374, 00. The average GRDP growth rate for the household sector is 4.11%. The total value of GRDP on the basis of constant prices for North Sulawesi Province can be seen in Table 2.

Table 2. GRDP data according to the constant ADH of North Sulawesi Province (BPS, 2020)

Year	Household	Business	Public	Industry
2016	Rp.74.764.660,00	Rp.19.644.714,00	Rp. 19.644.714,00	Rp. 28.901.688,00
2017	Rp.79.484.025,00	Rp.20.912.445,00	Rp. 20.912.445,00	Rp. 30.755.892,00
2018	Rp 84.249.720,00	Rp.22.255.628,00	Rp. 22.255.628,00	Rp. 29.701.817,00
2019	Rp 89.009.265,00	Rp.23.865.439,00	Rp. 23.865.439,00	Rp. 34.717.741,00
2020	Rp 88.126.374,00	Rp.23.189.124,00	Rp. 23.189.124,00	Rp. 33.837.938,00

Table 5. Scenario Assumptions

Factor	Smell	Indonesia Gold 2045
Economic Growth (GDP)	The growth of all sectors follows the average growth of historical data	In Indonesia Emas 2045, the assumption used is that industrial growth will grow 6% starting in 2025 in accordance with the average growth of the Bitung City industrial sector
Electric energy consumption growth	Following historical data	Following GDP growth
Growth in the number of customers	Following historical data	Following historical data
Electrical Energy Intensity	Following historical data	% Reduction every year

Projection Analysis and Discussion

Table 6. Scenario Key Variables

Variable Name	Value (%)
Population Growth Rate	6.00
Household Electric Energy Consumption Growth Rate	5.62
Business Electric Energy Consumption Growth Rate	3.21
Public Electric Energy Consumption Growth Rate	3.90
Industrial Electric Energy Consumption Growth Rate	24.50
Household Customer Growth Rate	4.77
Business Customer Growth Rate	3.81
Public Subscriber Growth Rate	5.91
Industrial Customer Growth Rate	4.57
Total GDP Growth Rate	4.11
Business GDP Growth Rate	4.15
Public GRDP Growth Rate	3.94
Industrial GDP Growth Rate	4.27

The projected demand and supply of electrical energy in North Sulawesi Province is divided into two, namely the Business as Usual (BaU) scenario and the Indonesia Emas 2045 scenario. The purpose of the BaU scenario is to calculate the demand for electrical energy in the absence of new policies that have an impact on the demand for electrical energy. The Indonesia Gold 2045 scenario was created to support the vision of Indonesia Gold 2045. Indonesia Gold 2045 is the dream of the Indonesian people to become an economic and educational center in the Asia Pacific region.

Table 7. Scenario Demand Projection Results Indonesia Gold 2045 (GWh)

Year	Household	Business	Public	Industry
2021	932	396	165	370
2026	1119	490	203	471
2031	1343	607	251	630
2036	1612	752	310	843
2041	1936	931	384	1128

Table 8. Total Projected Energy Demand for BaU Scenario (GWh)

Year	Household	Business	Public	Industry
2022	984	409	171	461
2026	1.225	464	199	1.106
2030	1.524	526	232	2.658
2034	1.897	597	271	6.387
2038	2.361	677	315	15.345
2042	2.938	769	368	36.867
2046	3.656	872	428	88.576
2050	4.550	990	499	212.812

North Sulawesi has two special economic zones (SEZs), namely the Bitung City SEZ and the Likupang SEZ. Bitung City is prioritized as an industrial area and Likupang as a tourism area. In the Indonesia Emas 2045 scenario, it will be assumed that there will be an increase

in GRDP in the industrial sector due to industrial activities in the Bitung City Special Economic Zone.

Bitung City had an industrial economic structure before being designated as a special economic zone. Based on BPS data from Bitung City, Bitung City contributed 12.65% of the total GRDP of North Sulawesi Province in 2018 and is increasing. to 12.86% in 2020. The distribution of GRDP according to the business field of Bitung City, the processing industry has a contribution of 32.86% in 2020. In the Indonesia Gold 2045 scenario, the assumption of an additional GRDP growth of North Sulawesi is 6.00%.

Electrical Energy Demand Projection

The use of assumptions and key variables in the projection of electrical energy is carried out to determine the effect of the new policy on the demand for electrical energy. Analysis of electrical energy demand is carried out for four sectors using the End-Use method. The four sectors are household, business, public, and industry. The key assumptions and variables applied to both scenarios can be seen in Table 5. The results of the projection of electrical energy demand can be seen in Figure 3. The average growth of electrical energy demand in the household, business and public sectors is 4.00%. The growth in demand for electrical energy in the industrial sector is 6.00%.

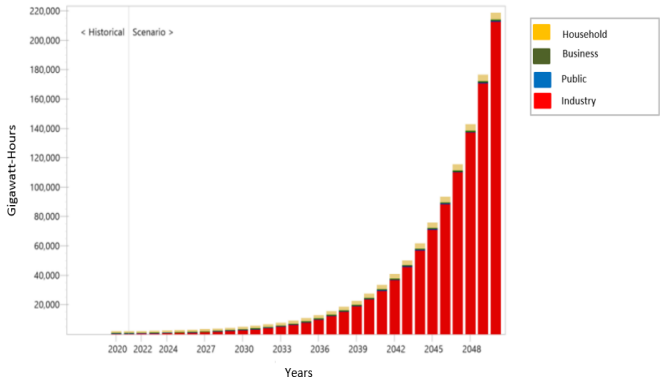

Figure 3. Result of BaU. Scenario Projection

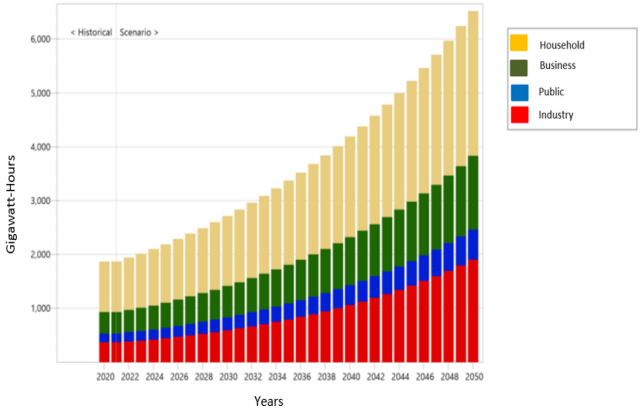

Figure 4. The Projection Result of Indonesia Gold Scenario 2045

The increase in energy consumption in the industrial sector is due to the influence of GRDP growth in the industrial sector

Energy Supply Scenario

The energy supply scenario is divided into two scenarios, namely the BaU Supply scenario and the Renewable Energy Supply scenario.

BaU BaU Provision Scenario

The scenario for BaU's energy supply follows the plan to add power plants planned by PT PLN Suluttenggo. The list of installed power plants and plans for additional power plants can be seen in Table 9 and Table 10. Power plants installed in North Sulawesi are mostly dominated by PLTD and PLTU. Based on data obtained from PLN, 84.00% of the archipelago area of North Sulawesi Province is supplied with electricity from PLTD. In the plan to add power plants in the North Sulawesi region, PLTU is still an option for archipelagic regions.

The main factor that makes the use of renewable energy increase is due to the depletion of fossil fuel reserves and the dangers of pollution from the use of fossil fuels (Salih et al, 2012).

Table 9. Number of Power Plants Installed (PT PLN)

Region Name	Generator Type							
	PLTM	PLTD	PLTS	PLTB	PLTU	PLTP	PLTA	PLTS Rooftop
Manado		3	1					1
mobagu city	3	3						
North Minahasa Regency		5	1				2	
South Minahasa Regency		1			4			
Minahasa Regency	1			1		2		
Sangihe District	1	10						
Siau District		4	1					
Talaud District			2					
Bitung City		1						
Tomohon City						1		

The results of the projection of electricity supply can be seen in Figure 4. In the projection results for the BaU scenario, the use of PLTD, PLTU, PLTA, and PLTP increases. This increase was due to its use as a reserve

margin planning. The selection of these four power plants is based on their large installed capacity. In 2020 the installed capacity for the North Sulawesi area is 557,245 kW with a supply capacity of 474,421 kW. The average load of North Sulawesi Province is 261 MW with a peak load of 355.35 MW. The largest generating capacity is in the PLTD IPP MVPP AMURANG, whose contract will expire at the end of 2021, so that PLTU, PLTA, and PLTP are used as reserve margins. The reserve margin settings follow the settings set in the LEAP software.

Renewable Energy Optimization Scenario

The use of renewable energy is expected to increase along with the increasing public demand for electrical energy (Ramadhan et al, 2016). The Renewable Energy Scenario will focus on the development of rural areas and special economic zones. These two areas are regional development priorities in the work program of the North Sulawesi Provincial government for the 2020-2024 period. Additional capacity for this scenario is planned for the 2022-2024 range and adjusts to the 2021-2030 RUPTL.

Table 9. Plans for Additional Power Plants (PT PLN)

Generator	Generator Type	Kapasitas (MW)	COD
Tahuna 1	PLTMG	2x5	2022
Tahuna 2	PLTMG	2x5	2023
Tahuna 3	PLTMG	2x5	2029
Talaud	PLTU	2x3	2022
Minahasa	PLTMG	3x50	2022/2023
Sulut 1	PLTU	2x50	2023/2024
Dominanga	PLTM	4	2023
Tahuna 1	PLTMG	2x5	2022

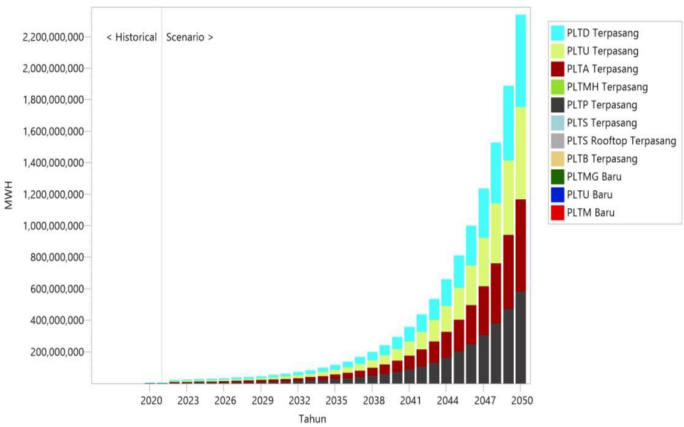

Figure 4. Projected BaU Supply Scenario

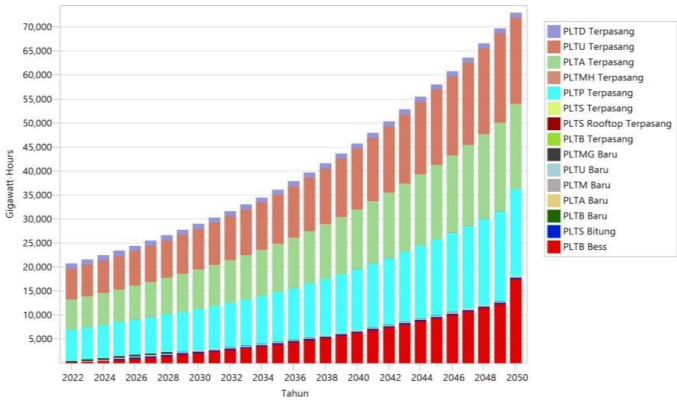

Figure 5. Results of Projected Scenario for Indonesia's 2045 Gold Supply

The addition of hydropower generating capacity follows the plan in the 2021-2030 RUPTL and the Decree of the Minister of Public Works and Public Housing Number 70/KTPS/M/2017 regarding the Water Resources Management Pattern for the Tondano-Sangihe-Talaud-Miangas River. In the two documents, it is planned to add two hydropower plants, namely the Sawangan hydropower plant and the Kuwil hydropower plant. The Sawangan PLTA is planned to be built with a capacity of 16.6 MW. The Sawangan hydropower plant will operate by utilizing the Sawangan dam located in Tombulu District. The Kuwil hydropower plant will be built by utilizing the Kuwil-Kawangkoan dam located in Kalawat District. The capacity for PLTA Kuwil is 1.30 MW. In this scenario, it will also be assumed to add a 0.5 MW PLTM in Lobong. This addition will be in accordance with the planned Decree of the Minister of Public Works and Public Housing Number 162/KPTS/M/2017 concerning the Water Resources Management Pattern for the Dumoga-Sangkub River Basin.The list of plans for additional PLTM and PLTA plants for the Indonesia Emas 2045 scenario can be seen in Table 11.

Table 10. Plans for Additional Power Plants in Bitung City

Generator Type	Capasity (MW)
PLTS	0.041
PLTB+Bess	63.00

Tabel 11. Plan to Add PLTM and PLTA

Generator Type	Capasity (MW)	Area
PLTM	0.50	Passi District, Bolaang Mogondow District
PLTA	16.00	Tombulu District, Minahasa Regency
PLTA	1.30	Kalawat District, North Minahasa Regency

The results of the Indonesia Emas 2045 scenario can be seen in Figure 5. Production for PLTD Installed, PLTU

Installed, PLTA Installed, and PLTP Installed is still dominant but electricity production from PLTB+Bess has only shown an increase. PLTB+Bess is a wind power plant with an additional battery energy storage system (Setiadi et al, 2021). Based on the projection results, PLTB+Bess has increased with an average growth of 23%. Energy usage projections follow the settings in LEAP. The LEAP software has settings for the use of generators according to the order in which the list of generators is entered. In this scenario, the first generator to be included is PLTD. The choice of PLTD is because the installed capacity is the largest compared to other generators. At the beginning of the year, the basic electricity production for PLTD was 1,553.87 GWh and increased to 19,302.84 GWh at the end of production.

Conclusion

There are several conclusions based on the results of the projections and discussions that have been carried out. Energy demand growth in the BaU scenario for the four sectors has increased with the average growth for the household sector is 6%, the business sector is 3%, the public sector is 4%, and 25% is for the industrial sector. The average growth in demand for electrical energy for the household, business and public sectors is 4% and the growth in demand for electrical energy for the industrial sector is 6% in the Indonesia Emas 2045 scenario. Energy supply projections for the BaU scenario are dominated by the use of PLTD, PLTU, PLTA, and PLTP. In the Indonesia Emas 2045 scenario, electricity production from PLTD Installed, PLTU Installed, PLTA Installed, and PLTP installed is still dominant but electricity production from PLTB+Bess shows an increase.

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