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Contributing to Low Emission Development through Regional Energy Planning in West Papua

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***Abstract*— A model of regional energy planning has been developed based in West Papua province. Regional energy planning had two major scenarios: baseline and mitigation. Mitigation scenarios consisted of energy efficiency and fuel switch scenarios. All scenarios are implemented for industrial, commercial, household, transportation, and other sectors. A baseline scenario has been used to reflect energy demand without any intervention from the new energy policy in West Papua Province. The energy efficiency scenario describes the impact of more efficient vehicles and appliances on energy consumption. In the transportation sector, the energy efficiency scenario included a mode change scenario. The use of renewable energy has been included in the fuel switch scenario. In supply-side planning, renewable energy sources have been accommodated to meet a portion of electricity demand. The model of regional energy planning has been implemented by Long-range Energy Alternative Planning software. A cost-benefit analysis has been included in this study. The result indicated that the same goal of a regional development program could be achieved with less emission. By implementing the mitigation scenario, overall energy demand at the end of the projection period can be reduced by 16.63 PJ compared to the baseline. As an impact, the mitigation scenario's global warming potential is 15.89% less than a baseline scenario. It can be concluded that the emission intensity by the implementation of the mitigation scenario is 8.93 Thousand Ton CO2, Equivalent/Billion USD.**

***Keywords*— Energy planning; renewable energy; emission.**

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I. INTRODUCTION

The increasing energy demand is in line with the growth of economic activity. West Papua province has high economic growth. Based on the national statistics council, West Papua province's gross domestic product (GDP) growth from 2011 to 2017 was about 5.0% [1]. High economic growth results in high urbanization and increases the economic level of the household. In 2017, GDP per capita of West Papua province was 4,343.29 USD. This value significantly increased by 19.45% compared to the value in 2011. In addition, the population growth in West Papua within the same interval year is about 2.5% [2]. This population growth is considered a high growth rate. The combination of the economy's and population's growth rate increases energy consumption. As a result, an increase in energy consumption leads to greenhouse gas (GHG) emissions. On the other hand, West Papua province has abundant renewable energy resources. The policy maker must include environment and locally energy resources in the regional energy planning to support development program.

CO_2 emission caused by fossil fuels is a major problem that results in global warming. A low carbon economy has been analyzed based on several scenarios [3]. This study has implemented three different scenarios into the energy planning model. These scenarios are baseline, low carbon, and frustrating low carbon scenarios. The result of this study showed that effective low carbon development could be achieved by adjusting industrial structure and strengthening energy efficiency programs. A model of low carbon-based social development has been proposed by Ali et al. [4]. This article uses a novel multi-criteria decision analysis to achieve low-carbon targets. Two scenarios to analyze the transition of low-carbon development were introduced by Weber and Cabras [5]. The best and the worst scenario for achieving a low carbon path is presented in this study.

Approaches to low-carbon development in two major actors, China, have been discussed in Tang et al. [6]. This country has moved on the right track regarding low-carbon development, and China has very good policies and consistent international engagement related to low-carbon strategies. Strategies for low-carbon development have also been proposed in China [7]. This study has been implemented in China's industries to reduce GHG emissions. Low-carbon-based power system expansion planning has been discussed in [8]. This model was implemented in Sweden to reduce GHG emissions by implementing renewable energy sources (RES).

The strategy to implement low-emission development can be categorized into supply and demand. The supply-side perspective emphasizes clean technology, RES, and mix-energy supply to generate electricity. Demand side strategy implements demand side management (DSM) or demand response (DR) to reduce the peak load of the electrical system and energy demand. The contribution of clean generator technology has been discussed in Morris et al. [9]. The impact of retrofit carbon capture ready (CCR) and carbon capture and storage (CCS) has been analyzed in this study. The role of RES development and CO2 mitigation policies gave an impact on power system expansion planning [10]. This study proposed high penetration of RES as a strategy to support a low carbon economy. The RES-based and conventional power plant integration has been discussed in Laha and Chakraborty [11]. This study presented a multi-objective framework to minimize expansion cost and CO_2 emission. A mixed energy supply for electrical power generation has been proposed with multi-objective sensitivity analyses [12]. Moreover, RES as distributed generation has been included in the integrated planning of electrical power systems as a single objective [13] and multi-objective [14] model. The reliability of RES in electrical power systems has been evaluated for wind technology integration [15].

A low carbon scenario incorporating DSM has been proposed in Baumgärtner et al. [16]. In this study, DSM impacts emission reduction of the power system grid. The options of DSM implementation have been analyzed from economic and environmental implications [17]. In this study, total cost and carbon emission can be reduced significantly as the result of the carbon tax and demand response on the thermal and electrical load. Sectoral-specific implementation of DSM has been proposed by Li and Pye [18]. DSM was implemented in the residential and transport sectors to reduce the peak load by 9%. In the building sector, DSM has been proposed by Lizana et al. [19]. Several strategies of DSM have been analyzed to develop low-carbon transportation development [20]. In electrical power systems, DSM implementation impacted RES penetration and CO2 mitigation [21]. In this study, DSM has a double impact of a reduction in electricity consumption and greater efficiency.

The contribution of this study can be stated as follow:

- Energy demand is aggregated into five sectors: industrial, commercial, household, transportation, and other.
- The developed model is based on a bottom-up approach and uses an energy intensity-based model.
- Integrated analyses of demand and supply side strategy are presented.
- Contribution to low-emission development is analyzed based on the intensity of GHG emissions.

The model is implemented in the West Papua Province of Indonesia. However, this province has abundant RES and is not optimized yet to supply energy demand. This study's proposed model is based on locally available energy resources, which are fossil- and renewable-based.

II. Materials and Method

A bottom-up approach to the energy model is used in this study. Energy demand in the model is aggregated into five sectors: household, industrial, commercial, other, and transportation. Other sector consists of the agriculture and mining subsector. These two subsectors are combined into another sector because of their low share of gross domestic product (GDP). Electricity generation is modeled as a transformation sector. Long-range Energy Alternative Planning (LEAP) software [21] implements and analyzes the developed model.

A. LEAP Model

Many publications used LEAP as a tool to develop and analyze energy models. The LEAP model implements integrated scenario analysis in air pollutant reduction [22]. This study showed the capability of LEAP to develop, analyze, and compare different scenarios to reduce air pollutants from the energy sector, and the viability of the model can be comprehensively analyzed using LEAP. Moreover, this study showed that long-range implementation of scenarios is also feasible using LEAP.

The flexibility of LEAP is demonstrated in Maduekwe et al. [23]. This study used LEAP to model energy demand for the transportation sector. The projection of transportation energy demand requires extensive data comprising energy types, the production of energy, and vehicle technology. This study developed an energy model for the developing country's transportation sector with limited available data. The flexibility of LEAP related to data availability is well demonstrated in this study.

Sectoral energy demand analysis can be conducted using the LEAP model [24]. This study examined demand-side management in the transportation sector. This study explained the use of LEAP to model the electricity demand in the industrial sector. The seasonal feature of LEAP is used to generate demand shifting scenarios. This study resulted in the transportation sector could reduce oil products by 2.97% in the high growth scenario.

A more specific sectoral energy analysis has been reported in Ates [25]. In this study, LEAP was implemented to analyze the energy demand of the iron and steel industry. LEAP was used to explore the potential of energy efficiency and emission reduction in the iron and steel industry. Several scenarios were analyzed to compare various mitigation strategies. Slow and fast implementation of energy efficiency and cleaner energy production were included in this model.

Integration of Logarithmic Mean Divisia Index (LMDI) and LEAP was proposed by Wang et al. [26]. This study uses LMDI to decompose energy demand into scale, structure, and efficiency effects. The qualitative decomposition of LMDI and a quantitative result of LEAP showed a consistent result. Projected energy demand by LEAP and decomposition by LMDI is comprehensively explained in this study.

The long-term projection of electricity demand and supply has been calculated by LEAP [27]. This study showed the capability of LEAP to project electricity demand and to plan generation expansion. In terms of generation expansion planning, LEAP used a single bus approach with no restriction on the capacity of the electrical network. This study explored several demand and supply scenarios to minimize the emission and cost of the expansion planning.

A comprehensive energy demand analysis, including climate phenomena, technology improvement, and increasing renewable energy, is presented using LEAP [28]. A long-range scenario is developed in this study for 2030 and 2050. LEAP was used to extrapolate energy demand. The negative and positive scenarios are developed in this study. The negative scenarios showed low economic growth due to energy efficiency programs. In comparison, the positive scenario had higher economic growth and the substitution of technology with higher efficiency. Scenario-based energy demand was integrally presented in this study.

B. Procedural analysis

Energy demand is aggregated into five sectors: household, industrial, commercial, other, and transportation. Generally, energy demand is calculated based on each sector's activity level and intensity. GDP and population growth are the main drivers of energy demand. GDP is used to represent the industry, commercial, other, and transportation sector activity level. The household sector's activity level is represented by demographic factors such as population, population growth, household size, and urbanization. The developed model extrapolates energy demand to 2050 as the end year and the base year is 2015.

GDP growth is one of the driver variables in the model. This growth represents the industrial, commercial, other, and transportation sectors' activity levels. GDP growth of West Papua province along the projection period is shown in Fig. 1. In this figure, GDP growth is based on the document of regional development target. At the end of the projection period, GDP growth of West Papua would be 7.10%. On average, annual GDP growth is 6.91% per year. With this growth, the GDP of West Papua at the end of the projection period would be 43.10 billion USD (1 USD = 15,000 IDR). GDP of West Papua along the projection period is presented in Fig. 2.

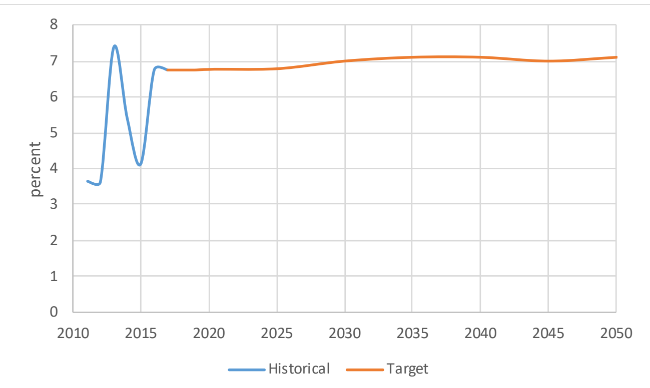

Fig. 1 The target of GDP growth along the projection period.

The three main factors in a household sector influence are population growth, urbanization, and the target electrification ratio. The population growth target in West Papua is presented in Fig. 3. At the end of the projection period, West Papua province's population growth is targeted at about 2%. Annually, the average growth of the population along the projection period is 2.17% per year. In 2050, the population of West Papua province will be 1780.84 thousand people. The population in West Papua province during the projection period is shown in Fig. 4.

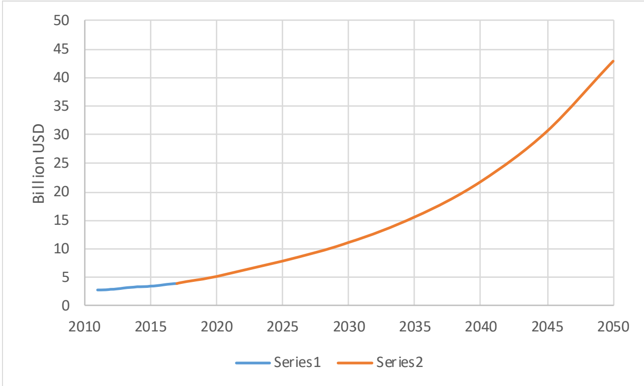

Fig. 2 GDP of West Papua along the projection period.

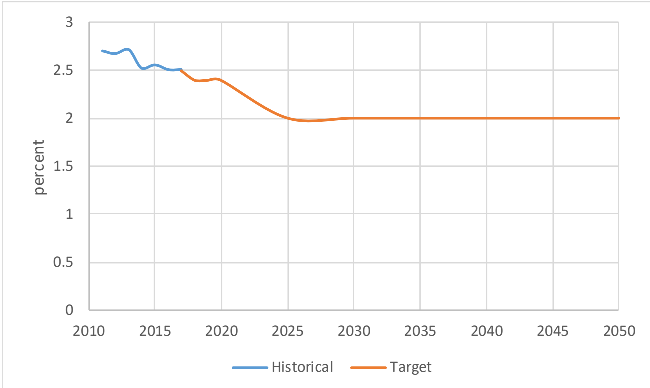

Fig. 3 The target of population growth along the projection period.

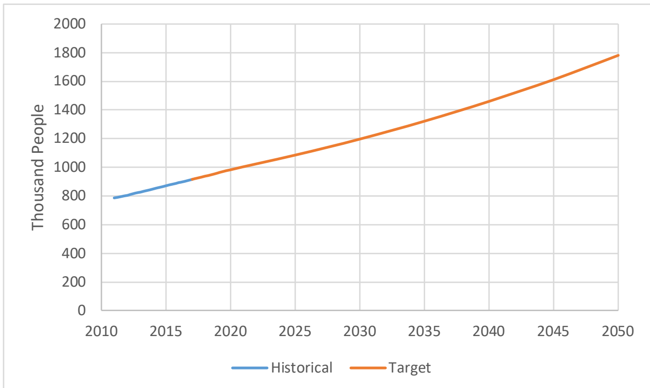

Fig. 4 Population of West Papua province along the projection period.

About 33% or 61.01 thousand households are in an urban area. In 2050, the number of households in urban areas will increase by about 53% of the total households in West Papua province. Therefore, 237.68 thousand households and 207.53 thousand households will be in urban and rural areas. The urbanization ratio in West Papua province along the projection period is presented in Fig. 5. Urbanization influences the projection of energy demand because the pattern of energy demand in urban and rural areas is different. The urban area has more energy intensive than the rural area.

The increasing electrification ratio influences electricity demand in the household sector. Fig. 6 shows the target electrification ratio of the national electricity company. It can be seen in the figure that 100% electrification ratio was reached in 2020.

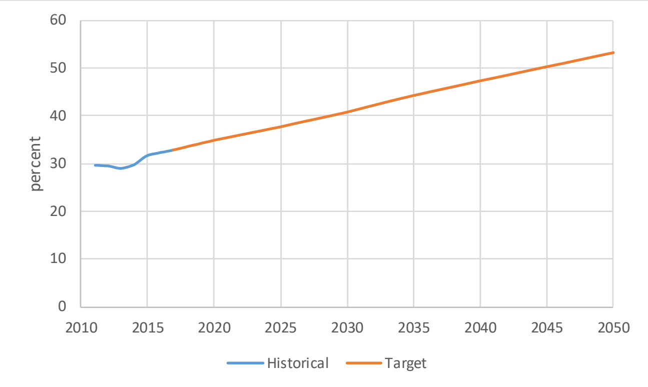

Fig. 5 Urbanization of West Papua Province along the projection period.

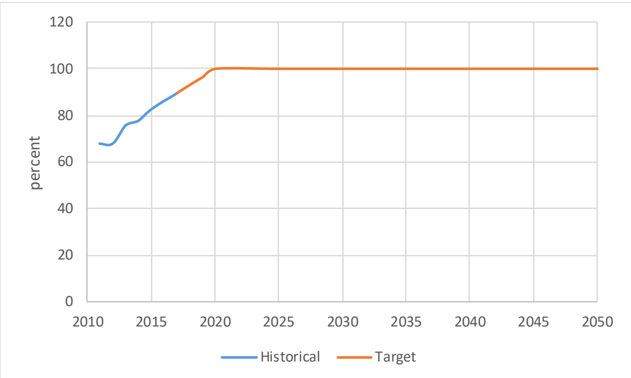

Fig. 6 Electrification ratio improvement based on the target of the national electricity company

Once the parameter of the driver variable is determined, the projection of total energy demand for West Papua province can be calculated. Total energy demand is the sum of sectoral energy demand for each year along the projection period. Specifically, the total electricity demand of West Papua province is used as the base of power system expansion planning. The combination of power generation technology is determined by a developed scenario that is presented in the following section.

C. Scenarios Generation

1) Baseline scenario

A baseline scenario (BS) is a scenario without any intervention of new policy related to the energy sector. In this scenario, the energy intensity and the share of fuel for all sectors remain unchanged. Moreover, appliance technology is not substituted in the household sector for more efficient appliances. In the transportation sector, vehicle technology and mode share remain the same. Moreover, there is no fuel substitution for the new or renewable energy sources in all sectors. In other words, the pattern of energy demand along the projection period is the same as the pattern of the base year. The energy demand of BS is only determined by the growth and the change of driver variables.

2) Mitigation scenario

Mitigation scenario (MS) consists of fuel switch (FS), energy efficiency (EE), and transportation mode change (MC). FS scenario is a scenario to analyze the impact of emission reduction by substituting fuel from fossil resources to renewable resources. In the household sector, FS is implemented for non-electricity-based activities, such as cooking. In industrial, commercial, and other sectors, FS is applied to all subsectors. Mostly, energy use in transportation is based on fossil sources, gasoline and diesel oil. By implementing the FS scenario, the share of renewable energy is increased for the transportation sector.

EE scenario represents the use of more efficient technology in all sectors. In the household sector, EE is applied by changing old appliances to more efficient ones. For example, the share of LED lamps or efficient air conditioners increases compared to the existing appliance. In industrial, commercial, and other sectors, EE is implemented by reducing the energy intensity for all subsectors. While in the transportation sector, EE is implemented by changing the existing vehicle to the new vehicle technology, which has more energy efficient. Moreover, the MC scenario is implemented in the transportation sector as one strategy to reduce energy demand in the transportation sector. In the MC scenario, a portion of passenger transportation based on private vehicles is switched to public transportation. For example, passenger by car or motorcycle is switched to bus.

D. Power system expansion scenario

Power system expansion planning is based on the result of the projection of electricity demand. Therefore, two scenarios of power system expansion planning are generated in the model. The first scenario is based on electricity demand that is resulted in BS scenario, and the second is based on electricity demand that is generated by MS. For each scenario of power system expansion planning. There are two generation expansion scenarios: generation expansion based on the fossil fuel source and generation expansion with the penetration of renewable energy sources.

III. Result and Discussion

A. The projection of energy demand

The projection of energy demand is calculated based on two scenarios, which are BS and MS. Fig. 7 shows energy demand along the projection period based on BS scenario. As explained in the previous section, there is no intervention of energy policy in BS scenario. Energy demand was only driven by the growth of driver variables, which are economic and demographic changes. In this figure, annual growth rate of total energy demand is 5.04% per year. The highest growth rate of energy demand is resulted by commercial sector with the average growth rate is 6.97% per year. On the other hand, household sector has the lowest average growth rate of energy demand, which is 3.33% per year.

In the end of projection period, total energy demand in West Papua province is 53.58 PJ. Industrial sector has the highest share of energy demand of 40.54% of total energy demand in 2050. The share of energy demand for industrial sector has increased compare to the based year with 26.75% of total energy demand in 2015. With the average annual growth rate of 6.30% per year, energy demand for the industrial sector in 2050 is 21.72 PJ. For the transportation sector, the share of energy demand in 2050 is 25.01% of total energy demand. The share of energy demand in the transportation sector is decreasing compared to the base year's share. In 2015, the share of energy demand for the transportation sector was 35.38% of total energy demand 2015. With the average annual growth rate of 4.01%, energy demand for the transportation sector is 13.43 PJ at the end of the projection period. By accelerating the GDP of the commercial sector, the share of energy demand for the commercial sector is significantly increased to 17.51% in 2050 from 9.28% in 2015. The commercial sector has a 6.97% per year of the average annual growth rate of energy demand. By this growth rate, the energy demand of the commercial sector in 2050 will be 9.38 PJ. In the household sector, the share of energy demand has significantly decreased to 13.90% in 2050 compared to 24.64% in 2015 of total energy demand. The average annual growth rate of energy demand in the household sector is 3.34% per year. The energy demand of the household sector in 2050 is 7.45 PJ.

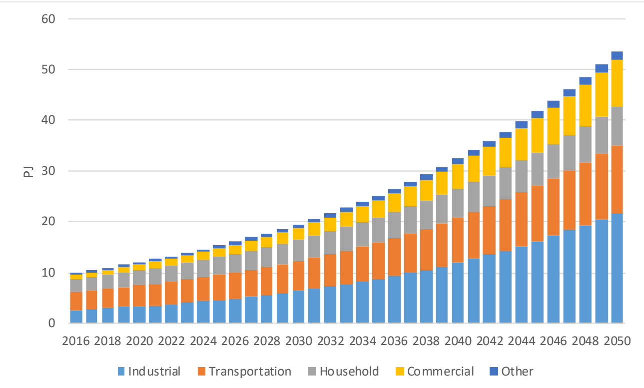

Fig. 7 Energy demand by sector based on BS scenario.

A different result of projected energy demand by sector is shown in Fig. 8. Energy demand in Fig. 8 is based on the MS scenario, consisting of energy efficiency, fuel switch, and mode change scenarios. By implementing a mitigation policy, the average annual growth rate of total energy demand in West Papua Province is 3.93%. This growth rate has significantly decreased compared to the growth rate based on BS scenario. The industrial and transportation sector significantly reduced the average annual growth rate of energy demand by MS scenario, which are 3.98% and 3.53% for industrial and transportation sectors, respectively. The household and commercial sector have little difference in average annual energy demand growth rate. By MS scenario, average growth rate of energy demand for household and commercial sectors is 3.24% per year and 6.25% per year respectively.

In total, MS scenario resulted in 16.63 PJ less energy demand than total energy demand based on BS scenario. The industrial sector has a significant reduction of energy demand by 11.96 PJ compared to industrial energy demand by BS. For transportation and commercial sectors, MS scenarios reduced energy demand by 2.01 PJ and 1.96 PJ, respectively. Only a slight reduction occurred for households and other sectors produced by MS scenario. The reduction of energy demand for households and other sectors based on the MS scenario is 0.24 PJ and 0.48 PJ, respectively.

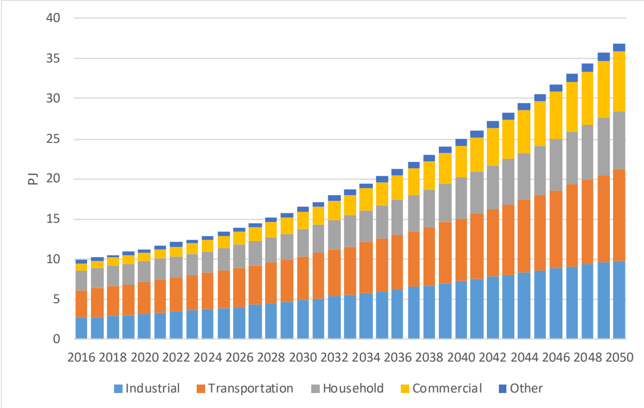

Fig. 8 Energy demand by sector based on MS scenario.

The projection of energy demand by fuel is shown in Fig. 9 and Fig. 10 based on BS and MS scenarios, respectively. Based on the BS scenario, oil-based fuel dominates by 69.24% and 65.51% of total energy demand in 2015 and 2050, respectively. In 2025, the energy demand for oil fuel will be 35.10 PJ. Diesel oil is the highest energy demand of oil fuel used by industrial, transportation, and commercial sectors. The total consumption of diesel oil in 2050 is 23.47 PJ. Natural gas and coal fuel share 7.40% and 6.10% of total energy demand, respectively. In 2050, the demand for natural gas and coal will be 3.96 PJ and 3.27 PJ, respectively. The fuel of renewable energy sources has a very small share of 2.95% of total energy demand in 2050. Traditional biomass has the highest share of total energy demand. In 2050, traditional biomass demand is projected to be 1.09 PJ or 2.04% of total energy demand. In total, the projected energy demand for renewable energy sources in 2050 is 1.58 PJ.

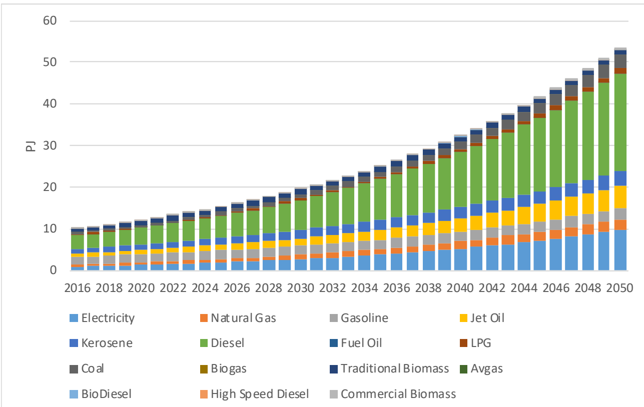

Fig. 9 Energy demand by fuel type based on BS scenario.

By implementing the MS scenario, the share of renewable energy sources to supply the energy demand of West Papua is increased. It is shown in Fig. 10. Based on MS scenarios, the role of renewable energy resources to supply energy demand has a share of 33.97% of total energy demand in 2050. The increasing renewable energy share is driven by biofuel use in the transportation, industrial, and commercial sectors. Biodiesel has a share of 25.01% or 9.25 PJ in 2050. Total demand for renewable energy sources in 2050 is 12.54 PJ. Kerosene substitution for LPG in the household, commercial, and industrial sectors has increased the share of natural gas fuel to 6.06 PJ or 16.32% of total energy demand in 2050. As part of the MS scenario, the FS scenario reduced the share of oil fuel. In 2050, the share of oil fuel is 16.29% based on MS scenarios. This share is much lower compared to the result based on BS scenario. The demand for oil fuel in 2050 based on MS scenario is 6.01 PJ or decreased by 29.02 PJ compared to BS scenario.

On the other hand, natural gas demand is increased by 2.06 PJ compare to BS scenario. The share of coal demand is also decreasing to 4.64% of total energy demand in 2050. Coal demand in 2050 is 1.71 PJ. Coal demand is decreased by 1.56 PJ compare to BS scenario. In total, energy demand based on MS scenario in 2050 is 36.92 PJ or decreased by 16.66 PJ from the result of BS scenario.

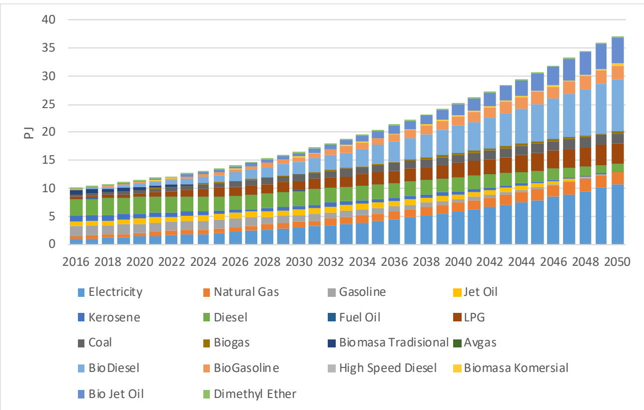

Fig. 10 Energy demand by fuel type based on MS scenario.

B. *Power system expansion planning*

Generation expansion planning is needed to meet the projected demand for electricity. Based on the BS scenario, electricity demand has an average growth rate of 7.10% per year, resulting in 2,684.56GWh of electricity demand in 2050. On the other hand, MS scenario resulted in average growth rate of the electricity demand of 7.39% per year. The higher value of average growth rate results from the FS scenario that substitutes oil-based fuel for electricity in industrial and commercial sectors. In 2050, electricity demand based on MS scenario is 2,951.24GWh.

The electrical power system must meet the projected demand of electricity. Generated electricity by a process based on BS scenario is presented in Fig. 11. In this scenario, total generated electricity for meeting the demand is 3,087.83GWh. Total generated electricity is higher than electricity demand by 13.06%. This percentage is represented network losses of electrical power system. Coal power plant is dominating to produce electricity along the projection period. Generated electricity by coal power plant is 2,653.44GWh or 80.44% of total generated electricity. Generated electricity by natural gas process is 430.30GWh.

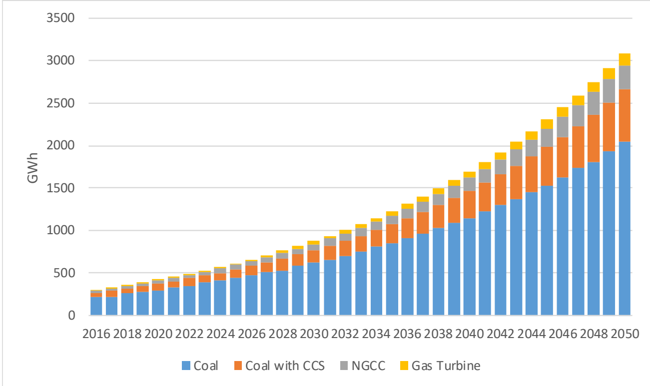

Fig. 11 Generated electricity by a process based on BS scenario.

For MS scenario, each process's generated electricity along the projection period is presented in Fig. 12. In 2050, the total generated electricity is 3,394.57GWh. Similarly, the electrical power system produced electricity 13.60% higher than electricity demand in MS scenario as the result of network losses. Power plant with renewable energy technology, which are wind turbine, solar panel, biomass, and biodiesel for diesel engine, produces some portion of generated electricity of the system. In 2050, electricity generated by a renewable energy power plants is 217.40GWh, or 6.40% of total generated electricity based on MS scenario.

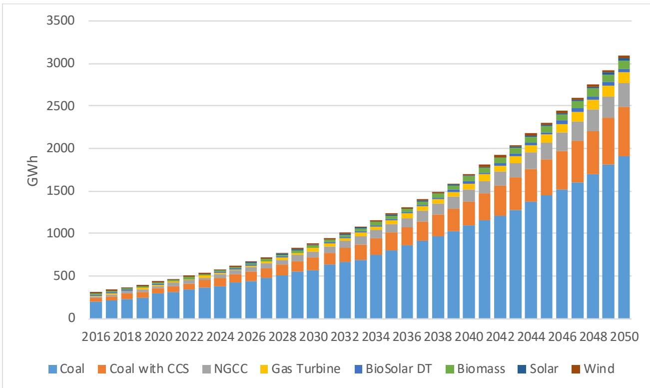

Fig. 12 Generated electricity by a process based on MS scenario.

Generation expansion planning determines the needed capacity size of a power plant in the system. Capacity addition based on BS scenarios is presented in Fig. 13. Along the projection period, the coal-based power plant dominates. In total, 25 GW coal-based power plants should be added to the electrical power system of West Papua along the projection period. On the other hand, only 3.8 GW of natural gas power plants must be built cumulatively. Based on power plant technology, coal power plant without carbon capture and storage (CCS) of 20 GW and a coal power plant with CCS of 6 GW must be built cumulatively. The natural gas combined cycle (NGCC) and gas turbine (GT) power plant must be built cumulatively with 3 GW and 2 GW, respectively. Based on the BS scenario, 32 GW of the power plant's capacity must be built along the projection period.

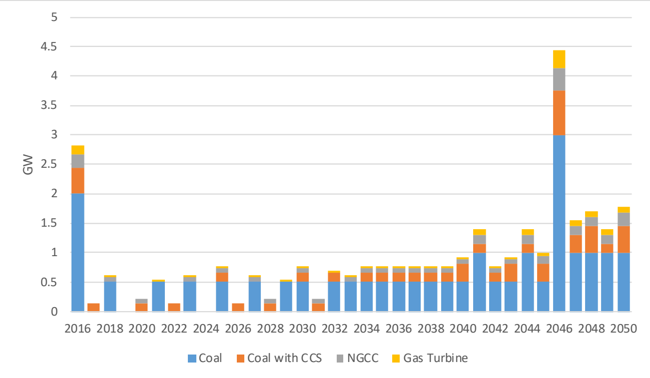

Fig. 13 Added power plant capacity by a process based on BS scenario.

MS scenario resulted in more capacity must be installed into the electrical power system of West Papua. The added capacity that must be installed along the projection period based on MS scenario is presented in Fig. 14. In total, 35 GW capacity of the power plant must be installed cumulatively into the system. MS scenario produces 3 GW more power plant capacity compared to BS scenarios. Coal power plants without CCS and CCS must be built with 20 GW and 5 GW capacity, respectively. NGCC and GT as natural gas power plant must be added with the capacity of 2.9 GW and 1.9 GW, respectively. Renewable energy power plants of biomass, wind turbine, and solar panel contribute to MS scenario. Totally, the renewable energy power plant must be added into the system with the capacity of 1.9 GW, 0.8 GW, and 0.8 GW for biomass power plant, wind turbines, and solar panels, respectively.

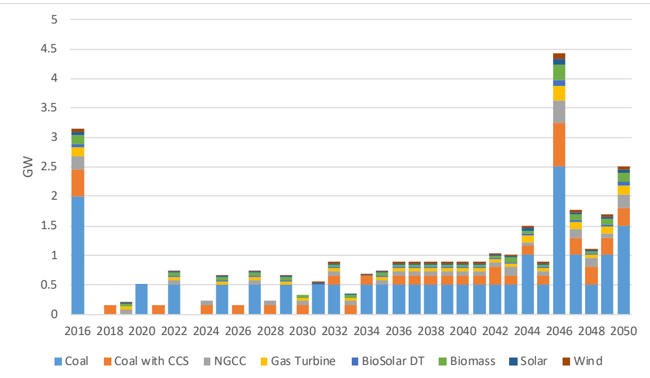

Fig. 14 Added power plant capacity by process based on MS scenario.

C. *GHG emission*

As an impact, GHG emission is produced due to energy consumption on the demand side and the transformation process on the supply side. Cumulatively, GHG emission produce by each scenario is presented in Fig. 15. Based on the BS scenario, 59.30% GHG emission is produced from energy consumption on demand side. While energy transformation to convert primary energy to electricity produced 40.70% of total GHG emission. On the other hand, energy transformation has more share of GHG emissions based on the result of MS scenario. Energy conversion from primary energy to electricity has 55.79% GHG emissions. Whereas, demand side energy consumption produced 44.21% GHG emission.

The GHG emission produced by the BS scenario is 88.29 million Ton CO2 Equivalent. Total GHG emission from demand and supply side based and BS scenario is 53.30 Million Ton CO2 Equivalent and 34.99 Million Ton CO2 Equivalent, respectively. On the other hand, the MS scenario produced 74.27 Million Ton CO2 Equivalent, which consists of 38.40 Million Ton CO2 Equivalent from the demand side and 35.87 Million Ton CO2 Equivalent from the supply side. The reduction of GHG emission by implementing MS scenario that consists of FS and EE scenario is 15.89% compare to GHG emission of BS scenario.

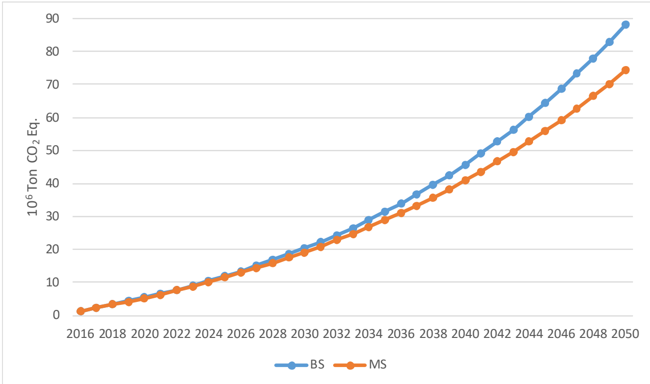

Fig. 15 Cumulative GHG emission by scenario.

With the same growth of economic and demographic parameters, lower GHG emissions can be produced by implementing MS scenario. Emission intensity as a ratio of produced GHG emission and GDP can be used to determine a low emission development strategy parameter. The implementation of MS scenario produced an emission intensity of 8.93 Thousand Ton CO2 Equivalent/Billion USD. This intensity is lower compared to the emission intensity produced by BS scenario. Based on BS scenario, emission intensity is 11.89 Thousand Ton CO2 Equivalent/Billion USD. This indicated that the same regional development parameters could be achieved with lower GHG emissions. By implementing MS scenario in regional energy policy, the development of West Papua province can be done with less GHG emissions.

IV. Conclusion

A model of energy from the demand and supply sides has been developed to support regional development with lower GHG emissions. The developed model consisted of baseline and mitigation scenarios. Fuel switch and energy efficiency scenarios are part of the mitigation scenario. By implementing the mitigation scenario, total energy demand can be reduced by 16.63 PJ compared to the baseline scenario. However, fuel switches in industrial and commercial resulted in higher electricity demand compared to a baseline scenario. In view of GHG emissions, the mitigation scenario produced 15.89% lower GHG emissions compared to the baseline scenario. The developed model also proved that with the same development parameters, the mitigation scenario resulted in lower GHG emission with an emission intensity of 8.93 Thousand Ton CO2 Equivalent/Billion USD.

The analysis of the integration of renewable energy sources as part of an energy supply chain can be enhanced by incorporating uncertainty parameters. The intermittent nature of renewable sources in the electrical power system can be analyzed further. In the view of regional energy policy, developed model can be used as starting point to develop a more comprehensive regional energy with considering energy sector. Further, the role of renewable energy sources in economic development can be analyzed.

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