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Article

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Indonesia's Energy Demand Projection Until 2060

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ABSTRACT

Changes that occur along with the times have consequences for increasing the need for various resources, especially energy. In Indonesia, various changes that occur will also affect the pattern of energy consumption, both qualitatively and quantitatively. This paper describes various aspects related to change and projects over the next 40 years the pattern and quantitative aspects of energy demand in Indonesia. This study is based on historical data by applying related parameters that influence one another. The methodology used is the application of a modeling system with the software "Model for Analysis of Energy Demand (MAED)." The results obtained are a description of Indonesia's energy demand projections until 2060 per sector and the form or type of energy needed. The projection results show that in the next 40 years the total energy demand will increase from 195.0 Mtoe in 2020 to 556.5 Mtoe in 2060. From this amount there is a percentage change in the need for each type of energy between the early years of 2020 to the end of 2060. Motor fuel changed from 28% to 34%, while electricity changed from 24% in 2020 to 28% in 2060. In the demand sector, the share of demand decreased in households from 29% in 2020 to 20% in 2060. While other sectors experienced an increase in share in various values. Transportation rose from 19% to 22%, ACM from 8% to 9%, manufacturing remained 34%, while services rose from 10 to 15%. During study period there two important parameters decrease, those are population growth and energy intensity.

Keywords: Population Growth, GDP Growth, Energy Intensity, Technological Developments, Energy Demand
JEL Classifications: C53, Q47

1. INTRODUCTION

Population growth and the national economy enhancement drive to increase energy consumption in Indonesia. In addition, technological developments in the transportation sector, which tend to lead to electric cars increasing demand for electrical energy as a substitute for motor vehicle fuel oil, although internal combustion system car still exist during study period. This paper aims to describe future energy demand based on demographic, economic and behavioral parameters of energy consumers for the next 40 years. In this energy demand analysis, MAED software is used. The results obtained indicate that in the future energy consumption will experience a change in the shape of the curve, i.e. there will be changes in consumption in all sectors.

Changes of shape of energy demand curve lead by economic situation, social life and also changes technology trend in the next several decades. For an example in transportation sector, electricity energy demand will increase in percentage. By consideration the environmental protection policies, the transportation mode more preverable to use the electric cars producing almost absolutely no emissions, because there is no combustion process in the drive system. The operation of electric cars as a substitute for fuel vehicles in a city avoids the emission of fossil fuel combustion. Along the way will be clean of smoke that is SOx, NOx CO and CO_2 which is usually read by internal combustion vehicles. However, even though electric vehicles do not emit combustion products, electric vehicles still use energy, that is electricity energy that is using many fossil fuels. Moreover, if the fossil fuel used

Figure 1: Working Scheme of MAED Program (Model for Analysis of Energy Demand (MAED-2) User's Manual 2006)

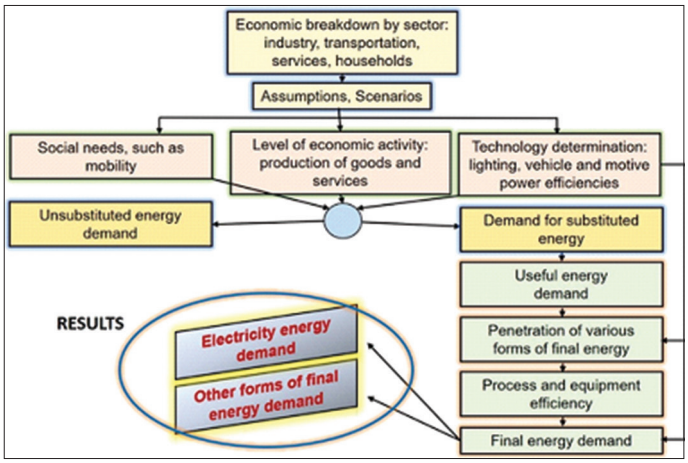


Figure 2: Output of MAED (CADES 2002)

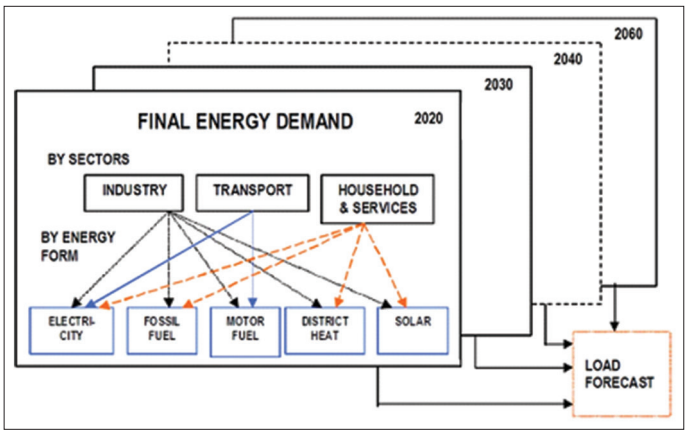
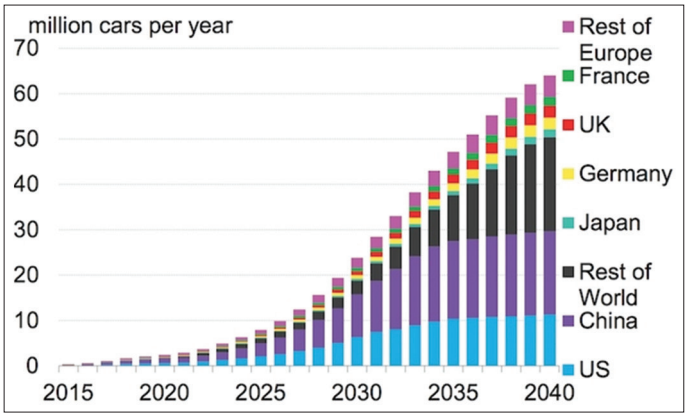


Figure 3: Electric car growth in the world (Kohn 2019)



for power generation is from the type of coal that produces high emissions, then the emissions caused by the use of electric cars turn into emissions from the power plant. There are several types of power plants that do not use fossil fuels such as hydroelectric power plants, geothermal power plants, solar power plants, wind power plants, and nuclear power plants. Availability of hydropower plant and geothermal power plant potential are very limited and will not be sufficient with the existing growth demand. Similarly, solar generating and wind energy, the problem is that they are low density energy sources, so they require a fairly high capital cost and their economic life is not too long. Meanwhile, from the last type, nuclear power plants do not yet exist in Indonesia. This type of power plant is capable of generating electricity on a large scale, suitable for carrying basic loads, industrial loads, and suitable for countries with large populations that require large amounts of electricity.

1.1. Purpose of study

This paper aims to discuss Indonesia's energy needs until 2060 in relation to changes in consumption patterns, especially in the transportation sector in Indonesia. As is known, the transportation sector in Indonesia generally uses fuel oil as an energy source. In addition to the existence of a period of scarcity of fuel oil after the next few decades, the tendency of the world community, which will also occur in Indonesia, the use of battery-based electric vehicles will be increasingly widespread. This of course will increase the increase in the electrical load, in which the electric vehicle requires charging the battery in order to rotate the motor to move on the highway.

1.2. Hypothesis

Based on historical data and studies of the potential of Indonesia's human and natural resources, the increase in energy consumption continues to grow quite high until the 2060s. It is estimated that, with the depletion of domestic oil reserves and the decreasing supply of petroleum from abroad, alternative energy supply will be more focused on electricity consumption. In fact, electric vehicles have gained market share in various countries following various incentives (Dhar et al., 2017). Electrification of road transport is also likely to have a positive effect on reducing carbon dioxide (CO_2) emissions as well as reducing economic benefits in the carbon trading market. This is due to the possibility of supplying energy for charging vehicle batteries from renewable sources or energy sources that reduce current carbon emissions (Fontaínhas et al., 2016). Another advantage derived from the use of electric vehicles is the ongoing improvement in energy diversification to all sectors. Concerns about energy scarcity for the transportation sector, which so far have only relied on fuel oil can be overcome with the option of charging electric vehicle propulsion batteries from various energy sources. has been converted into electrical energy (Van Mierlo, 2007).

2. DATA AND ASSUMPTION

2.1. Total population

Starting from 1930 data based on the population census, in that year the total population in the Indonesian Archipelago Region is now 60.7 million people (Junaidi, 2010), which increased to 97 million in 1960. Population projections require assumptions related to age-specific fertility rates (ASFR). BPS (Badan Pusat Statistik) calculates ASFR from the 2015 SUPAS data. This data is applied to the projected female population each year in the 2015–2045 period to determine the number of births and the number of residents in the future. Overall historical data entered is up to 2020, while from 2021 to 2060 are projections based on population growth analysis (Katalog BPS, 2018; 2019).

Figure 4: (a-c) Share of energy demand by sector

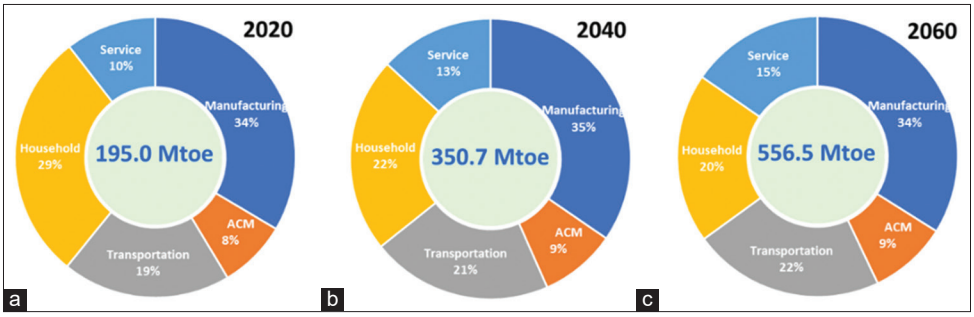
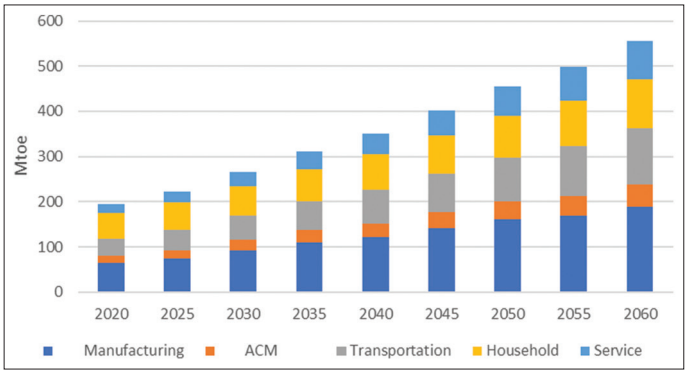


Figure 5: Total final energy demand by sector



Furthermore, in the last few decades the population growth rate refers to the BPS projection, which is then extrapolated based on the nature of the growth curve to the following years based on the consideration of the nature of population growth and comparison to several projection results. From the results of these projections, it is found that the population of Indonesia will be 294.2 million in 2030, 312.5 million in 2040 and 332.5 million in 2060.

2.2. Gross Domestic Product

The GDP figure applied in this study takes the 2010 constant value. There are several forecastings made by international institutions, including the OECD, World Bank, IMF and UN agencies. To estimate the short term, all of these institutions have these figures, although there are slight differences, while the OECD releases a GDP growth forecast for the long term which can be used as an average reference to project Indonesia's GDP growth. Figures released by the OECD are current prices, which in 2060 the value of GDP will be 13.2 trillion US$ (KNOEMA, 2021). The OECD estimates that the highest growth rate achieved by Indonesia is 6.4% in 2010. Meanwhile, the long-term GDP growth forecast will gradually decline to approach a linear curve from 5.35% in 2019 to 2.67% in 2060 (BPS, 2021). The calculation of GDP in filling out this model takes into account various information and factors based on processed from BPS data, the average inflation rate over the last decade (2010–2019) was 3.72% (BPS, 2019).

2.3. Changes in Energy Consumption Patterns

As a result of the shift from oil or gas fuel vehicles to the use of electric vehicles, there will be a significant surge in demand for electrical energy [9]. The energy burden for the transportation sector, which has been borne by fuel oil, will turn into electricity (Liun, 2018). Thus, sources of electrical energy generation are increasingly important to meet the needs of various sectors, including road transportation.

Government policies also affect the type of vehicle technology used. If the government's policy is that the motor vehicle emission tax is implemented, this type of vehicle will experience a reduction in interest in the user community. This affects the price of this type of vehicle in the market (I Dewa Made Raditya Margenta 2021). Therefore, one of the projection considerations for motorized vehicles is the future scenario of electric vehicles which are placed as environmentally friendly vehicles (Dhar, et al. 2017).

2.4. Technological Develompment

Technological developments have an impact on energy consumption patterns with a tendency to choose certain type of energy. Changes in rail transportation, for example, previously used diesel fuel, now switch to using electric power. Like wise with road vehicles such as private cars and public transportation, the trend in the future will use electricity as well (Rudolph, 2016). In terms of energy diversification, this is certainly beneficial in addition to other advantages of using electric cars compared to internal combustion system cars (Dhar et al. 2017) (Fontaínhas, et al. 2016). In addition to reducing dependence on fuel oil, it is also easy in terms of supply (Rinkesh 2021).

3. METHODOLOGY

Indonesia's energy demand analysis process is based on modeling using Model for Energy Demand Analysis (MAED) software. Many formula and equation in the model are not revealed in this paper. The energy calculation starts from demographic indicators which are population data since the last years and the trend of growth rates that are correlated with various population growth control policies until the next year's forecast in the scope of the study. The description of GDP per sector as an economic indicator in the model is formatted as a percentage of total GDP based on trends in historical data and various policies made by the government that may affect the value of the series in the future. Furthermore, the model specifies the energy intensity for each energy use in each sector (IAEA, 2006). Figure 1 show the working scheme of MAED Program which categorizes the analysis steps starting from macroeconomics to obtaining final energy demand.

Transport sector is split into freight and passenger subsectors, where the demand of freight is calculated as a function of the GDP contribution (t-km/MU) from the subsectors of Agriculture,

Construction, Mining, Manufacturing, Services and Energy sectors. On the other hand, the demand for passenger transport is determined from total population, share of population in large cities, and the average intercity and intracity distance traveling per person (Model for Analysis of Energy Demand (MAED-2) User's Manual 2006). In term of freight transportation, the amount of energy refers to the energy intensity in units of kWh/100ton-km. Previously, each mode of transportation was determined by the type of energy or fuel used in its natural units such as tons, liters and so on. The magnitude value is then converted into units in the form of kWh which is used in the MAED model. Energy intensity in the freight transport subsector is calculated in tons km/US$. The generation values of tons km/US$ variy by commodity type. For example, farming and fishing are each 0.816 tonkm/US$, while machinery and equipment are 0.500 tonkm/US$. Generally, the higher the value added of the commodity the lower the energy intensity.

3.1. Energy Demand Calculation Using MAED

The energy demand of each sector is calculated as a function of the possible development scenarios. In program implementation, MAED calculates the total energy demand for each end-use category, and combines the economic sectors into four main "energy consumer" sectors: Industry (including Agriculture, Construction, Mining, and Manufacturing), Transport, Services and Households as shown by Figure 2 used in cades study (CADES 2002). MAED provides a systematic calculation framework for evaluating the effect on energy demand of any changes in economic conditions or living standards of the population. There are two scenario elements applied in this calculation, namely those relating to (1) the socio-economic system that describes the fundamental characteristics of the social and economic evolution of the country; and (2) related to technological factors that must be considered in calculating energy demand, for example the efficiency of each form of alternative energy and its penetration into potential markets (Model for Analysis of Energy Demand (MAED-2) User's Manual 2006).

4. RESULTS AND DISCUSSION

4.1. Total Population

Historical data shows that the population has increased near a linear curve for several decades until 2020, so it can be said that population growth has decreased from year to year (BPS, 2013). Indonesia's population growth is still relatively high. Based on growth declining of the population, it is expected that the population will to continue to rise until the middle of the 21st century. Eventhough the population growth rate decreased from 1.07% in 2020 to 0.24% in 2060. Until the end of the study period, in 2060 it is projected that the population will reach around 332.5 million people.

4.2. Projection of GDP

Historical data shows a consistent increase in total GDP. This statement of course excludes emergency or incidental situations due to temporary crises, such as happened in 1997–1998, where Indonesia as one of the countries severely affected, there was a minus GDP growth, namely –13.1% (World Bank, 2021). The other case is global impact of covid-19 pandemic that presses national economy to a decline in GDP of –2.1% in 2020. By referring to historical data between 1960 and 2019 based on constant dollar value calculations, the average GDP growth is 5.3% per year as shown in Table 1. The growth of GDP over the last 20 years shows an increase in the range of 4–6 percent per year. Some of the sectors that have the most influence on the GDP growth rate show significant figures. It is the manufacturing sector contributing 17.9% on average experiencing GDP growth of approximately of 10.49% to GDP growth of 3.8% per year. Mining and quarrying sector contributed on average about 8.1% to GDP (Anonymous, 2018).

4.3. Energy Demand

Currently and for the next few decades, energy demand in Indonesia is projected to increase relatively high. Economic growth with the industrialization process in various regions and achievment of many regions advancing in economic project energy demand to accelerate. Several parameters driving energy demand growth include population growth, GDP growth, technology development, lifestyle changes, changes of public consumption patterns and government policies.

Technological developments that also drive energy demand growth are indicated by the increasing number of types of industrial products and technology in various sectors. The use of air conditioners, which a few decades ago was still very limited in number and capacity, has now expanded to various sectors including households in the village area. Likewise, other technological products such as work tools are increasingly widespread in the use of electricity.

The shift in lifestyle has led to an increase in energy use in almost all fields. The use of electricity in public facilities that previously

Table 1: Basic information on macroeconomic environment of Indonesia

Item	Unit	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060
Population	(million)	255.59	269.60	282.46	294.17	304.21	312.51	318.96	325.03	328.53	332.03
Pop. gr. rate	(%p.a.)	1.47	1.07	0.94	0.82	0.67	0.54	0.41	0.38	0.21	0.21
Urban pop.	(%)	44.00	45.00	45.00	45.40	45.80	46.30	46.50	47.00	50.00	52.00
GDP	(10^9 US$)*	958.21	990.25	1,225.79	1,497.11	1,807.49	2,157.13	2,542.25	2,950.03	3,378.59	3,844.99
GDP gr. rate	(% p.a.)	4.88	3.30	4.36	4.08	3.84	3.60	3.34	3.02	2.75	2.62
GDP/cap	US$	3,749.05	3,673.01	4,339.78	5,089.33	5,941.56	6,902.67	7,970.40	9,076.22	10,284.01	11,580.31
Agriculture	(%)	13.49	13.14	12.79	12.44	12.09	11.74	11.39	11.14	10.89	10.64
Construction	(%)	10.21	10.37	10.53	10.69	10.85	11.01	10.89	10.77	10.65	10.53
Mining	(%)	7.82	7.82	7.82	7.82	7.75	7.75	7.75	7.40	7.40	7.40
Manufacturing	(%)	22.64	22.36	22.08	21.80	21.52	21.24	20.96	20.68	20.40	20.12
Service	(%)	43.31	43.70	44.09	44.48	44.87	45.26	45.65	46.04	46.43	46.82
Energy	(%)	2.53	2.61	2.69	2.77	2.92	3.00	3.36	3.97	4.23	4.49

*In US$2010 constant value

did not exist, is now unavoidable. Energy in general and electricity in particular have become the primary life support and one of the main indicators of well-being.

Based on indicators that the demand for real energy is still high, the number of areas not yet covered by electricity, the dependence on fuel oil is still high, and the implementation of government policy programs in the industrial sector, especially mining, is currently increasing sharply. The government's policy in the mining industry sector is that it is mandatory for businesses to export mining or excavation materials to purify mining materials before they are exported to obtain adequate added value in the country.

In the mining sub-sector, Indonesia is the world's third-ranked tin producer, contributing 18% of world production and has around 17% of world reserves. Indonesia is also a nickel producer which accounts for 9.5% of world nickel mining production. Another important mining mineral is bauxite which in 2016 produced 241.2 thousand tons [19]. Based on the policy mandated in the law, these mining materials need to be processed before being exported. This means that there will be additional energy demand for the refining process of the material. There are still many other minerals that will increase the energy demand in the mining material processing industry, so that the energy demand for the industrial sector, especially manufacturing subsector is the largest.

4.4. Energy Demand in Transportation Sector

Energy for transportation projects the addition of electric cars during the study period. This is one of the reasons that the increase in the total demand for electrical energy is the highest among other forms of energy. The additions follow an estimated share of private electric cars rising from 0% in 2015 to 40% in 2060.

Although this issue is not fully discussed in this paper, in studies using the MAED Model it has been considered and projected into the next few decades. The various available information is used as input that the penetration of electric cars will be a favorite choice in the future, but this choice will not fully be the sole choice, because there are still many preparations and considerations for the disadvantages of using electric cars. One of the important pieces of information used in the consideration here is the projected growth of the world electric car (Kohn, 2019). In his research Kohn concluded that the electric car will reach high demand growth in the next decades as shown in Figure 3.

One of the reasons for the switch from road transportation to electric cars is the decline in battery prices (Lambert, 2017). A significant decrease, for example from $1000/kWh in 2000 to $227/kWh in 2016. Whereas last year there was a decrease of 35% (How Electric Vehicles Will Cause the Next Oil Crisis 2021). This of course has an important meaning because one of the biggest cost components in electric cars is the price of the battery. Electric car sales have increased significantly. New research from Canalys shows that global sales of electric vehicles (EVs) in 2020 increased 39% YoY to 3.1 million units. Canalys estimates that the number of EVs sold will increase to 30 million by 2028 and that EVs will represent nearly half of all passenger cars sold globally by 2030 (Canalys, 2021). The situation in Indonesia will certainly follow the developments and trends of world transportation patterns. The shift to electric cars around the world will be a necessity that the energy load for transportation will be partially taken over by grid electricity, so there will be a surge in electrical loads.

The development of battery technology also encourages the use of battery-based electric cars. The energy density of lithium-ion cells has been steadily increasing in recent years at gravimetric and volumetric levels. This energy density is projected to increase from 250 Wh/kg in 2020 to 323 Wh/kg (König et al. 2021).

The share of energy demand is analyzed based on both parties, namely the user sector and the type of energy or fuel that provides based on:

4.5. Energy Share by Sector

In this context, the projection of the energy share in the future tends to change. In 2020 the total energy demand is 195.0 TOE (tonne of oil equivalent) with a manufacturing share of 34%, household of 29% and transportation 19% of., as shown in Figure 4. The largest position of manufacturing energy demand will be slightly increasing to be 35% in 2040 and then back again to be 34% in 2060. Meanwhile, the share of the household sector is shrinking, which shows a different nature from the general European region, which requires room heating in winter which is 64.7% on average (Final energy consumption in the residential sector by type of end-use, EU-28 2021), while in the tropic regions generally are do not require such heating.

Entirely all sectors and subsector are growing for energy demand in the nominal number. The industrial sector is the highest in energy consumption. This sector houses four sub-sectors, namely manufacturing, agriculture, construction and mining. The manufacturing subsector alone accounts for 34, 35 and 34 percent for 2020, 2040 and 2060 respectively. Meanwhile, the Agriculture, Construction and Mining subsectors (the three are abbreviated as ACM) accounts for only 8, 9 and 9 percent in those years. In the next 40 years, energy demand will develop in a relatively similar way, as shown in Figure 5. The figure reflects energy demand increasing by sector and by year until 2060.

4.6. Final Energy Demand by Energy Type

Energy demand over the next 40 years will experience changes in its share both in terms of consumption per sector and in terms of demand for its form of energy. The influencing factors are the development of consumption of each sector, technological developments and economic aspects related to energy prices for certain needs. Energy for transportation and motive power for industry tends to be shared between fuel oil and electrical energy.

Although there is a tendency for the widespread use of electric cars in the future, it will not necessarily be able to replace oil-fueled vehicles, because there will be a lot of preparation that will be needed for this transition including the development of infrastructure that can fully accommodate and technical reliability for the provision of electricity in large scale. Therefore, it is predicted that the use of internal combustion vehicles will still prevail until 2060.

Figure 6: (a-c) Share of energy demand by energy form

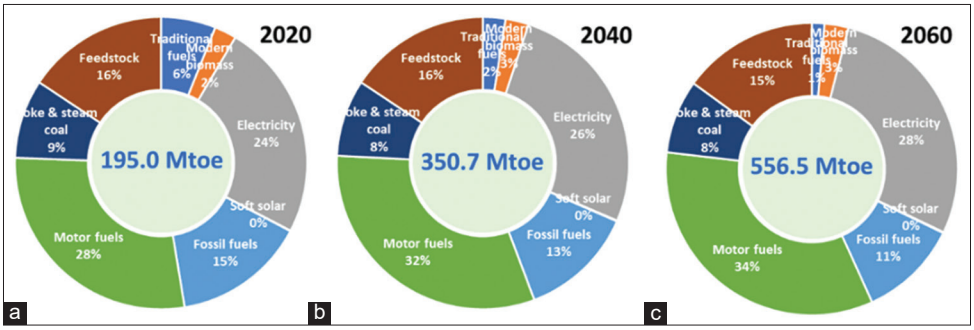


Figure 7: Total final energy demand by energy form

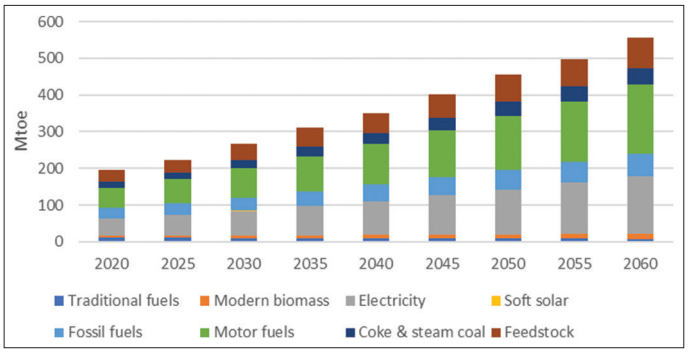
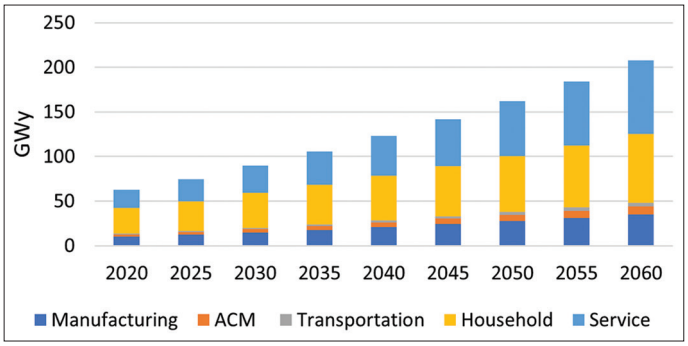


Figure 8: Total electricity energy demand by sector



The high demand for energy for the transportation and industry sectors that require an independently available generating system, the need for fuel oil (motor fuel) cannot be eliminated. The following Figure 6 shows the increasing share for this form of energy. Meanwhile, fossil fuels are still high, including to meet the needs of households, industry and services.

The services sector was the sector with the highest growth accounting for 10, 13 and 15 percent respectively for the years. In contrast to the position in 2020, the three largest demand sectors are manufacturing, household and transportation. The share of transportation sector is growing during study period from 19% in 2020 to be 21% in 2040 and 22% in 2060 as shown in Figure 7.

The change in the percentage share of each sector is an indicator of an increase in the population welfare. The increase in the share of the transportation and the service sectors also clarifies the improvement in the national economy.

Berbeda dengan kawasan Eropa, the use of energy in the household sector in Indonesia and the tropics is generally different from that of countries in the polar hemisphere. For example, there is no space heating in almost all sectors, so the input data in the model is adjusted to the real data in the field, on the other side, in Europe space heating is the important energy use.

The use of energy in the household sector in Indonesia and the tropics is generally different from that of countries in the polar hemisphere. For example, there is no space heating in almost all sectors, so the input data in the model is adjusted to the real data in the field. In Europe, more than 50% of energy in the household sector is used for space heating (Final energy consumption in the residential sector by type of end-use, EU-28 2021). Meanwhile in Indonesia it is almost non-existent, except in mountainous areas which are used very little.

In this study, all types of energy are categorized into nine main categories in the modeling, namely traditional fuel, modern biomass, electricity, district heat, soft solar, fossil fuel, motor fuel, coke & steam coal, and feedstock.

Electricity energy demand one of the energy form with high growth rate. The total of the demand will be account to 207.44 GWy (giga watt year) in 2060. This is 28% of total energy at that year and occupate as the second rank of the biggest after motor fuel as the first rank. The electricity energy of 207.44 GWy be able to interpretate requiring power generation about 277 GWe as a capacity factor average of 75%. Figure 8 shows that the electricity energy will increase in the highest growth compared to the other of energy types or increase of approach four times in 40 years.

4.7. Energy Demand per Value Added

The value of energy intensity and its development is obtained from various sources of technical innovation and increased use of energy in improving the national economy. Economic activities and forms of energy used have varying values of energy demand per value added (energy intensity). An increase in the value of GDP is at the same time an indication of a decrease in that value. The industrial sector, especially the manufacturing sub-sector, is the sector with the largest energy demand with the greatest intensity. The energy intensity of this sector is shown to decrease gradually over time from decade to decade in this sector, namely from 2.5 kWh/US$ in 2020 to 2,227 and 2,069 kWh/US$ in 2040 and 2060, respectively. the manufacturing subsector itself

was 5.2 kWh/US$ in 2020, falling to 4.64 and 4.25 kWh/US$ respectively in 2040 and 2060. Meanwhile in the ACM sub-sector the energy intensity was much lower.

4.8. Economic Activity

For the industrial sector (including manufacturing and ACM) in 2020 the total energy demand per value added is 2500 kWh/US$.

5. CONCLUSION

The development of economic potential in several sectors affects the national energy demand significantly. These economic sectors are mainly industry, services and activities in the transportation support sector.

Indonesia's energy demand over the next 40 years will adjust to the development of population growth, increase in GDP, technological developments and people's lifestyles according to the times. The energy demand will be increase to be an account in 2060 of almost 3 times of 2020 that will be dominated by electricity energy and motor fuels.

It is a challenge for Indonesia to meet energy needs in the future by considering the trend of green and environmentally friendly economic development, so clean technology is the consideration.

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