Investigation of availability, demand, targets, economic growth and development of RE 2017-2050: Case study in Indonesia

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Abstract

The potential for (RE) in Indonesia is quite abundant and is predicted to replace conventional energy which continues to experience depletion and depletion in the next few years. However, until now the use of RE has only reached 2% of the existing potential of 441.7GW overall. The main overview of this work is to investigate the availability of RE that can be utilized for electricity generation in Indonesia. National energy demand and targets in the long run during the 2017-2050 period are also discussed. Besides, government policies in supporting RE development are also considered in this work. The results show that the potential for RE in Indonesia can be utilized and might replace conventional energy for decades. Utilization of RE for electricity generation can be achieved with a government policy that supports the investor as the executor of RE development. The selling price of electricity from the use of RE is cheaper than fossils so that people's economy is more affordable. Finally, the government's target for the utilization of RE as the main energy in Indonesia can be done by implementing several policies for the development of RE. Thus, greenhouse gas emissions and the use of petroleum fuels can reduced.

1. Introduction

Indonesia is one of the countries in Southeast Asia and even in the world that has problems with the energy crisis. The number of Indonesia's oil imports during the 2009–2019 period reached 49.1 million tons or an annual average of 3.6% [1]. Based on the energy mix (EM), sustainable development (SD) and low carbon (LC) scenario that Indonesia's energy demand in 2025 will be 170.8, 154.7 and 150.1 MTOE, respectively. While in 2050 Indonesia's overall energy demand will reach 548.8, 481.1 and 424.2 MTOE [2]. Total primary energy production consisting of the petroleum, natural gas, coal and other RE in 2018 reached 411.6 MTOE. Of the total production, 64% or 261.4 MTOE were exported mainly for coal and LNG. Final energy consumption in 2018 (without biomass) reaches 114 MTOE consisting of 40% transportation sector, then industry 36%, household 16%, commercial 6% and other sectors 2%.

Energy is one of the main factors in the context of sustainable development to eradicate poverty, protecting the environment, increasing prosperity and speed [3]. The abundant availability of RE in Indonesia has been widely expressed by several researchers and has been widely discussed before. Indonesia has the highest availability of coal energy at 51% in Southeast Asia [4]. While the level of Indonesian oil production reached second after Brunei Darussalam each of 1202 and 1806 [5]. Indonesia has targeted the use of RE in 2025 is 23% with a feed-in tariff policy system. RE is very possible to be used as the main energy to replace petroleum (fossil) which continues to experience depletion every year. Discussions on Indonesia's RE policy and prospects have been conveyed [6]. The application of RE in various ways can also reduce carbon emissions which has been providing high enough air pollution, especially from vehicles and industry [7]. Determination of the RE target of 23% in line with the determination of the use of oil consumption by 25% nationally. The selection of a sustainable solar system (solar), a sustainable biogas system (biogas), an efficient lighting device (Lighting), an efficient cooling device (Cooling), and an efficient cooking stove (Cooking) scenario aim to reduce emissions levels sustainably. Where this action is targeted at 2050 can save cooling energy by 22.99% [8–12]. One RE that is attracting foreign investors in solar PV as reported by [13]. The installed solar PV capacity has increased from 9 megawatts (MW) to more than 240 MW in 2017. However, a problem often faced by foreign investors is the lack of government policy towards RE developers. Therefore, with this weak policy many interventions that are not expected in the field. Targets for achieving efficient use of RE systems have been prioritized in the decarbonisation of Indonesia's electricity systems [14].

The application of RE has also greatly impacted the economic improvement and reduced carbon dioxide emissions. Also, adverse effects on climate change and global warming can be reduced by applying RE permanently [15]. Investigations on the effects of economic policy uncertainty differentiation on various types of energy company investments using the panel regression model have been reported [16]. Economic growth with RE consumption can drive for long-term financial development [17]. Investigations into the short-term and long-term economic growth of RE use have also been discussed recently [18]. Where the results of their investigations show that the use of RE can significantly increase economic growth and improve welfare. The global energy transition system is one of the trends to provide promising economic opportunities in the future [19]. The use of RE can save money that has been used for energy needs. This is because the price of RE is cheaper than using fossil fuels. The impact of RE and financial development on carbon dioxide (CO_2) emissions and the economy has been reported [20]. Where the results of their investigation that RE consumption and financial development influence CO_2 emissions and economic growth. The effect of economic growth on the consumption of renewable and non-RE used to inspect Asia-Pacific Economic Cooperation (APEC) countries [21]. The consumption of renewable and non-RE used to achieve the target in reducing emissions globally has been implemented since 1997–2014 [22]. While in Indonesia emissions reductions have also been carried out such as the development of RE by implementing several policies towards developers. Policies that support RE developers must be made and implemented by the stakeholders. Besides, the government must also target more efficient use of energy in the future. The government's step in targeting the use of RE in the future is very appropriate. Besides that, the government can save more budget and can further improve the welfare of the community.

Energy from RE sources found in Indonesia is very abundant. However, it cannot be utilized optimally and the available resources are inadequate so that this has become the main problem faced so far. This review aims to investigate the availability and demand for energy in Indonesia during the period 2019 – 250. Targets for the use of RE to reduce dependence on conventional (fossil) energy are also discussed. Also, this research will investigate government policies in several regions/provinces in Indonesia in sustainably implementing RE. To reach the target in the use of RE, it needs sufficient resources and more costs.

2. Potential And Implementation Re In Indonesia

Reduced fossil energy production, especially petroleum and global commitments in reducing greenhouse gas emissions. So that it has encouraged the Government to increase the role of RE sustainably as part of maintaining domestic energy security and independence. Following PP No. 79 of 2014 concerning the National Energy Policy, the target of RE in 2025 are at least 23% and 31% in 2050. Indonesia has a RE potential that is large enough to achieve the primary energy mix target.

The total RE potential in Indonesia reaches 442 GW in 2019 with an installed power of 9.32 GW or only 2% that can be utilized. Total RE 442 GW is sourced from marine energy potential 17.9 GW, geothermal 28.5 GW, bioenergy 32.6 GW, wind power 60.6 GW, hydropower 75 GW and solar power 207.8 GW. While the implementation of RE sources only reached 2% from geothermal 1,949 GW, bioenergy 1,858 GW, wind 147.1 MW, hydro 5,417 GW and solar power 0.135 GWp is shown in Fig. 1 [23, 24].

The largest coal energy potential in Indonesia is in the five regions such as Sumatra, Java, Kalimantan, Sulawesi and Papua. The results of calculations carried out in 2017 amount of coal energy reached 125.177.59 million tons and coal reserves amounted to 24.239.96 million tons of coal. However, this number decreased by 2.885.05 million tons compared to 2016 [2]. This decline is closely related to global economic conditions triggered by global oil prices. Indonesia has considerable coal reserves and is estimated to be depleted in the next 61 years (2070). While for the energy potential of conventional natural gas in 2017 it reaches 142.72 TSCF[31] with details of 100.37 TSCF is proven reserves and 42.35 TSCF as potential reserves. Natural gas energy is spread between Natuna, East Kalimantan, South Sumatra, Maluku and Papua with an assumption of an average of 2.9 TSCF per year. The average natural gas production in the last year was 7.997 MMSCFD. However, this trend shows a decline compared to 2013 from 8.130 MMSCFD to 7.620 MMSCFD in 2017.

The highest geothermal energy potential is found in North Sumatera (Sumut) at 970 MW and followed by West Java (Jabar) at 790 MW. While Aceh Province ranks third with the most potential geothermal energy of 590 MW, East Java (Jatim) 405 MW, Lampung 395 MW, Maluku 290 MW, West Sumatera (Sumbar) 270 MW, Bengkulu and Central Java (Jateng) of 245 MW. While for other provinces the potential for geothermal energy is below 200 MW as shown in Fig. 2(a). The total geothermal energy in Indonesia totals 5,395 MW in 21 provinces [23, 24].

While for the overall hydroelectric energy potential (PLTA) in Indonesia is 12.281 MW which is divided into 17 provinces. The highest potential of hydropower energy is in the provinces of South Sumatera (Sumsel), East Java and West Java, respectively, 2.368 MW, 2.168 MW and 2,138 MW. While the Province of Aceh has a hydropower energy potential of 1.595 MW, Central Sulawesi (Sulteng) 670 MW, Jambi 374 MW, Central Java 360 MW, West Kalimantan (Kalbar) 198 MW, East Kalimantan (Kaltim) 168 MW and Maluku 156 MW. Meanwhile, for provinces with a hydropower energy potential below 100 MW as shown in Fig. 2(b) [23, 24].

One of the RE sources that cannot be utilized properly is solar energy in Indonesia. The potential of solar energy in Indonesia is almost in all provinces. However, until now its utilization is still very minimal, even though solar energy can be used as electrical energy, heating, cooling, etc. The highest potential of solar energy is found in the province of West Kalimantan amounting to 20.113 MW. Furthermore, the potential for solar energy is in the provinces of South Sumatra, East Kalimantan and North Sumatera, respectively 17.233 MW, 13.479 MW and 11.51 MW. While the least solar energy potential is in Jakarta and Bangka Belitung, respectively 225 MW and 281 MW as shown in Fig. 3. The total utilization of solar energy in Indonesia in 2018 is 0.05% of the total potential. However, the government's target for the use of solar energy in 2025 is 1.047 MWp compared to 94.42 MWp in 2018 [25].

The potential of RE in Indonesia such as geothermal, solar, bioenergy, wind, hydro, mini-micro hydro and tidal/wave as a whole reaches 239.970 MW. The total installed capacity of RE until 2019 is 8.215.5 MW. While the amount of new RE that can be utilized until 2019 is 17.452%. The amount of RE utilization is still very small compared to the existing potential as shown in Table 1.

Table 1
RE potential, installed and utilization in Indonesia [26, 27]

Energy Type	Geothermal (MW)	Solar (MW)	Bioenergy (MW)	Wind (MW)	Hydro (MW)	Mini-micro Hydro (MW)	Tidal wave (MW)
Potential	29.544	4.80 kWh/m^2/h	32.654	60.647	75.091	19.385	17.989
Installed capacity	1.438.5	78.5	1.671.0	3.1	4.826.7	197.4	0.3
Utilization	4.9%	0.04%	5.1%	0.01%	6.4%	1.0%	0.002%

The total target of RE development during the period 2019–2028 shows that the use of RE is more dominant. This is because conventional (fossil) energy reserves are running low so the government has to import substantial oil. With the development of RE, the government can reduce oil imports that have continued to soar in recent decades. Development for hydropower energy power plants is the highest compared to other energy. While PLTP, PLTMH and PLTS rank second, third and fourth during the period 2019–2028 as shown in Fig. 4 [2].

RE development in Indonesia is generally divided into five islands including; Sumatra Island, Kalimantan Island, Java-Bali Island, Sulawesi Island and Maluku and Papua are shown in Table 2. The highest total capacity target for RE is in Sumatra Island with a total capacity of 8.852 MW. While the highest potential for RE that has not been utilized during the 2017–2026 period was found in Sulawesi Island at 4.155 MW. The type of RE for the highest installed capacity is hydropower energy as a whole of 12.342 MW. While the potential of hydropower energy that has not been utilized as a whole is 6.869 MW. The total installed capacity of hydropower energy in Java-Bali is higher than Sumatra Island and other islands. However, the potential of hydropower energy during the period 2017–2026 no longer exists. While the highest potential of hydropower energy that has not been utilized is in Sulawesi Island of 3.852 MW. The total installed capacity of RE in Indonesia until 2026 reaches 21.549 MW and the potential for RE that has not been utilized in the same period is 9.3889 MW [24, 28, 29].

Overall, energy sourced from biomass found in 27 provinces in Indonesia amounted to 23,335.7 MW. The most biomass energy sources are in Riau province 4169.6 MW and followed by the provinces of North Sumatra and South Sulawesi (South Sulawesi) respectively 2,796.1 MW and 2,061.4 MW. While the smallest biomass energy source in Jakarta which only has 0.5 MW is shown in Fig. 5(a). The small potential of biomass in Jakarta is caused by the area of mapping and has been met by housing residents. Whereas for forest areas it is almost certain that there are no more in Jakarta. Meanwhile, if compared to the forest area in Riau and North Sumatra provinces, it is far more than Jakarta. Furthermore, the potential source of biogas energy in Indonesia is also very adequate when used for energy, especially for electricity generation. The first most potential sources of biogas energy are in Jakarta, Banten and North

Sumatera with 126.1 MW, 118.6 MW and 115.5 MW respectively shown in Fig. 5(b) [30, 31]. The high biogas in these three provinces could be due to the high number of the population so that the potential for biogas produced is more than that of the other provinces.

Table 2
RE capacity and potential in Indonesia 2017–2026

Regions	Sumatera		Kalimantan		Jawa-Bali		Sulawesi		Maluku & Papua		Indonesia Total	
Generator RE	Capacity (MW)	Potential	Capacity (MW)	Potential	Capacity (MW)	Potential	Capacity (MW)	Potential	Capacity (MW)	Potential	Capacity (MW)	Potentia
PLTP	3.305	**N/A**	**N/A**	**N/A**	2.510	**N/A**	400	**N/A**	75	**N/A**	6.290	**N/A**
PLTA	4.284	1.193	1.056	1.804	4.562	**N/A**	2.323	3.852	118	20	12.342	6.869
PLTMH	938	752	10	**N/A**	437	**N/A**	221	**N/A**	43	**N/A**	1.694	752
PLT Solar	5	59	**N/A**	12	**N/A**	200	52	38	**N/A**	6	57	315
PLT Bayu	**N/A**	200	150	**N/A**	250	823	170	5	**N/A**	**N/A**	570	1.028
PLT Biomass	274	135	41	30	206	**N/A**	21	10	55	**N/A**	597	175
PLT Wave	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	250	**N/A**	**N/A**	**N/A**	250
PLT Bio-Fuel	411	**N/A**	830	**N/A**	439	**N/A**	4.423	**N/A**	469	**N/A**	6.572	**N/A**
Total	8.851	2.339	1.257	1.846	7.965	1.023	3.186	4.155	290	26	21.549	9.389

3. Results And Discussion

The installed power plant capacity in Indonesia in 2018 is 56,509.53 MW. This amount was sourced from PLN 40,486.60 MW, from the private sector amounting to 13,350.79 MW and 2,672.14 MW sourced from rental power plants. Most of the sources of electricity generation in Indonesia are coal energy by 49%, PLTG/PLTGU/PLTMG 27% from PLTD 12%, PLTA/PLTM 11%, PLTP 3% and the rest comes from RE. The capacity of this power plant continues to increase every year from 48,739.00 MW in 2014 [32, 33].

Petroleum production in Indonesia in 2018 decreased to 283 million barrels (778 thousand bph) compared to 2009 of 346 million barrels (949 thousand bph) [2, 34, 35]. The decline in oil production was caused by several factors such as production wells that were no longer feasible. While the development of wells for new production is still very limited. However, until now Indonesia still has a dependency on petroleum. Existing petroleum cannot meet the needs of existing refineries so the Indonesian government continues to import from other countries such as the Middle East. The number of Indonesia's oil imports from 2009–2018 reached more than 35% shown in Fig. 6(a).

Energy demand in general in 2018 will reach 465.7 million barrels/year including biodiesel fuel. Total domestic oil production is 278.1 barrels. While the total amount of oil imported by the Indonesian government from oil-producing countries is 165.4 barrels per year. Comparison of production output and total oil imports each year as shown in Fig. 6(b). In 2017 Indonesia was ranked the third-largest country in terms of crude oil imports after Singapore and Thailand at US$ 21.4 billion and US$ 20.1 billion, respectively. Indonesia's total oil imports were US$ 8.1 billion, Malaysia US$ 3.9 billion, the Philippines US$ 3.5 billion, Brunei Darussalam US$ 1.6 billion and Vietnam US$ 93.2 million [36].

Natural gas consumption in Indonesia in 2018 amounted to 1.7 million MMSCF for the industrial sector of feedstock/energy, electricity generation, city gas (household and commercial) and gas lift [2]. In addition, this natural gas is also an export commodity with an annual average of 1.2 million MMSCF in the form of LNG and gas. LPG consumption in 2018 was 7.5 million tons, this amount was taken from imports of 74% (5.5 million tons) and domestic production of 26% (2 million tons). The total percentage of LNG exports to natural gas decreased in 2018 to 40% compared to 2009 by 50% shown in Fig. 7.

Conversion of kerosene to LPG by the government has increased the consumption of LPG. While the availability of LPG produced domestically is still very limited. Consumption of 3 kg LPG continues to increase due to subsidies from the government. So the government must anticipate this increase because its use is considered not on target.

4.1 Target RE

At present, the development of RE refers to Perpres No. 5 of 2006 concerning National Energy Policy. In the Perpres it was stated that the contribution of RE in the national primary energy mix in 2025 was 17% with the composition of Biofuel by 5%, Geothermal 5%, Biomasses, Nuclear, Water, Solar, and Wind 5%, and coal liquefied by 2%. For this reason, the steps to be taken by the Government are to increase the installed capacity of the Micro Hydro Power Plant to 2,846 MW in 2025, the installed capacity of 180 MW Biomass in 2020, the installed wind capacity (PLT Bayu) of 0.97 GW in 2025, solar 0.87 GW in 2024, and nuclear 4.2 GW in 2024. The total investment absorbed by RE development until 2025 is projected at 13.197 million USD.

Utilization of solar energy as electricity generation aims to increase national energy security, reduce dependence on the use of fossil fuels and increase economic investment. In addition, domestic industries are more efficient, reducing greenhouse gas emissions and to meet the government's target of RE use by 23% by 2025. The Indonesian government has set targets for the use of installed solar energy in 2025 by 1.008.4 MW [2, 37]. The use of the energy mix in

2025 is targeted by the government for coal 54.6%, natural gas/LNG 22%, RE 23% and BBM 0.4%. The target for energy use in 2025 is adjusted to government policies in utilizing RE and gas so that dependence on fossil energy can be reduced. The development of RE can be increased until 2028 by seeking to be able to increase the capacity of PV roofs (PV roof) of 3,200 MW for 1.6 million customers. Electricity energy production in 2028 is targeted at 500.691 GWh, mostly produced from coal energy of 272,354 GWh, gas 110,150 GWh, hydro 54.736 GWh, Geothermal 48.217 GWh, RE and BBM respectively of 13.205 GWh and 2,019 GWh shown in Fig. 8(a). Based on the composition of electricity production by type of fuel, the government's target to reduce the use of fossil fuels and reduce imports can be achieved. However, to achieve this target, a strong government policy and adequate resources are needed. Meanwhile in Fig. 8(b) is the composition of the energy mix for electricity generation. Based on the composition of the power plant using the energy mix, the government's target to reduce greenhouse gas emissions in 20028 can be achieved. So that air pollution caused by industrial fuels and vehicles can be realized. The composition of production and generation with a mixture of energy during the period 2019–2028 is shown in Fig. 8(a) and 8(b). To be able to support this energy production target, sufficient fuel is needed with adequate availability. If the availability of this fuel is lacking, it is highly unlikely that targets for energy production and emission reductions can be achieved.

RE targeted by the government in 2025 is 23% and in 2050 to 31% is shown in Fig. 9 (a) and (b). So that the RE target becomes greater than the other energy mix. While the petroleum energy mix will decrease to 20% by 2050. The increasing population has driven the increasing demand for energy, especially for transportation and electricity. Meanwhile, fossil energy production (non-renewable) will continue to decline, forcing the government to import petroleum to meet domestic needs. To overcome fossil fuels that continue to experience depletion, the government has made several policies to support the use of RE nationally. The government's target is to meet national energy, it will build several electricity generators such as geothermal energy, solar energy, bioenergy, hydropower and wind power. Besides, the government also made policy on the use of biofuels (B-20), namely mixing diesel engine fuel with palm oil to reduce the use of fossil energy [23, 35, 37].

4.2 Energy Demand

National energy demand in 2050 is targeted at 548.8 MTOE (5.0%) sourced from the energy mix (EM), sustainable development (SD) 481.1 MTOE (4.7%) and low carbon (LC) 424.2 MTOE (4.3%). The SD to EM scenario can save final energy reaching 12% by 2050. While the final energy demand from the LC scenario to EM can save 23% by 2050 is shown in Fig. 10. The final amount of energy demand in 2050 is predicted to be still dominated by the transportation sector and the industrial sector. This is due to industrial growth and the increase in the volume of motor vehicles accompanied by an increase in population which increases every year. Final energy demand by type of energy in 2050 shows that electricity demand will dominate by 35% (EM), 34% (SD) and 33% (LC) respectively [2, 37]. The high demand for electricity can be influenced by the increasing use of electronic devices, especially in the household sector. Also, the substitution of the use of generators in the industrial and commercial sectors with fuel oil to using electricity on the grid.

Energy demand for the industrial sector in 2050 is estimated to reach 230.9 MTOE sourced from EM, SD 194.3 MTOE and LC 157.7 MTOE. The use of energy in this industry is divided into six parts including the cement industry, fertilizer, paper, ceramics, metals and the food/beverage industry. The total amount of energy demand in the industrial sector reached 87%. For the transportation sector, energy demand is still dominated by fuels such as diesel, gasoline, biodiesel, bioethanol, gas, avgas and avtur. The transportation sector consumes 96% of fuel in 2018 and the rest is supplied by natural gas and biodiesel. The biggest energy demand for transportation in 2018 is dominated by motorcycles by 41%. Energy demand for air transportation in 2018 also increased and in 2050 demand for aviation fuel is predicted to reach 27.6 MTOE. Energy demand for the trucking sector in 2050 is projected at 43%. For passenger car transportation, although there is an upward trend in energy demand, its growth has been able to be tempered by the use of more efficient technology. So that energy demand in 2050 increased from 6.7 MTOE in 2018 to 23.7 MTOE in the EM scenario and 21.1 MTOE in the SD scenario and 20.9 MTOE in the LC scenario.

Energy demand in the household sector is affected by the increasing number of households predicted to reach 70.6 million in 2025 and 2050 an increase of around 80 million. In addition, the level of urbanization also drives future energy demand increases. Based on BPS projections, in 2035 the urbanization rate could reach 67% compared to 2010 which was only 49.8%. Energy demand in 2050 for the household sector reaches 120 MTOE (EM), 109 MTOE (SD) and 94.7 MTOE (LC). The dominant use of energy for the household sector in 2050 is electricity. So that the share of electricity demand in 2050 increased by 90% compared to 2018 by 60%. Energy demand for the commercial sector such as offices, hotels, restaurants, hospitals and other services. The use of energy in the commercial sector such as electricity, LPG, solar, gas, biodiesel and DME use electricity around 60% -70%. Total final commercial energy demand in 2050 is estimated at 47.7 MTOE (EM), 40.5 MTOE (SD), and 36.2 MTOE (LC). While in the agriculture, mining and construction sectors. Energy demand in this sector is generally sourced from coal, diesel, biodiesel and electricity. Coal is used in the mining sub-sector, while diesel and biodiesel are used as generators as electricity supply reserves. In 2018 energy demand for the three mining sectors will decline by 43% and in 2050 to 27%. However, the construction sector experienced an increase from 26% in 2018 to 42% in 2050. This was greatly influenced by increased economic growth in line with the increasing population [2, 38].

Energy demand in the industrial sector in 2050 is estimated to reach 230.9 MTOE (EM), 194.3 MTOE (SD) and 157.7 MTOE (LC) shown in Fig. 11(a). While energy demand for transportation in the EM scenario and the sustainable development scenario (SD) shows the share of conventional oil demand until 2050 is still high. However, in the low carbon (LC) scenario the share of conventional (fossil) oil demand in 2050 decreases. This is due to the application of mixing biodiesel by 100% (green diesel) and bioethanol by 85%. Thus, the share of oil demand in the LC scenario in 2050 becomes 37% and the RE demand share increases to 62% shown in Fig. 11(b). Energy demand for the household sector in 2050 is estimated to reach 323.7 MTOE sourced from 120 MTOE (EM), 109 MTOE (SD) and 94.7 MTOE (LC). The share of electricity demand has increased from 60% in 2018 to 90% in 2050. The increasing electricity demand is driven by the increasing use of electronic equipment such as air conditioners, refrigerators (refrigerators), water pumping machines, including induction electric stoves. While the demand for LPG in the EM, SD and LC scenarios in 2050 reached 4.8 MTOE, 4.3 MTOE and 3.4 MTOE is shown in Fig. 12(a). While for the commercial sector such as offices, hotels, restaurants, hospitals and other services, the demand for energy is dominated by electricity, LPG, diesel, gas, biodiesel and DME, which reaches around 60% -70%. Electricity consumption is used for air conditioning (AC), water pumping machines and lighting (lamps).

Total final energy demand for the commercial sector in 2050 reached 124.4 MTOE sourced from 47.7 MTOE (EM), 40.5 MTOE (SD), and 36.2 MTOE (LC) shown in Fig. 12(b).

4.3 Energy Supply

In 2050 the primary energy supply is targeted to reach 943 MTOE compared to 2025 at 314 MTOE. The supply of primary energy for power plants is included in the modelling based on the assumption of generating capacity according to the electricity supply business plan (ESBP) which generates the primary energy requirements for each power plant [2, 28, 39, 40]. Of the energy amount of 298 MTOE (32%) sourced from coal energy. It is expected that the use of coal can increase added value to the process of coal gasification and coal liquefaction. Energy demand sourced from gas pipelines, LNG and LPG in 2050 is predicted to be 222 MTOE (24%) of the total primary energy supply. While for the supply of RE around 29% (275 MTOE) in 2050. The increase in the supply of RE is influenced by the optimization for the utilization of solar cell energy, geothermal energy, biomass and water that is destined for electricity generation and fuel subsidies in the transportation sector. In the SD scenario, the primary energy supply is smaller than the energy mix (EM) scenario of 828 MTOE in 2050. However, in the SD scenario, the RE energy is greater than the EM scenario, which is 23% in 2025 and 32% in 2050. This figure is following the targets listed in the KEN and RUEN. In the special LC scenario, RE increased significantly by 58% in 2050 compared to 2025 by 36%. Comparison of the primary energy mix with SD and LC 2025–2050 scenarios is shown in Fig. 13(a) and (b).

4.4 Economic Growth

Indonesia's economic growth in 2017 and 2018 were 5.07% and 5.17% respectively as mentioned in the data from the Central Statistics Agency (CSA) [41]. While Indonesia's economic growth in 2019 has increased to 5.3% and in 2045 its growth is targeted at 5.6%. Indonesia's economic growth according to ESBP using the BAPPENAS scenario in 2028 of 6.45% [24]. This is one of the factors to consider in making scenarios of long-term domestic energy demand. Economic growth statistics are accompanied by energy demand in general.

Energy demand is closely related to economic activity so the assumption of economic growth will be very sensitive to energy demand from the three scenarios developed are shown in Table 3. Indonesia's economic growth during the 2013–2018 period tended to decrease from 5.6–5.17%. As a result of the global economic downturn due to financial market uncertainty and declining trade volume at the world level. The assumption of economic growth is adjusted to the "Vision of Indonesia 2045" published by Bappenas [42, 43]. Where Indonesia's economic growth in the next few years is supported by rising domestic needs, including consumption and investment, as well as better export growth including in the manufacturing sector which is a major energy consumer in the industrial sector.

Table 3
Assumptions and RE scenarios

Assumption	Energy Mix (EM)	Sustainable Development (SD)	Low Carbon (LC)
Economic growth	1. (2045)		
Population growth	0.7% (2045)		
Biodiesel target	20% (2025)	30% (2025)	30% (2025)
	30% (2050)	30% (2050)	100% (2050)
Bioethanol target	5% (2025)	20% (2025)	20% (2025)
		50% (2050)	85% (2050)
Jargas growth	4,7 SR (2025)	1 juta SR/years	> 1 juta SR/years
LPG substitution with Electric Induction Cooker	0.5% (2025)	1% (2025)	2% (2025)
		2% (2050)	5% (2050)
LPG substitution with DME	20% (2025)	20% (2025)	20% (2025)
Electric Car Target (% of total population) vehicle)	0.01% (2025)	0.01% (2025)	0.5% (2025)
	0.07% (2050)	0.24% (2050)	1.18% (2050)
Electric Motor Target (% of total population) vehicle)	1.38% (2025)	1.44% (2025)	1.18% (2025)
Power plants	1.5% (2050)	1.7% (2050)	3% (2050)
	Electricity supply business plan (ESBP)	RUEN	Emission Reduction > RUEN
		10% Switching Capacity PLTU to PLT Biomass	30% Switching Capacity PLTU to PLT Biomass
		25% of Luxury Homes use Solar Rooftop	30% of Luxury Homes use Solar Rooftop

4.5 RE Policy

To accelerate the development and development of RE, the Government has established several regulations or policies which are considered to be very supportive including the following:

1. Indonesian government policies in 2014 and 2017 concerning national energy policies and national energy general plans with Presidential Regulation numbers 79/2014 and 22/2017 respectively [28].
2. Presidential Regulation No. 4 of 2016 (Article 14) concerning the Acceleration of Electricity Infrastructure. The government mandates to be able to implement and accelerate the development of electricity infrastructure by prioritizing the use of RE [44].
3. Central and Local Governments can provide support in the form of fiscal incentives, licensing and non-licensing facilities. Besides, determining the purchase price of electricity from each type of RE source, the establishment of a separate business entity in the context of supplying electricity to be sold to PT PLN (Persero), and/or providing subsidies.
4. Presidential Regulation No. 66 of 2018 concerning the Second Amendment to Presidential Regulation No. 61 of 2015 concerning Collecting and Using Palm Oil Plantation Funds, which require the use of biodiesel for PSO and non-PSO following article 18 paragraph (1b) [45].
5. Regulation of the Minister of Finance No.177/PMK.011/2007 concerning Exemption of Import Duties on Imported Goods for Upstream Oil and Gas and Geothermal Business Activities [46].
6. Minister of Finance Regulation No. 03/PMK.011/2012 concerning Procedures for Management and Accountability of Geothermal Fund Facilities [46].
7. Minister of Energy and Mineral Resources Regulation No. 49 of 2017 is an improvement to the ESDM Permen No. 10 of 2017 concerning Principles of Electricity Sales and Purchase Agreement [47].
8. Minister of Energy and Mineral Resources Regulation No. 50 of 2017 is a revision of the ESDM Regulation No. 12 of 2017 concerning Utilization of RE Sources for Electricity Supply, which is issued to create a better business climate while still encouraging efficiency practices and realizing reasonable and affordable electricity prices.
9. Minister of Energy and Mineral Resources Regulation No. 49 of 2018 concerning Use of Roof Solar Power Generation Systems by Consumers of PT Perusahaan Listrik Negara (PLN).

KEN mandates for RE mix target in the primary energy mix of at least 23% by 2025 and minimizes the use of petroleum less than 25% by 2025. In addition, energy efficiency is also targeted to decrease by 1% per year to encourage savings in energy use in all sector. Some targets in the KEN which are also considered in the projected energy demand include optimization of the use of natural gas for domestic use and priority use of fossil energy for national industrial raw materials. This policy is implemented to maximize the use of RE, minimize the use of petroleum, optimize the use of natural gas and RE, use coal as a mainstay of national energy supply and use nuclear as a last resort. With the regulations set by the government, it is expected that the developers (investors) can work better and the targets set can be achieved.

4.6 Risks & Challenges RE

In the construction of RE project, investors sometimes need to evaluate the risks that may arise when construction or operations begin. Each RE project has different types of risks and obstacles [48]. A study conducted by the United Nations Environment Program (UNEP) elaborates some of the risks that are generally inherent in the development of RE projects as shown in Table 4 [49, 50].

Table 4
Risks and Challenges in RE Projects

Type RE	Risk Issues	Risk Management Consideration
Biomass	• Availability/variability of fuel supply. • Variability in resource prices. • Environmental obligations are related to fuel handling and storage.	• Long-term contracts can solve resource problems. • Fuel handling costs. • Emission control.
Biogas	• Resource risks (eg reduction in quantity and quality of gas due to changes in organic raw materials). • Opposition planning is related to the smell problem.	• Strict safety procedures are needed such as loss control such as firefighting equipment and services. • High level of wear.
Wind	• Long waiting times and upfront costs (e.g. permit planning and construction costs). • Failure of important components (eg gear train/box, bearings, blades etc.). • Variability of wind resources • Offshore cabling.	• Turbine makes and models. • Manufacturing guarantees from component suppliers. • Good wind source data. • Loss control e.g. Firefighting can be difficult if the location is off the coast or altitude. • Development of procedures that are generally used
Tidal/Wave	• Survival in a harsh marine environment. • Various designs and concepts but without a clear winner. • Prototype/technology risk. 1. Small scale and long waiting time	• Most of the prototypes and technology demonstration projects. • Good resource measurement data.
Geothermal	• Drilling costs and risks that arise (blow out). • Exploration risk (Unexpected temperature). • Important components that are damaged, such as pumps. • Long waiting time (Permission).	• Limited operator experience and different aspects of technology at different locations. • Limited sources of measurement data. • Agreement on planning can be difficult • 'Technology stimulation' is still unproven but can reduce the risk of exploration.
Solar Thermal	• Prototype/technology risks as project size increases and is combined with others. • RETs, for example, solar towers	• Good operating history (already since 1984). • Maintenance can be neglected (especially in developing countries).
Small Hydro	• Flood. • Seasonal/annual source variability.	• Prolonged damage due to off-site monitoring (long response time) and lack of spare parts.
PV	• Component damage (e.g. Short-circuit current). • Weather damage • Theft/vandalism	• Performance guarantees are available (for example up to 25 years). • Standard components, with easy substitution. • Maintenance can be neglected (especially in developing countries).

4. Conclusions

Investigation of the potential for RE regarding the amount of utilization, energy demand and the target of power plant construction during the period of 2017-2050 has been completed. Various findings have been presented and discussed earlier so that conclusions can be drawn as follows:

1. The government is targeting the use of RE in 2025 by 23% and in 2050 to 31%.
2. The target of electric energy production in 2028 is 500,691 GWh sourced from 272.354 GWh, gas 110.150 GWh, hydro 54.736 GWh, geothermal 48.217 GWh, RE and BBM respectively 13.205 GWh and 2.019 GWh.
3. The policy set by the government in supporting the development and development of RE to achieve the target of energy use by 23% in 2025 and to reduce the use of petroleum by 25% in 2050.
4. National energy demand in 2050 is estimated at 1,545.1 MTOE sourced from EM 548.8 MTOE (5.0%), SD 481.1 MTOE (4.7%) and LC 424.2 MTOE (4.3%).
5. Economic growth with the use of RE is targeted to increase to 5.6% in 2045 compared to 2019 of 5.3%.
6. Time of permit issuance, construction price, resource price, intimidation, etc. Is a risk that is often faced by investors in the construction of RE.

Abbreviations

Nomenclature

RE	Renewable energy	EM	Energy mix
SD	Sustainable development	LC	Low carbon
MTOE	Million tonnes of oil equivalent	GWh	Giga what per hour
BBM	Bahan Bakar Minyak (fuel)	ESBP	Electricity supply business plan
PLN	Perusahaan Listrik Negara	KEN	Komite Economic National
LPG	Liquefied petroleum gas	DME	Dimethyl ether
CSA	Central statistics agency	LNG	Liquefied natural gas
MMSCF	Million standard cubic feet per day	PLTA	Hydroelectric power plant
PLTP	Geothermal power plant	PLTMH	Micro hydro power plant
PLTM	Gas power plant	PLTD	Diesel power plant
PLTG	Solar power generation	PLTGU	Gas and steam power plants
PLT Solar	Wind power plant	PLTMG	Gas engine power plant
PLT Bayu	Biofuel power plant	PLT Biomass	Biomass power plant
PLT Bio-Fuel	Trillion standard cubic feet	PLT Wave	Tidal/wave power plant
TSCF	Gigawatt-peak	GW	Gigawatt
GWp	Solar power generation	MW	Megawatt
PLTS	Komite Economic Nasional	MWp	Megawatt-peak
KEN		UNEP	United Nations Environment Program

Declarations

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Figures

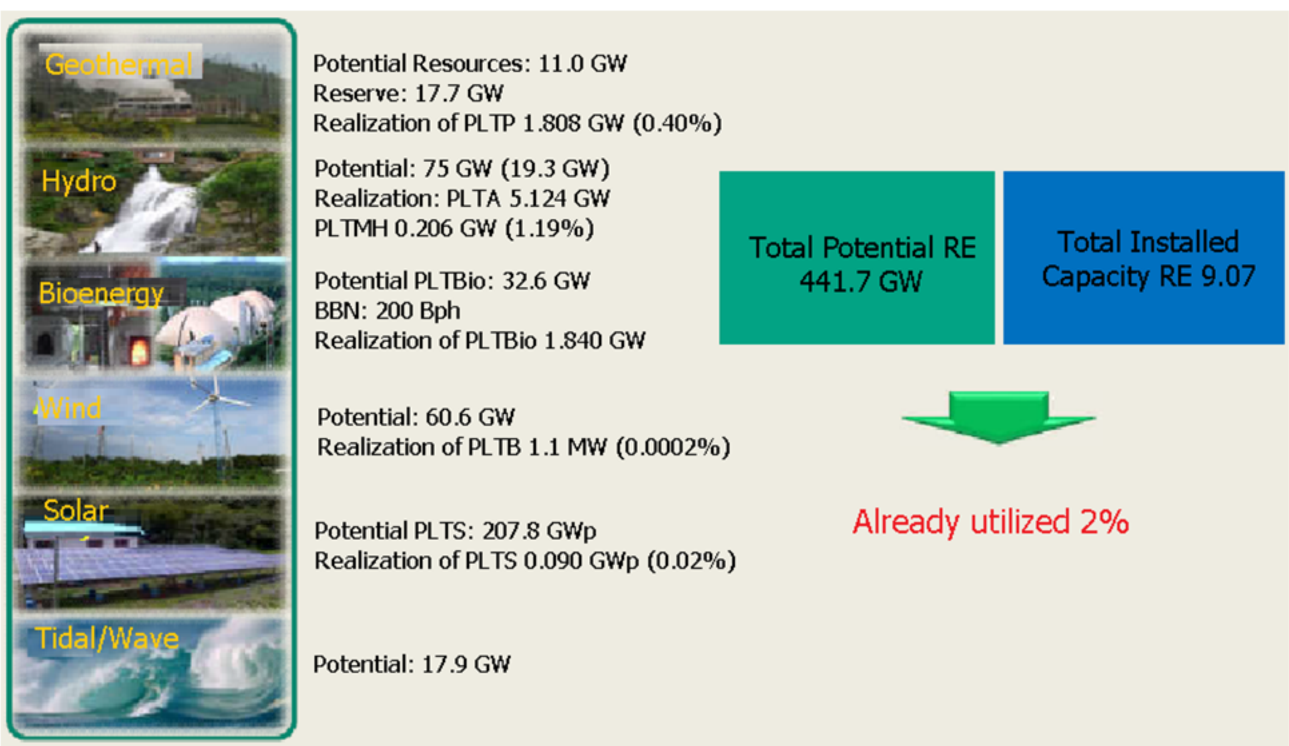

Figure 1

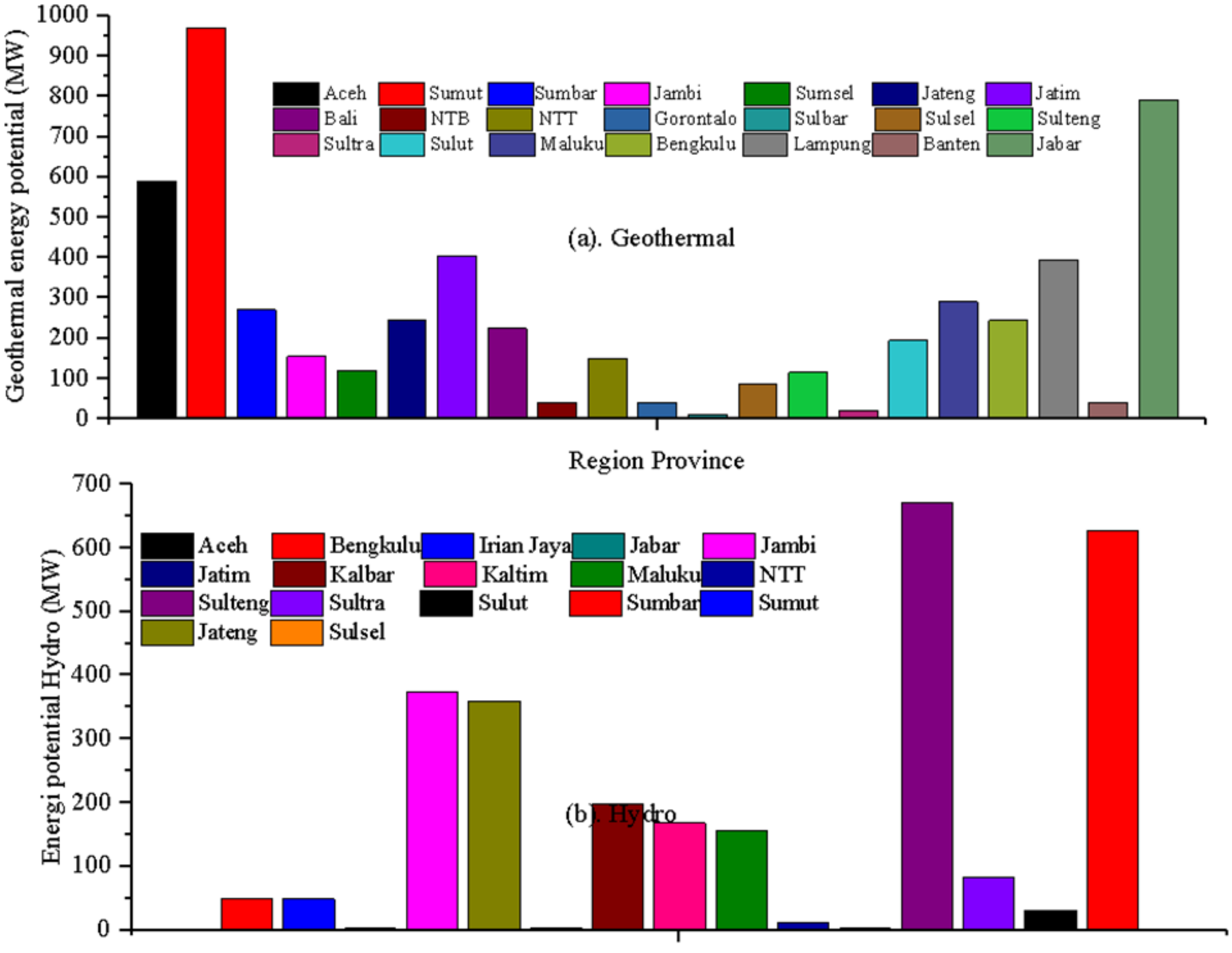

Figure 2

(a) and (b). Total geothermal and hydro potential for the different province in Indonesia

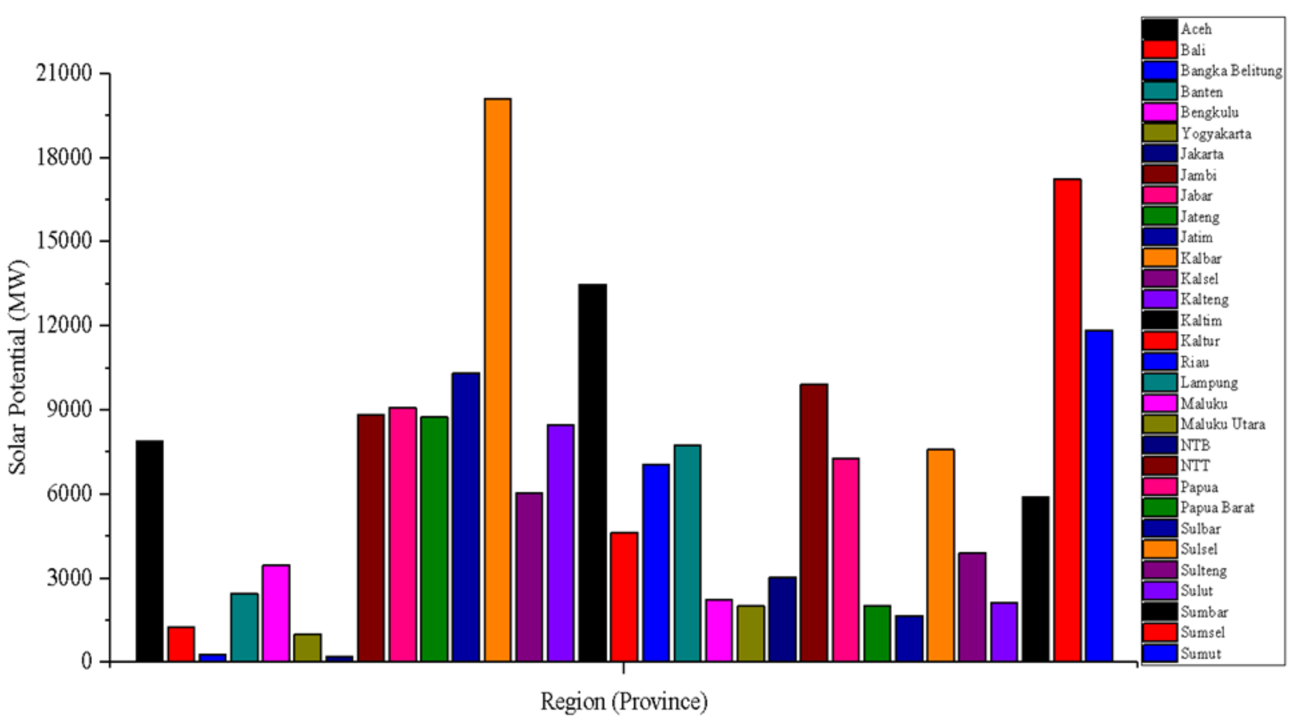

Figure 3

Solar potential in Indonesia for different Province

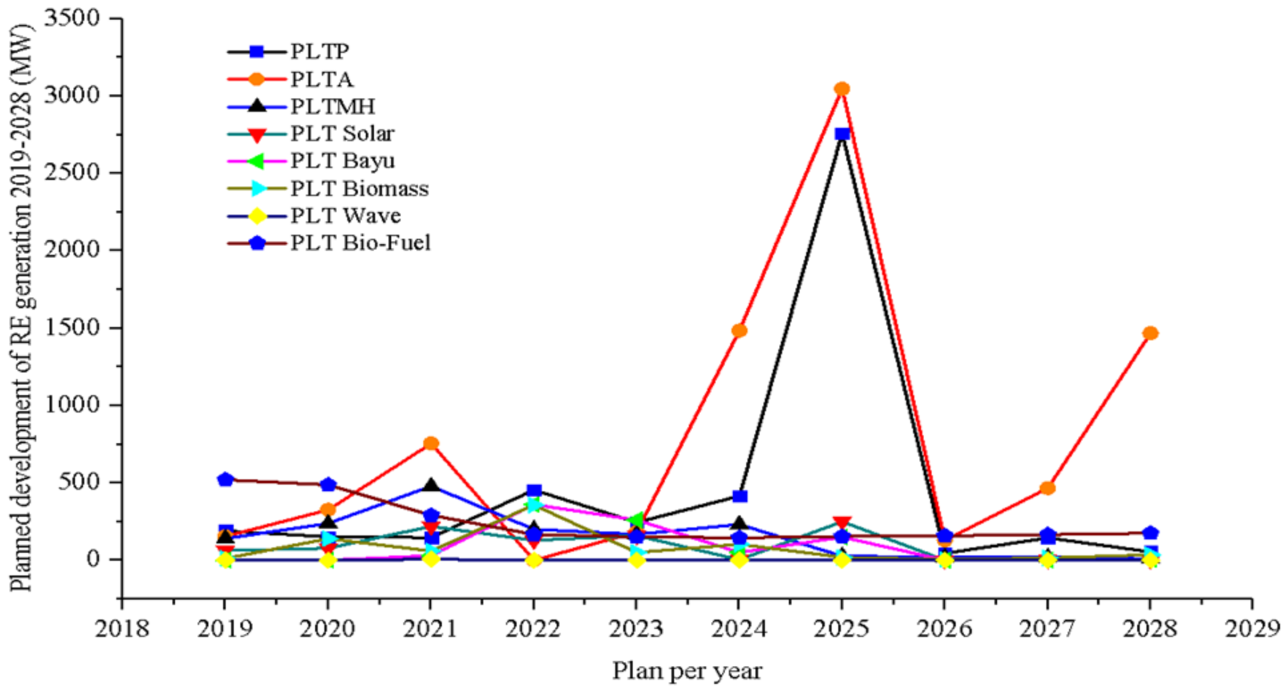

Figure 4

Total development of RE generation for 2019-2028

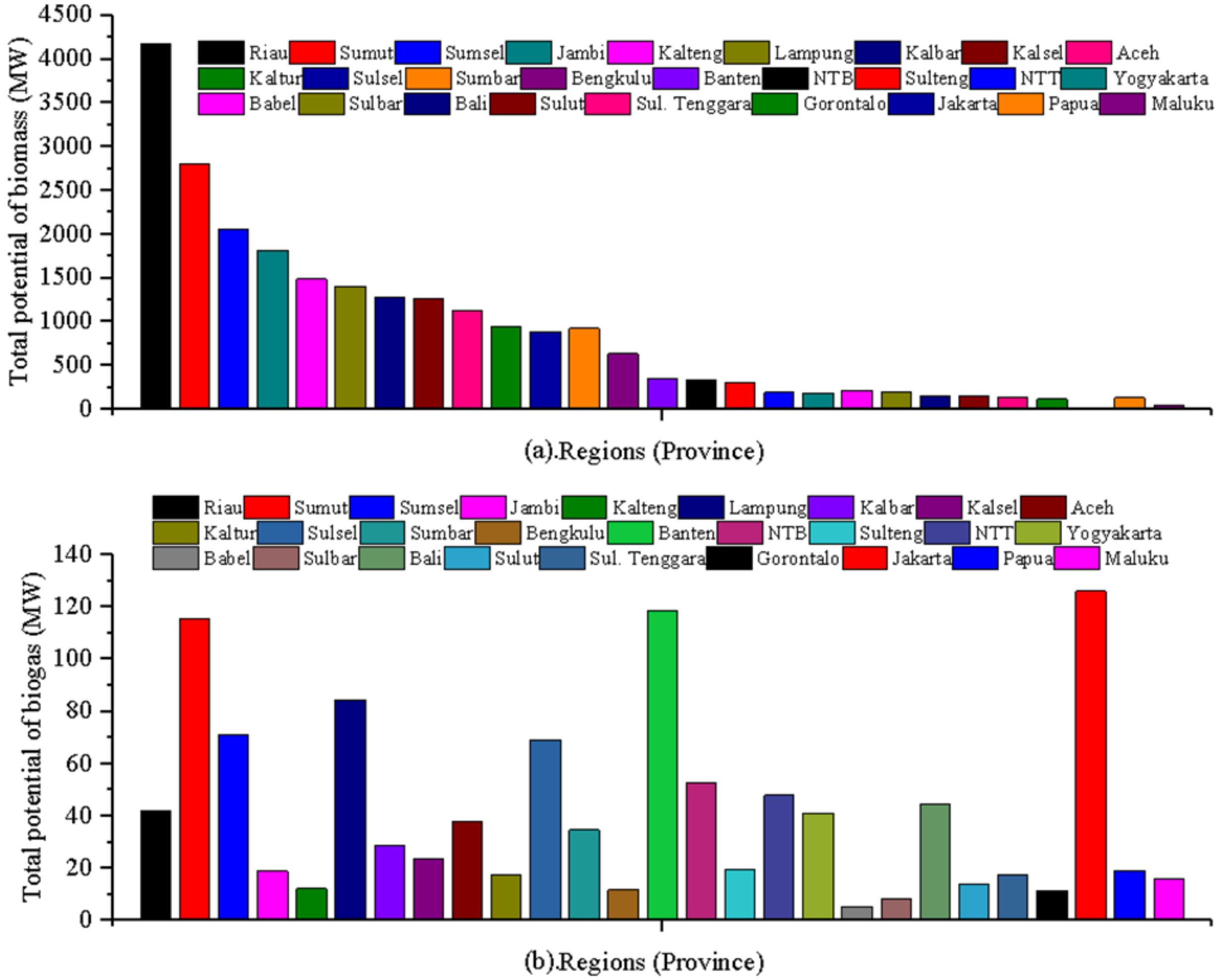

Figure 5

(a) and (b). Total potential RE of biomass and biogas for different province [30].

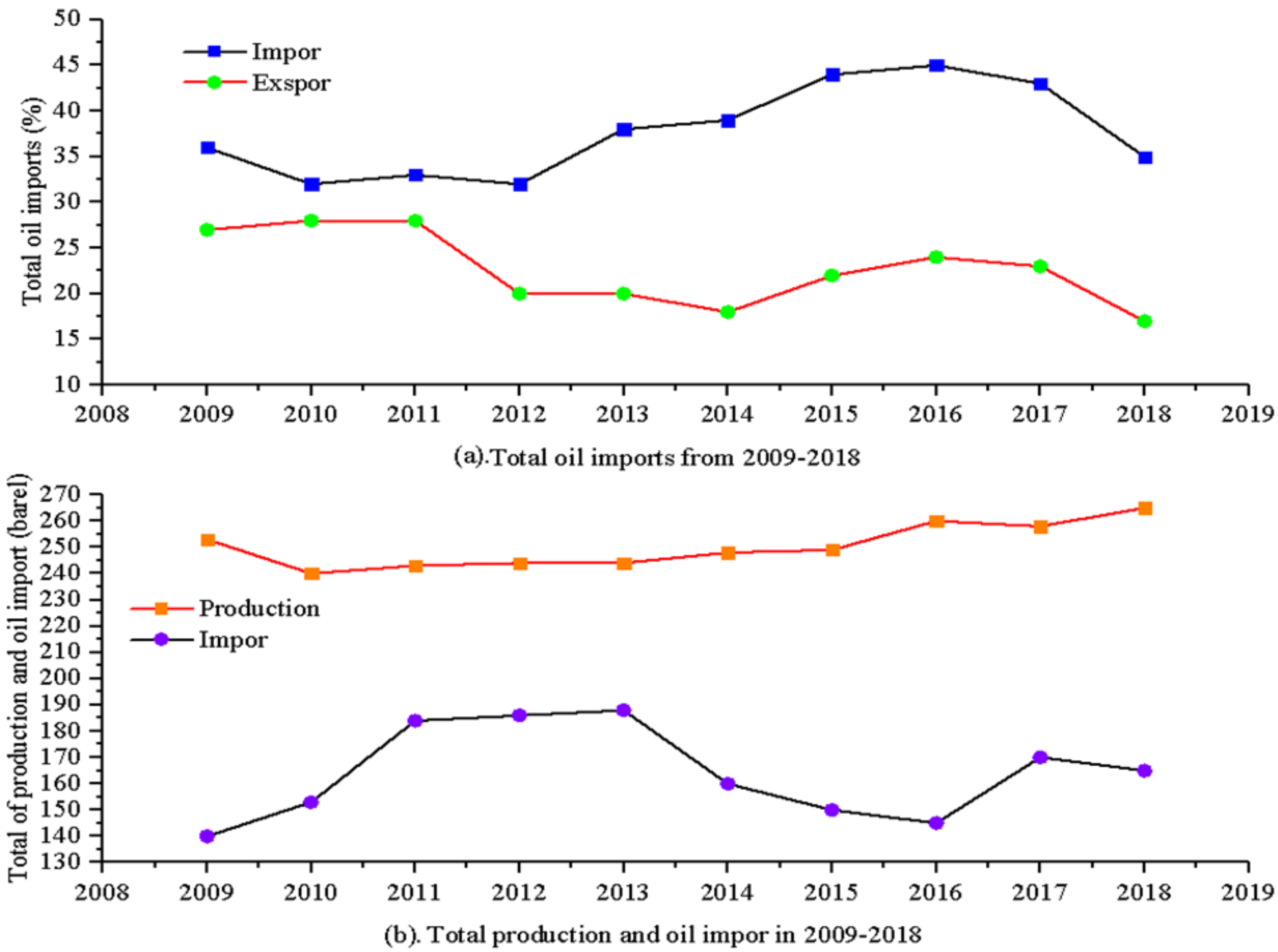

Figure 6

(a) dan 6(b). Total imports, exports and Indonesian oil production for 2009-2018

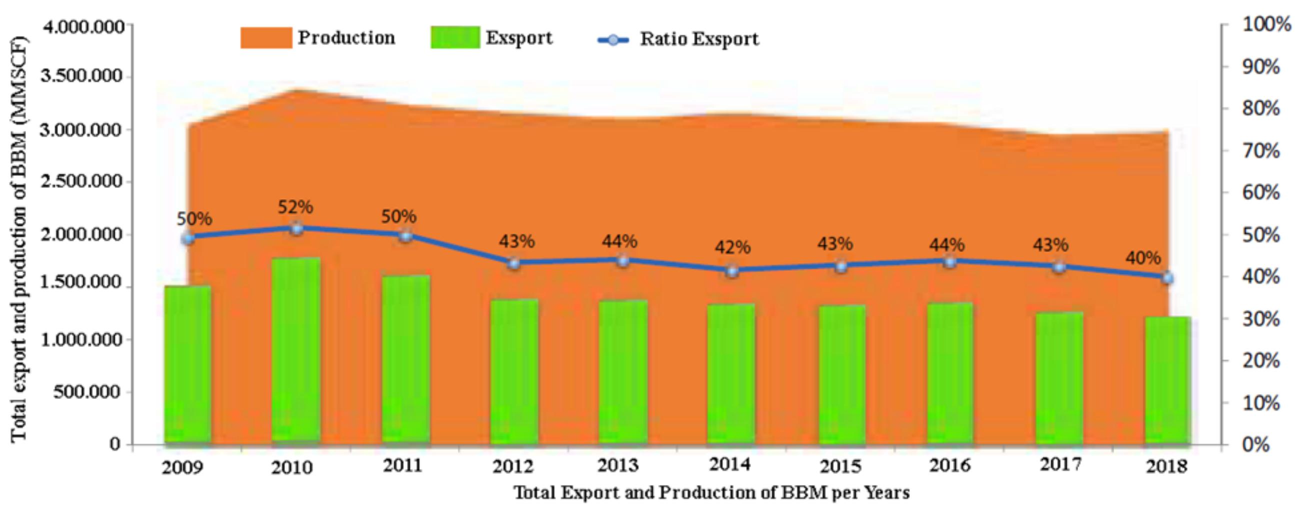

Figure 7

Total Export and Production of Natural Gas

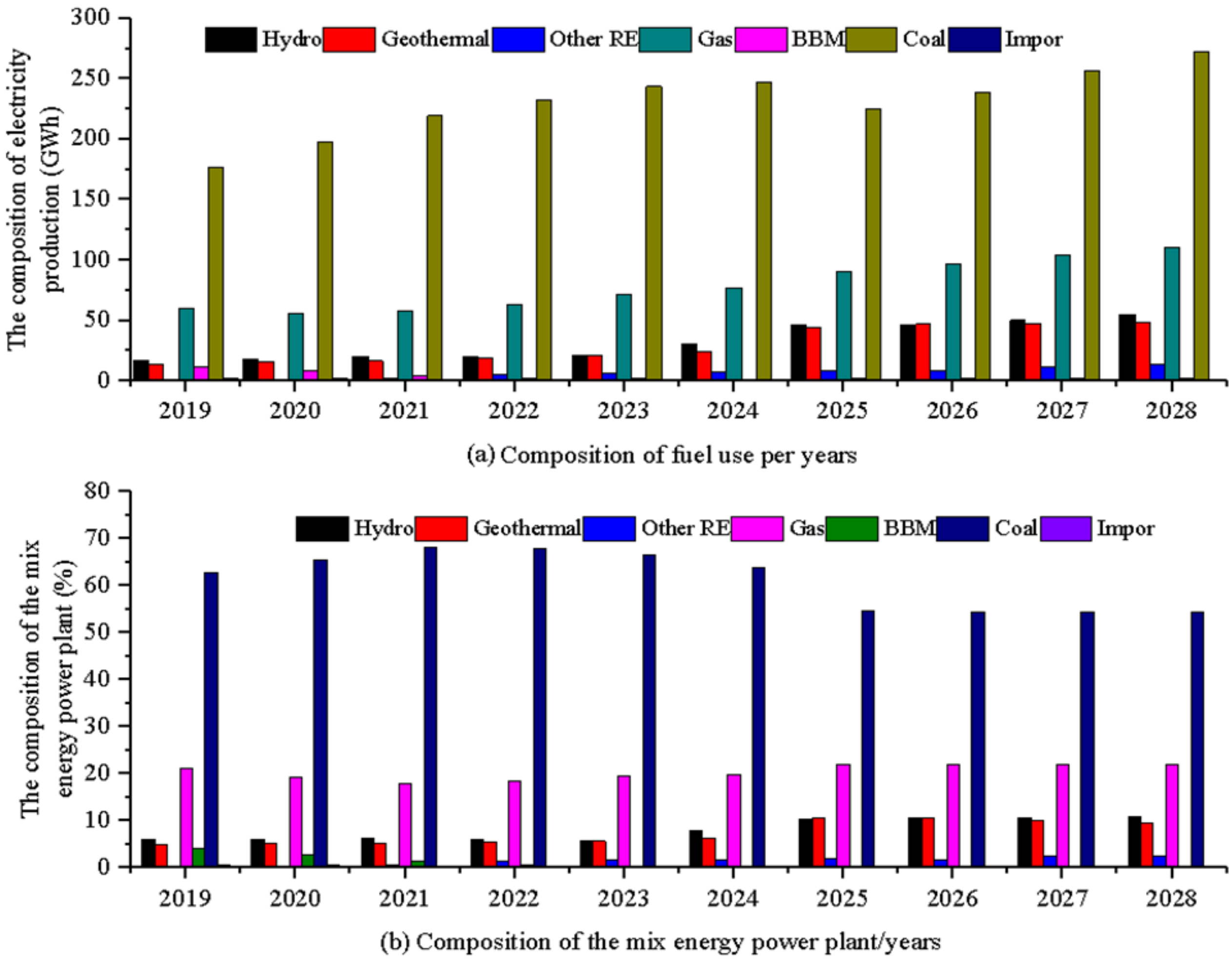

Figure 8

(a) Composition of production and (b) Composition of mix energy

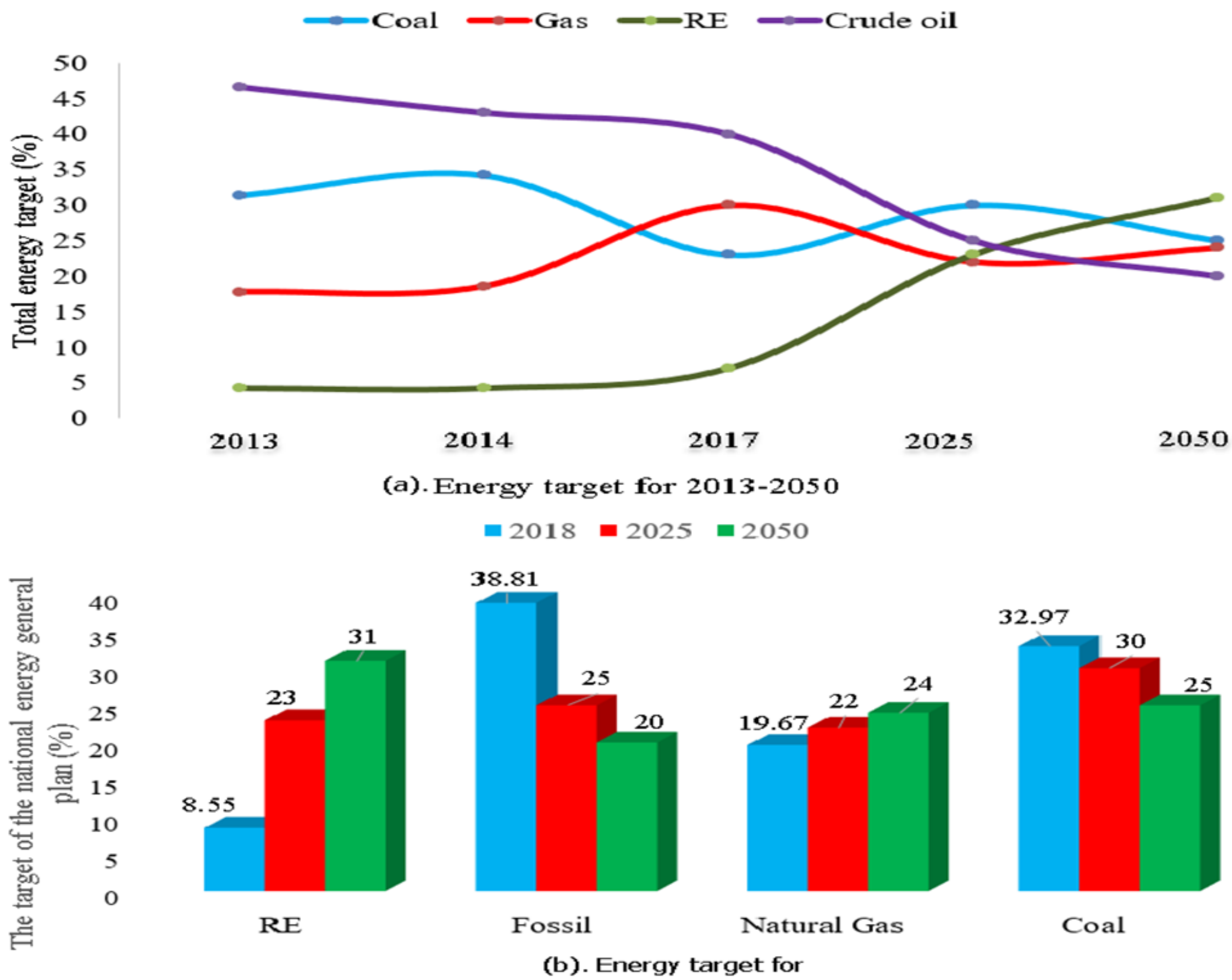

Figure 9

(a) and (b). Total target RE for years 2013-2050

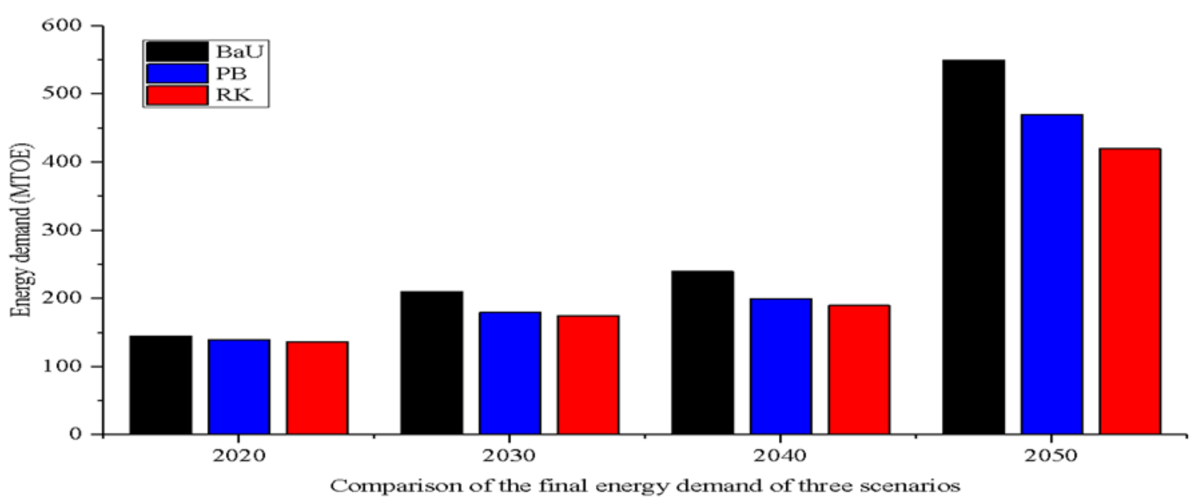

Figure 10

Comparison of energy demand 2020-2050

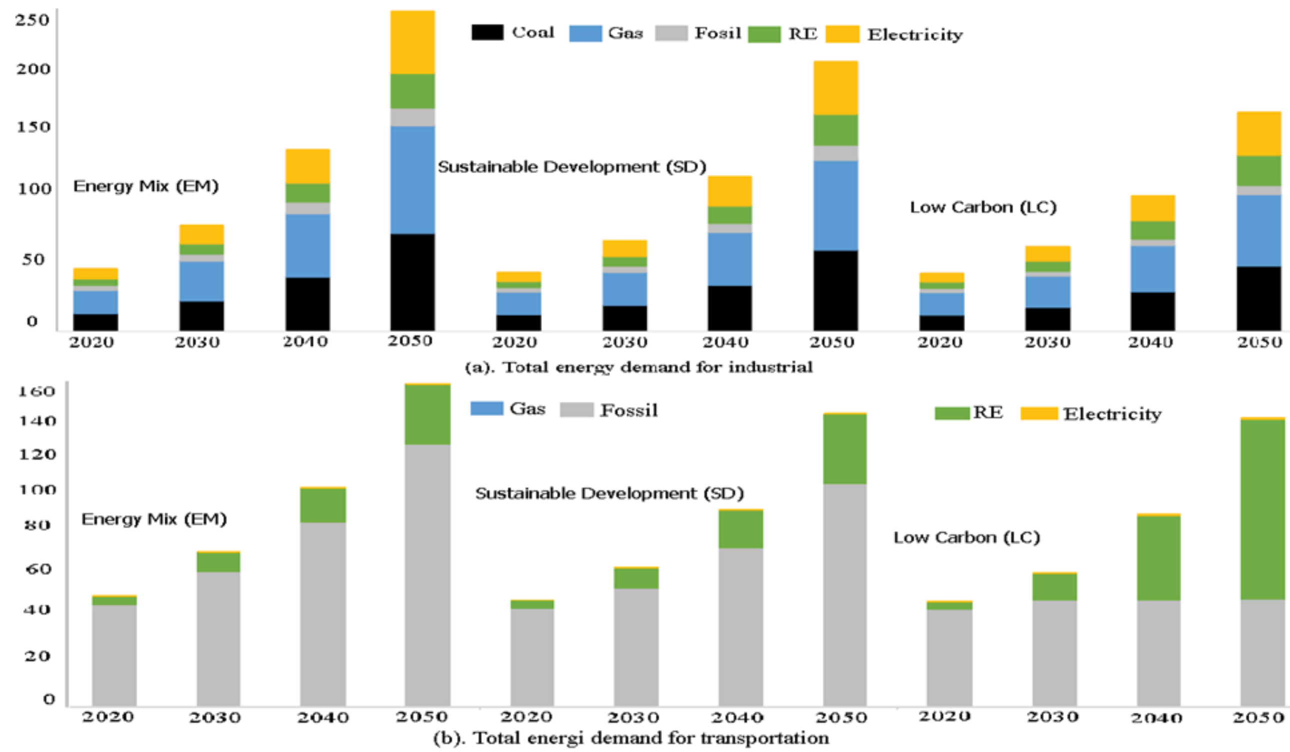

Figure 11

(a) and (b). Total energy demand for industrial and transportation

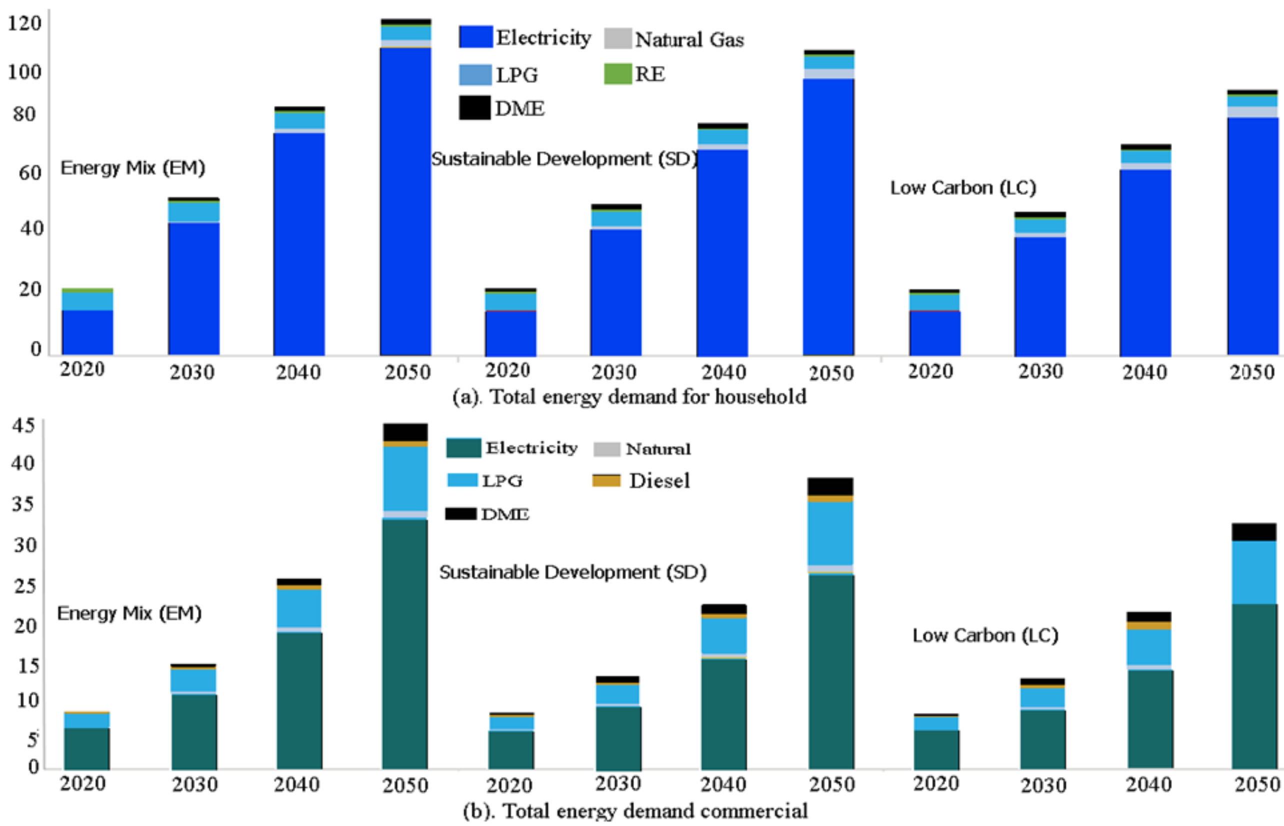

Figure 12

(a) and (b). Total energy demand for sector household and commercial

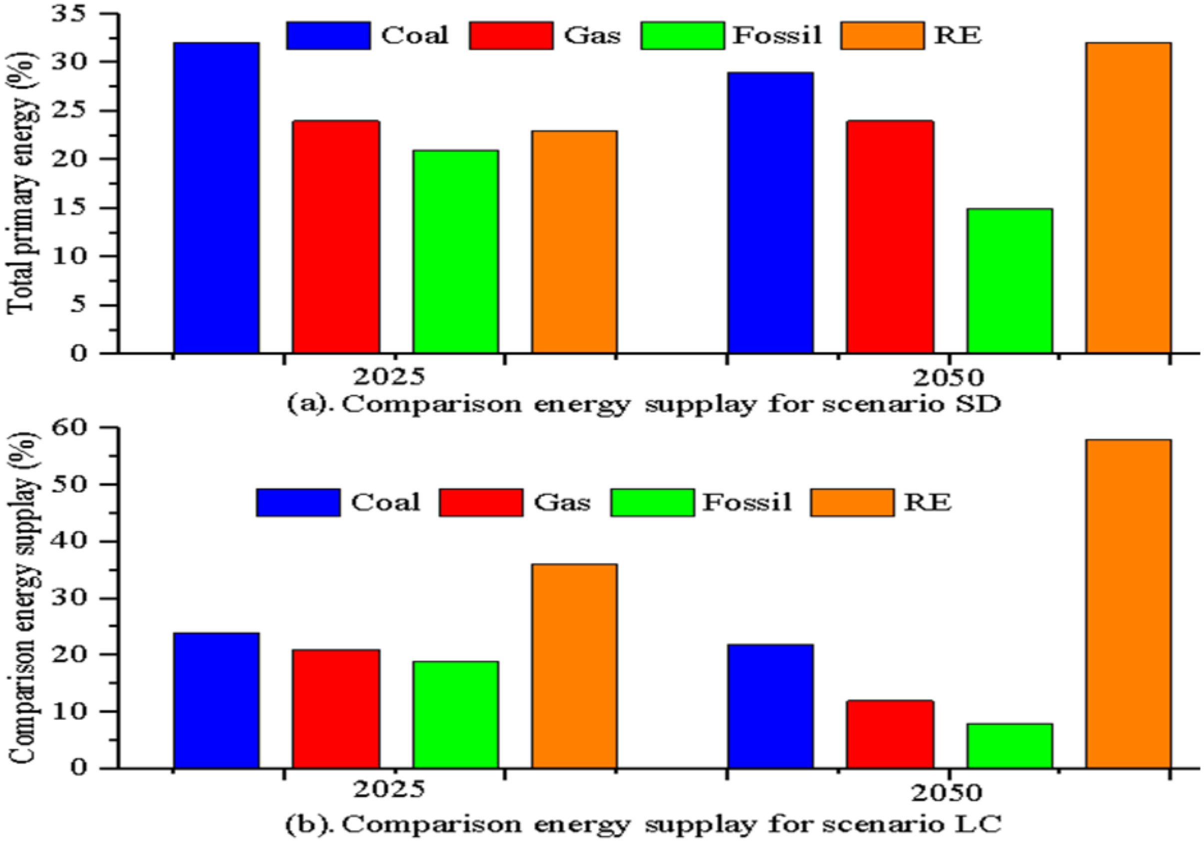

Figure 13

(a) and (b). Comparison of primary energy for scenario SD and LC