Predicting the future of Indonesia: energy, economic and sustainable environment development

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Abstract. Indonesia was one of the most top oil exporters which believe it has a vast fossil fuel reserve. However, after some decades of exploration, oil production decreasing gradually. In around 2004, the oil production lowers than consumption that forced Indonesia to enter the period of oil net importer. The other fossil energy resource depletion predicted will happen soon. Indonesia will enter the era of natural gas and coal net importer around 2028 and 2038, respectively. The fast depletion of fossil energy reserves, the momentum of the "golden age" population, environmental protection, and technological limitations to exploit new and renewable energy resources pose particular problems in Indonesian economic development. By using several energy forecasting results that are modelled in several ways, the discussion then is conducted qualitatively from the correlation between energy, economic, and environmental perspectives to predict the future conditions of Indonesia. From this study, we argue that there are several challenge scenarios that will ultimately overcome, especially in increasing energy security or suppressing the growth of energy consumption by curbing industrialization.

1. Introduction

Indonesia is one of the countries within the largest territory and population in the world. As a tropical country, Indonesia endowed with an abundant diversity of natural resources, not least for the energy sector. All types of energy sources ranging from non-renewable such as petroleum, natural gas, coal, and uranium, to renewables such as biomass, wind, and solar found. Although rich in diversity, very poor in intensity. Indonesia has minimal oil reserves. The availability of natural gas and coal predicted will deplete quickly. Whereas on the other side, the utilization of new and renewable energies is going very slowly.

In its effort to become a developed country, Indonesia is encouraging economic growth through industrialization in various fields. It has driven urbanization, resulting in population density being concentrated only in some large cities. It also has a direct impact on the environment both caused by land conversion and the release of pollutants such as hazardous and toxic materials and greenhouse gases, which ultimately also affect public health. On the other hand, industrialization is also thirsty for adequate energy supplies availability, which brings up the next big question. How to secure the energy supply for sustainable economic development without sacrificing the environment?

Energy security is one of the big concepts that elaborated to solve such kind of question. Asia Pacific Energy Research Centre (APERC) delivered four generic energy security indicators: availability, accessibility, affordability, and acceptability [1]. Availability is related to how much reserves of energy sources are available in a place and in a unit of time. Accessibility is the ability to access and obtain
energy sources related to economic, political, and technological factors that affect the possibility of its exploitation. Affordability relates to the value of energy that will decided it can be reached by the public's purchasing power and also the availability of infrastructure for utilization. In contrast, acceptability is usually more concerned with environmental problems that affect people's acceptance of an energy source. Although this concept is criticized by some academia [2], this concept is still used widely with several specific modifications.

In this article, the future of Indonesia's energy security discusses base on the energy security concepts qualitatively using several related data. The remainder of this article started in Section 2 by briefly reviewing the general energy-related condition of Indonesia and discussing energy forecasting and potential problem identification. Section 3 discussing some scenarios as part of proposed problem solving and closed by the conclusion in Section 4.

2. Current status of Indonesian energy resources

Although almost all types of energy sources available in Indonesia, this country is a low-energy resource country for non-renewable and renewable energy. Indonesia's petroleum production rate has dropped dramatically. Proven natural gas and coal reserve also decrease gradually. From all of the renewable energy resources mapped, only hydro, geothermal, and biomass have been used effectively in a relatively small capacity.

Indonesia decided to exit from the Organisation of Petroleum Exporting Countries (OPEC) in 2007 due to since 2004, Indonesia entering a net oil importer era [3]. Base on the data shown by the official source, the remaining proven reserve of Indonesia's petroleum to be exhausted within the next nine years [4]. Indonesia's petroleum consumption in 2016 is about 22.9 million kilolitres, with an upward trend of about 4.7% per year [5] [6]. It is just that, on the other hand, petroleum production is only about 5.4 million kilolitres with a downward trend of about 4% per year [5][6]. This condition resulted in import burdens, which increased from time to time.

The downward trend carried out by petroleum production also occurs in natural gas. However, the condition is not as worse as petroleum since domestic natural gas consumption smaller than gas production. In 2016 Indonesia's natural gas production reached around 3 million Terra Joules (TJ)-gross with a production decline rate of about 3% per year [4]. The consumption itself is about 0.65 million TJ-gross, with a consumption rate increase of about 6.3% per year [4]. Based on these data, coupled with export-import contract cooperation, Indonesia predicted will enter the gas net importer era starting from 2028 [5].

For coal, Indonesia still can breathe a sigh of relief since the large reserve with a production ratio, which is around 67 years [5]. From about 410 million tons of coal production per year, about 310 million still use as an export commodity [6]. The domestic coal demand itself is still relatively low. However, as the non-renewable resource, based on the existing energy resource, production rate, and export needs, the reserve with a production ratio of medium to high-quality coal (> 5,100 kcal/kg) will be exhausted by 2038, and for medium to low-quality by 2048 [5].

One of the renewable energy sources that have been good utilized is hydro energy. Indonesia has a hydro energy potential of more than 45 GW plus around 19 GW for mini and micro-hydro [5]. However, only about 11 GW was utilizing to generate electricity [5]. The difficulty of hydro, mini, and micro-hydro energy resource utilization is since most of the available potential resources are far away from the load region or relatively hard to be accessed. As a country that is prone to drought due to deforestation, one of the significant challenges to maintaining the potential of hydro energy is how to keep the sustainability of forest areas, especially in watersheds.

Indonesia is a country with a “ring of fire” because around 29,544 GW geothermal energy potential has been identified [5]. However, only about 1.438 GW use as a power plant [5]. Similar to hydro energy, most of the potential geothermal resources located in mountainous areas in remote, difficult to be accessed or protected as a conservation area. High investment risk for geothermal exploration, making it quite difficult to find private companies that dare to prepare large budgets for drilling activities with high uncertainty. The geothermal industry was also possibly facing several other potential business
uncertainties, such as various regulatory issues. However, geothermal is one of the potentials energy future to be developed by the Indonesian government.

Biomass also plays a vital role in the energy mix program. It is widely used traditionally for household needs such as cooking, biomass used in various modern sectors. The most utilization of biomass is from palm oil as a blending of diesel fuel that is usually called biodiesel. Currently, the Indonesian government requires biodiesel with a palm oil concentration of 20% and is forcing to increase become 30% starting from 2026 [7] [8]. Indonesia's diesel oil consumption today reaches around 30 million kiloliters per year [8]. The estimation is that palm oil used for biodiesel is about 6 million KL or 12.4% of annual domestic production. The level of biomass utilization other than biodiesel still limited because of some constraints such as technological issues, floating price competition with petroleum, a potential increase of operation and maintenance costs for the industry when utilizing high palm oil concentration, deforestation issues, etc.

The other renewable energy sources are solar and wind. These sources still in limited use in Indonesia because of some factors such as high generation price, cloudily, and unstable wind flow, and also the price is relatively higher compared with the other sources. Until now, the utilization of solar and wind energy just around 14 MW and 1.96 MW, respectively [5]. This amount is still far away from its potential, around 4.80 kWh/m²/day for solar and 970 MW for wind energy [5]. Related studies also have identified other potential renewable energy such as waves, ocean heat, and tides in a relatively large amount. However, all of those energy sources have not utilized at all because there is no proven technology yet, or the availability of technology that is already can compete head to head with other energy sources, especially from fossil.

Although the proven uranium and thorium reserves are already known and can exploit in some areas and some functional study already conducted but until now, there is no strong indication that Indonesia will use nuclear energy. Nevertheless, based on the regulation, Indonesia still gives a little space for nuclear to increase the diversity of its energy mix sources.

3. Future energy needed and potential problems

Forecasting of the Indonesian future energy needs has been studied widely by many stakeholders starting from the university, national research institutes, related ministries, and agencies, including several international organizations using some energy modeling software such as Long-range Energy Alternatives Planning System (LEAP), The Integrated MARKAL-EFOM System (TIMES), Availability of the National Energy Modelling System (NEMS), and Model for Analysis of Energy Demand (MAED). The modeling results by the Agency for The Assessment and Application of Technology (BPPT) based on MAED and National Energy Council of Indonesia (DEN) base on LEAP used for this article [5][6]. Although those models have their unique algorithm, all models utilized several basic assumptions and used the same concepts. Assumptions used are income, inflation rate, population growth, GDP, energy consumption, and import-export over the past few years. Another assumption used is about related technological developments such as machinery energy efficiency. Contrast, the basic calculation uses macroeconomic theories, energy elasticity and intensity, and so on. The result between BPPT and DEN can be said similarly except in some areas since BPPT tried to put nuclear energy on the energy mix and the several basic assumptions result. Almost all data in this article cited from the results of the modeling conducted by BPPT and DEN. Because of that, the citation will not show except stated otherwise.

As a developing country with an energy elasticity level larger than one, Indonesia's energy needs predict to be slightly greater than its economic growth assumption of around 5% per year. With a primary energy supply of about 1,319 Million BOE in 2016 and increasing to 1,733 Million BOE in 2019, it estimated that energy demand increase to 2,338 Million BOE in 2025 and even reach 7,207 Million BOE in 2050 or an increase of around 5.3% per year. Looking at the past few year trends, it estimates that the growth of the energy mix will remain at 11% to a maximum of 15% in 2050 due to many obstacles such as low efficiency, high investment value, the distribution of diverse potentials that makes it difficult to compete with fossil energy. The expectation is the role of oil and natural gas declined from
38% to 31% and 22% to 18%, respectively, in 2050. As a result, the expectation of the role of coal is increasing dramatically from 28% to 32% in 2030 and become 36% in 2050. Following this scenario, Indonesia expects to enter the era of energy net importers in 2032. The value of energy imports continue growing to about 6.7% per year and will even reach almost half of the total needs by 2050.

All the above forecasting will be nearly true if all the critical scenario assumptions are correctly defined. However, a model cannot always precisely describe the actual condition, considering that many things are difficult to be quantified, such as unstable policy. The prediction is not correct perfect. Nobody can guarantee that economic growth will always be positive, and nobody knows that after the election, the new government will prohibit the use of the petrol-based car. There will be a point where economic growth reaches equilibrium due to several constraint factors, such as the availability of natural resources, population growth, and environmental capacity. This equilibrium point is known as the "steady-state economy." Unfortunately, both BPPT and DEN studies are unable to do the dynamic calculation to find the equilibrium condition that should be archived that makes the prediction conducted qualitatively.

The Indonesian population continues to increase gradually from year to year. In the 1970s, the population growth rate was 2.5%, but the trend was decreasing and reach the lowest rate of 1.1% in 2019 [9]. The population will continue to increase but will decline to start in 2060 [9]. Based on the ratio between the number of productive ages with non-productive age (including children and the elderly), the lowest dependency ratio will occur around 2030 to 2050 [9]. It is means on these years, Indonesia will have the most optimal productivity to boost its economic growth. It will be challenging for Indonesia to go out of the middle-income trap if they fail to use this momentum.

Even so, economic growth cannot be without an appropriate energy supply. As has been predicted, around 2032, Indonesia will enter the era of energy net importers and be dominated by fossil fuel, especially petroleum and natural gas [5].

This condition makes Indonesia must have secured its fossil energy reserves from exporting countries through many contracts, including guarantees of price stability to ensure the unbreakable supply chain. However, 'can Indonesia actively involved in taking an equal role with the superpowers in the geopolitics of the world to secure its fossil fuel reserves in the Middle East?' The answer to the previous question needs to look at recently military, political, and economic abilities. A reasonable choice in Indonesia should increase its energy mix diversity as soon as possible by reducing its dependency on petroleum and natural gas.

The increase in imports, including the form of energy, must be balanced with the value of exports to keep the foreign exchange stability. The next problem is the added value that can offer and whether it can push the optimal economic growth. The growing industry trend today is exploiting natural resources, including mining and assembly industries, by big companies. Local communities generally focus on traditional industry, tourism, farm, and agriculture with relatively small turnover values. Labour-intensive industries are still becoming the main focus of government as an effort to reduce the unemployment rate. Research and development activities for technology is the last priority. It means that industrial activities added value based on skilled & unskilled labour and export of natural resources. As a result, probably, the demographic bonus that occurs in 2030 cannot use as a steppingstone for transforming Indonesia from "natural and human resources-based industries" to "brain-based industries." Alternatively, in other words, Indonesia will lose the opportunity to become a developed country.

Greenhouse gas pollution produced by Indonesia is still relatively small, which is only about 1.7% of the total pollutants produced by China, which reached 45,261 MtCO2e [10]. Therefore, there is still a vast space for industrialization without ignoring the greenhouse gas release limits. The fact that coal will be the only potential energy resource for the near future will increase the greenhouse gas release gradually. However, industrialization development is still centralized on Java Island, especially around the capital city of Jakarta. Because of that, it is not surprising that from the last few months, Jakarta has often become one of the worst air quality cities in the world. Environmental protection in Indonesia is also fragile, which causes unhealthy industrialization. A lot of mining exploitation carried out in various regions without ending with reasonable restoration efforts of the environment. Large-scale agriculture
industry by deforestation and land burning occurs everywhere. A Low level of legal action against environmental pollution due to inadequate waste disposal by both companies and householders is still happening in any city and village. Besides damaging the environment, this condition will also reduce public health quality. The decline of public health quality will have an impact on increasing the country's burden on the health budget, decreasing productivity ratio, and ultimately will hampering economic growth.

4. Result and Discussion

Indonesia has many problems that have the potential to prevent it from utilizing demographic bonus momentum. All these problems has been addressed in less than a decade. By considering energy security indicators, Indonesia's energy is still far from satisfactory. There is a study said that if there were chaos such as war or social conflict, Indonesia's energy supply would only be able to last for less than four days [11]. This means that after four days of supply chain disruption, the entire economy and even Indonesia's defence system will paralyze. Thus, the prediction that the Indonesian economy will continue to grow by more than 5% per year until 2050 as assumed by several studies is very fragile. The source of fragility come from the uncertainty of energy supply, and also caused by other factors such as the relatively bad regulation and bureaucracy, social problems potency, the environment limitation to receive pollution which has not been well managed.

Revamping the regulatory and bureaucratic sectors is the most basic foundation that must be resolved immediately since this is directly related to all other aspects. However, some critical points must be highlighted from an energy and environmental perspective, which are covered by the general indicators of the energy security concept, including availability, accessibility, affordability, and acceptability.

Availability is not only related to domestic energy reserves but also regarding international supplies within its supply chain. The energy availability equilibrium in Indonesia is obtained by the importing of petroleum and followed by the exporting of natural gas and coal. In general, current public resources are still quite good, but it still needs to be fixed as it is predicted that in 2030 there will appear difficulty in improving oil and natural gas both in terms of supply and price. When global oil and gas reserves decreasing gradually and almost all countries need it, then it will increase difficulties in supply chain maintenance. Therefore, several efforts must be carried out by Indonesia, such as securing supply chains by making long-term agreements with countries that have huge oil and natural gas reserves. It will increase energy diversity by releasing support for fossil fuels immediately and increasing the role of new and renewable energy in its energy mix. Nuclear is the right choice, which has well comparable to fossil energy. The utilization of nuclear energy sources with hydro, geothermal, biomass, and other kinds of renewable energies, should be pushed to reduce fossil fuel dependency as well as to increase energy diversity without discrimination.

The accessibility of Indonesian energy varies significantly from one source to another. Energy accessibility for gas and coal and traditional energy sources such as firewood is still good. However, the political policy that maintains subsidies to final energy, such as petroleum for a household activity will cause some potential problems primarily caused by import dependency. Oil prices are very volatile and exceedingly difficult to predict underworld geopolitical conditions. To maintain public accessibility of fuel oil with oil price policies that tend to be the same through subsidies, it will create increasingly burdensome state finance, especially when there is an increase in world oil prices. The politics of the final energy subsidy is for electricity. Although the level of fluctuation is not as large as petroleum, the policy is increasingly burdening the state finances. In 2018 an energy subsidy was around 160 Trillion rupiahs or US$ 12.3 Billion [12]. If this policy continues, then the state financial burden for energy subsidies will undoubtedly continue to increase in line with the increasing value of energy imports. Accessibility for new and renewable energy resources can be said to be very low. Technology research and development have not become a priority, so there are almost no significant technological discoveries that can increase accessibility to new and renewable energy. The fact that renewable energy is still difficult to compete with fossil fuels also makes it difficult to bring in investors to invest in this sector. Better regulations and policies are needed to stimulate renewable energy exploration.
In terms of affordability, the purchasing power of final energy sources such as electricity and fuel oil for Indonesian people is quite well. The level of purchasing power is even driven by the energy subsidy policy even though it is enjoyed by the middle to high-level economic society. Nevertheless, the sustain of this condition and especially when entering the era of the energy net importer is a challenge. Another issue related to affordability is the availability of energy infrastructure. Indonesia’s energy infrastructure is still abysmal for the island of Java, which has been the centre of development. The reliability of the electricity network is still low, as shown by the System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI) indicators [13]. A low level of network reliability will also make it challenging to increase the supply of power in large numbers. Therefore, only the Java and Bali electricity networks will be ready to receive electricity from large-scale power plants (produce electricity more than 1 GW). At the same time, the electricity network in other regions will be more suitable to be supplied with small and medium power plants. It means micro grid and smart grid are suitable more to develop in some parts of Indonesia, especially in remote areas. Indonesia also has a limited natural gas distribution network that is still far behind even with Japan, which incidentally has minimal natural gas resources. One of the root problems of this infrastructure problem is the unhealthy energy business. Currently, the domestic energy business monopolizes by several state-owned companies. The monopoly activities eventually lead to unfair business competition and, on the other hand, hamper the optimization of corporate governance. Therefore, one way to improve affordability is by restructuring regulations and removing monopolies in the energy business.

There are some points from the acceptability indicator concerned with environmental problems and people’s acceptance. There no energy source that does not harm the environment. Fossil energy has known as the world’s primary source of greenhouse gas contributors. Fossil fuels also produce various other particles such as SO$_2$, NO$_x$, micro dust, etc. that directly reduce public health standards. Nuclear energy also has the possibility of releasing some radioactive particles into the environment. The entire process, from mining to solar panels, also has the potential to pollute the environment. The construction of dams, the establishment of windmills, geothermal drilling, and various other types of renewable exploration also have the potential to damage ecosystems, which threaten the survival of some species. The level of awareness of the Indonesian people towards the environment basically can be said to be still low unless it is directly influential in his personal life. So, from this condition, there is no difficulty whatsoever for the government to optimize all types of energy sources. However, surely the government must give several considerations not only to optimize all available potentials but also to mitigate all adverse impacts that may cause because, after all, the negative impact will have a reciprocal effect on the country’s economy.

From another perspective, the efficient use of energy is essential. So Thus, one of the steps is how to encourage energy elasticity to have the smallest possible value. Besides increasing the efficiency of all household appliances and factory machines, another thing to do is encouraging the growth of specific industries such as the software industry, industries based on research and innovation, as well as creative and tourism industries based on local wisdom. These industries, in general, require less energy consumption but have a multiplicative effect on tremendous economic growth more. If the things above cannot implement, then the final scene that possibly will come true that must be prepared, of course, suppressing the economic growth rate itself to strike a balance between economic development, environmental sustainability, and by paying attention to the energy system. In the worst case, possibly negative economic growth will occur.

5. Conclusions
There are various potential problems will make Indonesia challenging to maintain the sustainability of their development. Without ruling out the environmental limitation, social & political conditions, one of the biggest problems arises from the energy sector. Although Indonesia gets a demographic bonus opportunity that will accelerate the development optimally, unfortunately, at the same time, it will also enter the energy net importers era. To overcome these challenges, Indonesia needs to increase energy
security with various efforts: optimizing the role of new and renewable energy, reducing the petroleum and natural gas dependency, push the utilization of coal although will increase greenhouse gas release gradually, securing energy supplies and supply chain by making new contracts with exporting countries, increase the energy diversification without discrimination including utilization of nuclear energy, promoting “low energy intensity industries. If those efforts cannot implement in a short time, then negative economic growth will be unavoidable.

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