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ACCRETION OF INDONESIA'S ENERGY SECTOR T HROUGH RENEWABLE ENERGY

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Abstract

As the global demand towards conventional fossil fuels is persistently increasing over the decades, exploring the potential of other sources of alternative energy is a crucial measure to have more diversified supply of energy and to anticipate unexpected scenarios where the availability of fossil fuels becomes uncertain as it cannot be equally distributed in order to satisfy the customers' energy needs. This paper scrutinizes the contribution of renewable energy to the future global energy mix and the encountered challenges in energy development. When implementing renewable energy in our country, it has its own challenges due to the technological barriers among the other countries. However, it also gives benefits to the country itself when CO_2 emission can be reduced and become more environmentally friendly, especially to society and ecology. The study was conducted based on Indonesia's scenario, incorporating two specific examples of renewables namely, biofuel and geothermal energy. This paper further assesses the existing challenges associated with renewable energy development and the latest proposed solution to secure Indonesia's energy supply.

Keywords: Biofuel, Geothermal, Indonesia's Energy security, Renewable.

1. Introduction

One of the key factors that define the sustainability of economic growth is the availability of accessible energy to meet the growing demand at an affordable price. It is comprehensible that fossil fuels have always been the leading contributors in the global energy system due to their relative abundance, high energy release, and cost-effectiveness. Besides, availability is also the definition of energy security, where the main components of energy security are reliability, affordability and environmental friendliness [1].

Considering that Indonesia has finite and exhausted oil reserves, it is needed to build up other sources of energy in order to enhance energy security such as natural gas, coal and renewable energy. Furthermore, for the long term plan of energy security, the government need to support the implementation of renewable energy as a substitution of power plants [2]. Energy security has to be a rising issue when the main energy resources depleting. The transition of the net oil importer from the gives a big deal because, at that time, the development of the electricity network is when the oil price was inexpensive and abundant. Besides, it depends heavily on oil fuel power plants that generate power using diesel fuel [3]. Figure 1 highlights the huge consumption of oil, gas and coal compared to the primary sources of energy such as renewables, hydro and nuclear. With continuous reliance, fossil fuels will account for about 72% of the global energy mix in 2040 [4].

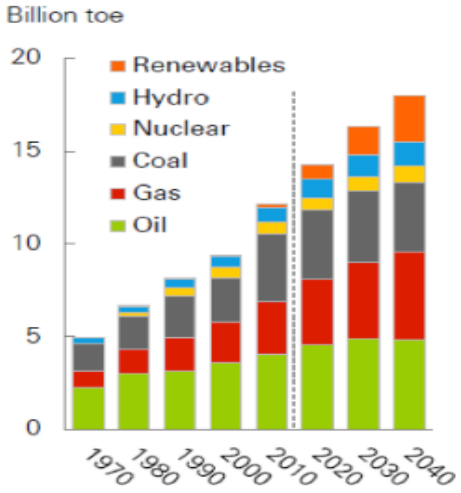

Fig. 1. 70 Years growth of world's primary energy consumption.

Even though several measures have been taken in pursuit of clean energy, there is no guarantee for fossil fuels to be fully replaceable by other energy sources. For instance, as a developed country the United States is still in a dire need of fossil fuels, where the U.S. Energy Information Administration [5] estimates 77% of the nation's energy will be covered by fossil fuels in 2040 and 78% in 2050. Notwithstanding the high contribution of fossil fuels towards the global energy mix, which may seemingly be sufficient enough to meet energy demand growth, the resulting impact of excessive exploitation of fossil fuels in environmental, economic and political aspects need to be taken into great consideration.

One of the most evident factors, which directly affect the environment, is the greenhouse gas emission. Shukla et al. [6] reported that 85% of conventional fossil fuel combustion accounts for 56.6% of greenhouse gas emissions. Ethane and propane are two examples of greenhouse gases emitted through during natural gas extraction and distribution. Although the levels declined in the 1980s and 1990s, the continual growth of global demand for natural gas can rise the abundance of these gases in the atmosphere. Therefore, a balanced role of energy should be achieved by the transition towards lower-carbon energy sources and minimized reliance on fossil fuels. The technologies of low carbon offer several advantages, such as primary energy supply is decreasing and CO_2 emissions and air pollution also reduced [7].

In economics and political aspects, price volatility and unequal distribution of energy supply in economically-vulnerable countries are subjected to the instability of energy security. Reduced spare energy capacity due to slow infrastructural development and interrupted distribution of energy can add up more burden on the economy. Taking this scenario into account, diversification of alternative energy, particularly renewable energy, becomes a suitable resolution to save the country from energy deficiency. Nowadays, not only government and non-governmental organizations support and encouragement for the embracement of renewable energy, but the industries sector also support this effort [8]. In 2040, nuclear and renewable energy will grow by nearly 50% and will account of about 25% share of the world's energy mix [9]. Most of the renewable energy will be utilized for electricity generation as more citizens in developing countries are connected to the electrical grid.

Nevertheless, the ultimate barrier that promotes the challenge to renewable energy is the high expenses. The term challenge here means how renewable energy can successfully satisfy the energy demand especially at peak times as well as exploiting the energy sources that are depleting and discontinuous nowadays. It is required for the infrastructure and technology, thus investment in renewable energy is perceived as a risky option. Unlike fossil fuels, the associated risk for investment is not too devastating as the fuel cost is passed onto the consumer in tax form [10]. A lot of renewable resources are also still having low energy density and insufficient power levels for large industrial-scale operation. Accordingly, the impediment to optimizing the use of renewable energy turns the country's dependency back on conventional fuels. Another factor that can somehow affect the availability and accessibility of renewable resources is climate change. U.S. Energy Sector Vulnerabilities to Climate Change and Extreme Weather, elaborates some of the impacts to be the reduction of water availability required for cooling purpose in power plants and the risk of physical damage of electricity distribution system as a result of extreme weather [11]. This paper will elucidate the potential of renewable energy to meet the growing demand for energy. The review centralizes its focus on two of the potential renewables available in Indonesia (biofuels and geothermal energy), explaining the encountered challenges in renewable energy development and the proposed solution to improve Indonesia's energy security.

2. Indonesia's Consumption Rate

Indonesia is the largest energy consumer in Southeast Asia, comprising 36% of the total primary energy consumption in 2011 [12]. Electricity consumption will

increase to 491 terawatt-hours (TWh) by 2030. Substantial increase in electricity consumption emphasizes the need to raise electricity generation capacity up to 4.1 gigawatts (GW) per year, with 50% of the installed capacity are based on coal [13]. With the combination of strong growth in the national economy (5.2% per year through 2025) and declining oil and gas production from maturing fields, Indonesia's energy consumption outstrips its energy production and the country has shifted from becoming net oil exporter into net oil importer. In 2016, oil remained as Indonesia's dominant fuel, with 41% of the primary energy consumption, followed by 36% of coal and 19% of natural gas [14].

Figure 2 displays three of Indonesia's largest consuming sectors in 2015 were the residential sector (38%), industry and services (29%), and transport (27%) [15]. In the case of transportation, motorcycles are the leading form of passenger transport in Indonesia. If the penetration of electric two-wheelers is boosted to match the current level in China, Indonesia can avoid USD 800 million of oil imports in 2030 compared with the current projections. Trucks account for 40% of Indonesia's total road transport energy use. If fuel efficiency standards that improved efficiency at the same rate as in China were introduced, USD 630 million in oil imports could be avoided in 2030 alone [15]. Together, these two measures would reduce energy use in 2030 by over 75,000 barrels of oil per day, equivalent to 13% of Indonesia's current net oil imports. Indonesia's goals of reducing energy intensity by 1% annually to 2025 and achieving an average saving of 17% in energy utilization across the industry, transport, residential and services sectors are outlined in National Energy Policy 2014 and 2017 [16].

As per World Bank in 2010, Indonesia is positioned number 14 in the world of nations due to CO_2 emission discharged to the air around 433.989 million tones and the CO_2 release per capita is 1.8 metric tons. The generation of carbon discharge is brought by energy used of many substances. Besides, Indonesia distributes a presidential guideline in 2020 for a national action plan to minimize the emission by 26%. Therefore, CO_2 discharges turn into a critical issue in conjunction with supply chain process that prompted to climate change [17].

Table 1 below shows that Indonesia is bestowed with extensive energy resources. Indonesia is also known as resource-rich country and a significant player in the world energy economy. Based on studies by Salleh et al. [17], there are several resources that were utilized intensively in order to meet the demands of domestic and export. In addition, the government can generate the revenues due to the utilization of energy sources from market sales, via taxes and royalties.

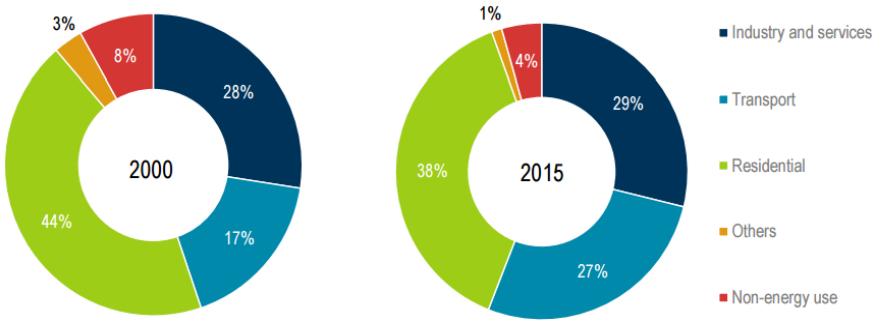

Fig. 2. Indonesia's sector-based energy use in 2000 and 2015.

Table 1. Energy resources of Indonesia [7].

Energy resources	Potential power
Hydro	75,000 MW
Geothermal	29,000 MW
Micro-hydro	750 MW
Biomass	14,000 MWe
Solar	4.80 kWh/m^2/day
Wind	3-6 m/s

3. Indonesia's Renewable Energy Potential

By 2050, renewable energy sources including geothermal, hydro, solar, biomass and ocean energy can be exploited up to 300 Mtoe per year, which is equivalent to 20% of primary energy supply [18]. Although the availability of abundant natural resources in Indonesia can hold for promising renewable energy prospects in the future, many of them are still undeveloped due to certain limitation in infrastructure, insufficient investment, and complexity in the administration system to allow exploration of energy reserves. Two of the potential renewable energy sources regarded in this paper will be geothermal and biofuels.

3.1. Geothermal

Indonesia is the third-biggest geothermal energy producer, ranked behind the United States (3,591 MW) and the Philippines (1,868 MW) in January 2018 as shown in Fig. 3.

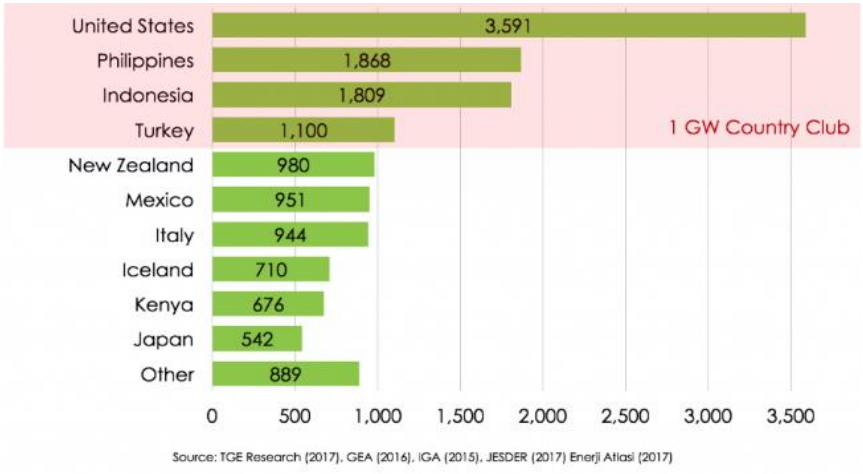

Fig. 3. Installed geothermal capacity in 2018.

The Ministry of Energy and Mineral Resources in Indonesia plans to maximize its geothermic capacity by 5,000 MW in 2025. So far in 2018, the Ministry expects an addition of 255 MW to the nation's installed geothermal power plants production capacity along with Sarulla Unit 3 (110 MW), Ulubelu Unit 4 (55 MW), Karaha Unit 1 (30 MW), and the Sorik Marapi Modular (20 MW) [19]. Comparing the utilization ratio with the potential capacity, geothermal development in Indonesia is considered low because of the constraints for exploration.

Geothermic capacity can be boosted up if Indonesia is able to utilize 50% of the geothermal potential in the Sumatra Islands. According to Mappangara and Warokka [20], as a matter of fact, only 5% is obtained from Sumatra and Sulawesi while the remaining 95% centred on the islands of Java and Bali. Existence of fuel subsidy also implies why renewable energy is less competitive. Overall, the installed current capacity for geothermal accounts slightly higher than 5% of the estimated geothermal potential, i.e., 1533.5 MW out of 28,910 GW. Data in Fig. 4 encapsulates the review conducted by Pambudi (2018), showing updated data of the existing geothermal power plants in Indonesia.

To promote the development of geothermal energy, Law No. 21 of 2014 is established by the Indonesian government. This regulation allows exploration of geothermal on land without being classified as mining activity, which would otherwise be constrained as mentioned in The Environmental Law No. 32/2009 and the Law on Mining and Minerals No. 4/2009 and The Forestry Law No. 39/2004. Improvement of technology should also be established to meet the targeted capacity for geothermal-based power generation with regards to Indonesia's existing geothermal power plants as narrated in Table 2.

Table 2. Indonesia's existing geothermal power plants [21].

No.	Field	Unit	Total capacity
1	**Sibayak**	Monoblok 2 MW, Unit-2-3, 2 × 5 MW	12 MW
2	**Ulubelu**	Unit-1-3; 3 × 55 MW	165 MW
3	**Salak**	Unit 1-3; 3 × 60 MW, Unit 4-6 3 × 65.6 MW	377 MW
4	**Wayang Windu**	Unit 1: 110 MW Unit 2: 117 MW	227 MW
5	**Patuha**	Unit 1: 55 MW	55 MW
6	**Kamojang**	Unit 1: 30 MW Unit 2-3: 2 × 55 MW Unit 4: 60 MW Unit 5: 35 MW	235 MW
7	**Darajat**	Unit 1: 55 MW Unit 2: 94 MW Unit 3: 121	270 MW
8	**Dieng**	1 × 60 MW	60 MW
9	**Lahendong**	Unit 1-6: 6 × 20 MW	120 MW
10	**Ulumbu**	Unit 1-4: 4 × 25 MW	10 MW
11	**Mataloko**	2.5 MW	2.5 MW
		Total	1533.5 MW

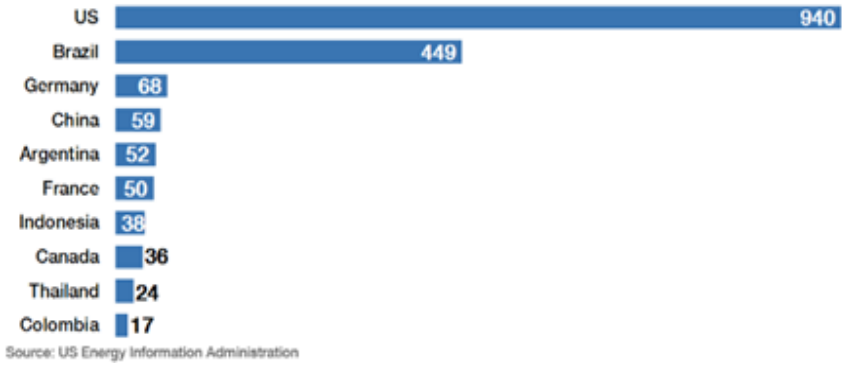

Fig. 4. Indonesia existing geothermal power plants.

3.2. Biofuel

Indonesia's government has put a target of replacing fossil fuel with 15% of bioethanol and 20% of biodiesel by 2025 in line with the development of biofuel. Recently, the development of a Directorate General of New Energy, Renewable and Energy Conservation has mentioned about biofuels in Indonesia. There is research shown that the production of biofuel based on palm oil become the most sustainable related to soil quality maintenance. Moreover, the palm biodiesel application in Indonesia can possibly lower the emissions of GHG, improve the energy security in the power generation area, and also enhance the economic growth in the rural community [22]. Besides, in the past few years, it seems that there is immediate development of global in liquid biofuels. Therefore, the probability of biofuels as resources that can meet the demand of future energy is high [23].

Bioethanol is alcohol-based on organic waste blended with gasoline, while biodiesel is composed of oil derived from plant or animals blended with petroleum diesel [24]. Indonesia's biofuels comprise mainly palm oil-based biodiesel and bioethanol. In 2015, it is ranked as the 7th country that produces the most biofuel, 38 thousand barrels per day (Fig. 4).

Ministry of Energy and Mineral Resources describes that biodiesel production in 2016 reached 3.656 billion litres. The production declined in 2017 into 2.9 billion litres then rose again in 2018 with an estimated 3.3 billion litres, assuming minimal export demand and stable domestic consumption [25]. In 2025, the capacity of biofuel will comprise 15.9 billion litres of ethanol and 16.5 billion litres of biodiesel. Compared to the predicted annual demand of ethanol (15.87 billion litres) and that of biodiesel (18.48 billion litres per year), the values signify a tight balance in the supply and demand of ethanol and insufficient biodiesel capacity to meet the foreseen demand [26].

Duncan [27] mentioned that an issue associated with biodiesel is that the price is more expensive than regular diesel, even though one litre of biodiesel has 8.65% lower energy than diesel. This corresponds to the higher cost of feedstock production due to costly inputs for biofuel production and low recovery from the feedstock [28].

There are several key factors that verify the effect of the biofuels, which are the contribution of biofuels to the land-use change, the usage of raw resources and the technology concerns. Therefore, biofuels give the benefits in term of economic and at the same time can decrease the emissions of gases and also can contribute to energy security [29].

4. Results and Discussion

Indonesia's energy sector faces a number of challenges that lead to the falling of production capacity with respect to the increasing economic growth. Economic growth reached 5.07% in the last four years [30]. In the National Development Plan 2015-2019, the total value of investment required for infrastructure development reaches 4.769 trillion Rupiah (US$348.1 million) [31]. Because the government can only cover 41.3% of the amount, Bambang Permadi Soemantri Brodjonegoro, the Head of National Development Planning Agency, encourage the private sectors to invest.

Contribution of the prevailing renewable energy sources is still inadequate to meet the customers' energy demand. Therefore, by 2050 the need for oil and gas is still high to sustain the growth of Indonesia's economy. Moreover, Indonesia's reliance on coal supply is projected to be high in 2030 due to its abundant reserves of steam coal and also it is a rather affordable way of generating electricity for more than 400 million people with no access to electricity [32]. However, long-term dependence on coal disrupts the uptake of renewable energy and planned the expansion of coal generating power plant can burden the government with an estimated USD$16.2 billion expenditure [33].

According to this paper, the potential renewable energy in Indonesia has been focused more on biofuels and also geothermal. This is due to the several factors that lead the government of Indonesia to focus on these two potential renewables energy. Both biofuels and geothermal energy had chosen as future options for the energy system in Indonesia, where there is a target of 5% for both biofuels and geothermal by 2025 [34]. Moreover, nowadays, geothermal energy is increasingly known as renewable energy sources. Besides, Indonesia is situated in the Ring of Fire so it has an extraordinary potential for geothermal energy.

The penetration of renewable energy had demonstrated its accomplishment in a wide range of nations in the world, and it is progressively turning into an indispensable segment of the energy mix later on plan for others. However, in order to shift the existing energy sources to the renewable energy will require confronting a few challenges in term of a few aspects that will give some impacts whether in a good way or vice versa to the sustainable development of Indonesia. Among the challenges that government has to overcome is how to handle a complex energy trilemma engaging the rival energy security demands, mitigation of climate change and also manage the energy shortage. This is because both climate change and energy security concerns had become huge challenges that faced by the world nowadays.

Besides, the other challenge of renewable energy development is a high cost incurred whether in installation, maintenance and other activities. Nevertheless, it is expected that the cost competitiveness of renewable energy will be improved in the coming years because of the development of advanced technology and also the economy of scale impact [35]. Furthermore, specialized difficulties will be created with renewable energy ventures, for example, variations of frequency and low power factors brought about by the discontinuity of renewable energy itself.

Additionally, there are also several implications when harnessing both renewable energy; geothermal and biofuels energy. For instance, geothermal power is considered as a source of energy that reliable, environmentally friendly and also cost-effective. In Indonesia, geothermal power is an increasingly significant source of renewable energy. In addition, geothermal energy is one of the major energy sources of the country that will have a mix of energy consumers and offsets energy users, which will make the nation's energy security and support the country's economic growth [36].

It has been notable that geothermal energy is a domestic source of energy that does not require intensive carbon fuel to run power generation. Geothermal energy also may replace the utilization of fossil fuels, therefore can diminish our dependence on fuel markets from other countries. At the point when the power plants harness the geothermal energy in the best possible way where it is not

harmful to the environment, there is a potential to help reduce global warming if it is widely used in fossil fuels.

Meanwhile, by utilizing the biofuel energy, it is looking forward to decreasing reliance on imported oil with related political and financial vulnerabilities, diminish emissions of greenhouse gasses and other pollutants. Besides, biofuel also may revive the economy by expanding the demand and costs of agricultural products. However, in order to meet the biofuel supply, the government has to make available the energy plantations and also the facilities of infrastructure to support the biofuels sustainable availability. Biofuel also offers the viewpoint of new financial chances for society in rural places.

On the other hand, currently, harnessing the source of renewable energy from biofuel energy to substitute the petroleum fuel by now had caused the import activity of petroleum fuel reduced. Therefore, it needs support in order to upgrade its function by giving encouragement and modification of the existing rules. Nevertheless, for the effectiveness of strategy and policy aspect on harnessing the biofuels, Indonesia still needs huge enhancements so as to accomplish better outcomes.

In terms of energy security, Indonesia is facing insecurity. First, the transforming status from net oil exporter to importer forces Indonesia to fulfil its needs for oil from international markets, bearing in mind that the price volatility can lead to a substantial increase in price. This uncertainty certainly burdens the economy. Due to domestic energy demand and consumption growth, Indonesia became a net importer of oil and natural gas, respectively in 2013 and 2023 [37], which increases energy insecurity and harms the economy. The Ministry of Energy and Mineral Resources estimates that domestic energy consumption in the country will rise by seven percent per year, with electricity demand tripling between 2010 and 2030. To address the growing demand, the government created a National Energy Policy, which established an energy mix target of 25% oil, 22% gas, 30% coal and 23% renewable energy by 2025 [38].

Asian Renewable Energy Hub (AREH) [39] is a newly introduced project to be fully operable by 2029, which involves the construction of solar and wind hybrid power plant in Northwest Australia via high voltage DC transmission cables. Uninterrupted stream of energy supplied by AREH can export the generated energy to Indonesia up to six gigawatts of energy [39], thus improving Indonesia's energy security by concerning on the use of renewable sources to reorient the energy mix that has been dominated by fossil fuels, to reduce greenhouse gases emission from fossil fuel exploitation and to improve the economy by raising the export of domestic fuels.

Besides, another option had been suggested to improve energy security in Indonesia, which is increasing the technologies that have more energy-efficient and also improving the development of renewable energy. Tongsopit et al. [40] reported that these efforts would bring Indonesia toward accomplishing energy security particularly and achieving sustainable development goals.

In addition, by growing the renewable share in the energy mix can bring broad socio-economic advantages to Indonesia itself. These benefits comprise of energy security improvement via fuel diversification and also mitigation of climate change by minimizing GHG emissions.

Moreover, it has been shown that in order to strengthen the overall energy security, all 4A's dimensions of energy security, which are availability, applicability, acceptability and affordability need to be improved. Indonesia has to pay attention to all these energy security elements so that can prevent any crisis caused by the energy sector in future. The bilateral relationship with Northwest Australia to access Asian Renewable Energy Hub and effective enforcement of the energy policies are expected to reduce fossil fuels consumption by increasing renewable energy share in the national primary energy mix up to 23% by 2025 and 31% by 2050 under National Energy Policy [41].

In addition, the main way to lower the impacts on environmental is by enhancing the energy system's performance, for example, the technologies of energy generations. Besides, power plants that used fossil fuels in their power generation technologies also can replace the fossil fuels with other resources that more efficient and clean such as hydrogen, gas, fuel cell and renewable energy in order to reduce the effect on ecology. Even though the cost of renewable energy systems become a barrier to implement renewable energy schemes, the ratio of energy such as wind, solar and biomass are better than the current one.

According to Krisnanto et al. [42], the technology advanced nowadays, in which, the renewable energy price is declining and the market share is rising. Moreover, even the government are preferred on shifting the current energy resources to renewable energy; it is also required to look at back-up non-renewable energy sources. Hence, it is necessary to do research and analysis of hybrid systems of both renewable and non-renewable energy sources. However, the main concern is to emphasize decentralized renewable energy sources that protect the natural resources, preserve the impacts on environmental and also widen the context of sustainable energy supply [43]. In Indonesia, in order to reduce the use of fossil fuels, avoid hike in the renewable energy cost and besides utilize Renewable Energy. For instance, the government must develop the policies and new technologies in Energy Efficiency such as minimizing the energy usage in the buildings, upgrade the efficiency of automobile and transportation system, maximize the efficient energy use and inspiring best industrial ecology actions that lessen wastages and endorse recycling practices [44-51].

5. Conclusion

Fossil fuels such as oil, gas and coal are the prime contributors to global energy mix due to their relative abundance, high energy release, and cost-effectiveness. However, excessive exploitation of fossil fuels results in greenhouse gases emission and instability of the economy with respect to price volatility and unequal distribution of energy. This triggers the policymakers and energy sectors to reduce reliance on fossil fuels by alternating to renewable energy.

Nonetheless, high expenses to build up infrastructure, insufficient investment, the effect of climate change, and regulatory issue become a major impediment to maximize the use of renewable energy. When investing in renewable energy is perceived as an unattractive option, many countries still rely heavily on conventional fuels to meet their growing energy demand. Indonesia is one of the developing countries with abundant sources of renewable energy, in which, two of them are biofuels and geothermal energy. To keep up with the rapid increase in the

rate of energy consumption, Indonesia aims to increase the production capacity of alternative energy. Nevertheless, Indonesia is facing several challenges to achieve this goal because the utilization ratio is shown higher than the production capacity, which is prone to the insecurity of energy supply. Optimization of Indonesia's energy security can be done through enforcement of National Energy Policy and bilateral relationship with Northwest Australia to access Asian Renewable Energy Hub. Furthermore, the solutions are expected to promote renewable energy use and to reduce fossil fuel consumption.

The shape of a projectile is generally selected on the basis of combined aerodynamic, guidance, and structural considerations. The choice of seeker, warhead, launcher, and propulsion system has a large impact on aerodynamic design. Consequently, various configurations have evolved, each resulting from a series of design compromises. During the supersonic flight, the drag component that results from the change of the cross-section of the projectile is referred to as wave drag and it is attributed to the shock waves formed. This normally happens at the forebody (nose) and afterbody (tail). Since the wave may be the prevailing drag form at supersonic speeds, careful selection of the nose and tail shapes is mandatory to ensure performance and operation of the overall system.

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