Alternative fuels for transportation sector in Indonesia

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Abstract

Only a few countries in the world have rich energy resources like Indonesia which owns practically all-natural energy resources, including biological resources. Japan, a country renowned for its technological advancements, lacks sufficient land to cultivate crops used as raw materials for biofuels. Several countries near the north pole, do not expose to sunlight throughout the year like Indonesia, which impacted to development of solar energy to provide electricity. Therefore, this short article reviews the three main energy sources available in Indonesia for the transportation sector, which include: natural gas and coal as new energy sources; natural energy for electricity and hydrogen supply, and energy from biological sources.

Keywords: Alternative fuel, Transportation sector, Natural gas, Liquified coal, Hydrogen energy

1. Natural gas and coal as new energy sources

Natural gas and coal are not renewable energy, but they have the potential as alternative fuels to replace gasoline and diesel. Based on the BP Statistical Review of World Energy 2021 [1], Indonesia’s natural gas reserves are ranked sixth in the Asia Pacific, after Australia, Bangladesh, Brunei, China, and India. Although the proven reserves have reportedly decreased since 2017, at least there is still 1.25 trillion cubic meters owned by Indonesia as alternative energy for the transportation sector. Natural gas cannot be utilized as in its original form, they must be converted into Compressed Natural Gas (CNG) or Liquified Natural Gas (LNG) to be distributed in a wider range. Good practice of CNG for transportation in Indonesia has been implemented for a long time for environmentally friendly Taxi, Trans, City transportation, and Bajaj, and for private vehicles that are converted as Natural Gas Vehicles (NGV).

Coal as a fuel source for the automotive sector has been discussed since 1977 by E.L. Clark in the book “Future Automotive Fuels” [2]. Reported by BP Statistical Review of World Energy 2021 [1], Indonesia has coal reserves ranked fourth in the Asia Pacific, after Australia, China, and India. Indonesia’s total coal reserves are estimated to reach 34,869 million by the end of 2020. Like natural gas, coal cannot be utilized in its solid form for the automotive sector. However, it can be converted into liquid coal, gas, or hydrogen which can be used for vehicles with cleaner emissions.

2. Natural energy for electricity and hydrogen supply

In recent decades, the availability of fossil fuels has become a concern of many stakeholders [3], [4]. Crude oil from current production fields may have passed peak production. The problem of peak oil will cause oil scarcity, production costs and demand will increase, while supply is limited [5]–[7]. Another issue is global climate change caused by burning fossil fuels. Greenhouse gas emission reduction costs will increase over time, if not controlled properly. In the future, before Battery Electric Vehicles (BEVs) are widely introduced, there will be several changes in the fuel pathway from basic materials to being used for vehicles, as presented in Figure 1.

Geothermal, water, sunlight, wind, waves, and ocean currents are natural energy that can be converted into electrical energy through a typical power plant (Figure 1). Geothermal energy resources in Indonesia are estimated to reach around 28.5 GigaWatt electrical (GWe) consisting of 11,073 MW of resources and 17,453 MW of reserves, which makes Indonesia one of the countries with the largest geothermal resources in the world [8]. Furthermore, Indonesia has a hydro energy potential of 75,000 MW (study of PLN with Nipon Koei in 1983). This study was followed by a screening of potential locations which were summarized in the Hydropower Development Plan in 2011. This study improved the quality of hydro potential data so that the original potential of 75,000 MW in 1,249 locations became 12,894 MW in 89 locations. The results of this study are
then included in the power plant development plan until 2027 [9]. The potential of solar energy in Indonesia is also very large, which is around 4.8 kWh/m². Until 2020, the use of solar energy in Indonesia has only absorbed 153.4 MW of a total potential of more than 207.8 GW. This number represents a fairly large market potential in the development of solar energy in the future [10].

Meanwhile, wind energy potential in Indonesia has been identified in several locations, especially in Java, South Sulawesi, Nusa Tenggara, and Maluku. Several energy developers have proposed the construction of wind energy in several locations such as Sukabumi, Sidrap, Bantul and Jeneponto. The government is targeting the development of wind energy plant of 2,500 MW by 2025 [11]. Indonesia, as an archipelagic country directly adjacent to the Hindia and Pacific Oceans, has very strong currents in several straits, such as the Sunda strait, the Capalulu strait and the Larantuka strait. There is potential for the development of an Independent Power Producer (IPP) project based on ocean currents in the Larantuka strait and could become the construction of the first Ocean Current Power Plant in Indonesia and the largest in the world, with a potential of up to 20 MW [12].

All electrical energy generated from geothermal, water, sunlight, wind, waves, and ocean currents can be used directly to charge batteries in electric vehicles or to produce hydrogen for Fuel Cell (FC). Fuel cells for Light Duty Vehicles (LDVs) have so far been used though on a limited scale and most automotive manufacturers have targeted for commercial sales. Fuel cell vehicles will most likely concentrate in areas that are ready with hydrogen refueling infrastructure such as in Japan, Germany, and the United States, and then will spread to several countries, including Indonesia. City buses driven by fuel cells are showing growth year after year, with more prototypes being introduced.

3. Energy from Indonesia’s original biological sources

In total, there are around 50 to 60 alternative plant species that can be used as raw materials for biofuels, including jatropha, sugar cane, corn, cassava, sweet potato, saga utan, winged bean, moringa walnuts, kapok, tengkawang furnacel, mindi, margosa, bengku, rambutan, soursop, sesame, sunflower, kemiri sunan, nyamplung, and all plants containing cellulose, and oil can be used as sources of biofuel production. In general, there are two main types of biofuels that can be applied today, namely biodiesel for diesel engines and biogasoline for gasoline engines.

1. Biodiesel

The palm oil-based biodiesel industry in Indonesia experienced a major expansion in 2018. Domestic consumption is expected to increase substantially in the coming years for the transportation sector. Meanwhile, exports are expected to remain high based on continued demand from the EU and China [13]. Many studies have reported on the potential for biodiesel development in Indonesia and many researchers agree that biodiesel is feasible to be applied as a mono fuel or mixed fuel for the transportation sector, including as fuel for fishing boat engines and agricultural machinery [14]–[19]. In addition, many basic researches for property improvement and evaluation of their use in the automotive sector are also being carried out [20]–[25]. This is not only for biodiesel from palm oil, but also for biodiesel from Indonesia’s biodiversity [26]–[32].

Indonesia’s biofuel program is a key component of the National Energy Policy (KEN), as regulated in Government Regulation number 79 of 2014. KEN targets the use of renewable energy nationally at 23% by 2025 and 31% by 2050. Biofuels are also a priority on the national research agenda. An evaluation of the Science and Technology Index (Sinta) in 2020 found a recognizable trend between the government’s target to increase the use of biodiesel as a substitute for fossil fuels and the trend of funding biodiesel research by the government through the Ministry of Research and Technology. Interestingly, these research funds are distributed across almost all research schemes, including competitive research, assignment research, and capacity building.
research. This shows the potential for sustainable biodiesel research by utilizing Indonesia's biological resources, which in the future can reduce imports of fossil fuels [33].

In fact, there is potential for the implementation of 100% biodiesel (B100) for diesel-engined vehicles in Indonesia. The use of B100 produces a lower noise level compared to diesel. Thermal efficiency with B100 in diesel engines can be improved due to its high oxygen content to increase the combustion process and combustion rate, reduce specific fuel consumption (SFC), and reduce smoke due to its high oxygen content and short carbon chain, as we reported in our previous study [34]. The properties and characteristics of biodiesel can also be improved by the intervention of Artificial Intelligence in its formation process, as we reviewed in our recent study [35], [36].

2. Biogasoline

Ethanol can be produced from biomass/plants containing sugar, starch, or cellulose material. However, for now, the price of ethanol is 5 times that of gasoline, so it is not yet feasible to use it as a non-mixed fuel. The use of various food crops as raw materials for ethanol will also cause socio-economic problems because it will conflict with the availability of land to produce food. As an alternative fuel, ethanol has the advantage of being renewable and has a higher-octane rating than gasoline (107 RON). It is possible to apply ethanol to engines with high compression ratios (up to 19.5) to improve thermal efficiency and exhaust emissions. Meanwhile, for applications with high concentrations of ethanol, modifications are needed not only in the compression ratio but also in several engine components so that the vehicle can run smoothly and prevent damage. However, there is potential for blending ethanol in gasoline to form a homogeneous mixture, which provides advantages on both engine and environmental side [37], [38]. The application of ethanol in SI engines is relatively easy and can be accepted by all types of Light Duty Vehicles (LDVs). However, the application of the CI engine requires some modification of the engine and the use of a cetane enhancer [39]. Figure 2 presents some examples of materials for Bioethanol and Biodiesel as part of efforts to reduce greenhouse gas emissions.

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