Type of contribution:
▶ Editorial
Research Paper
Case Study
Review Paper
Scientific Data
Report of Tech. Application

mesi
e-issn. 2798-5245
Mechanical Engineering for Society and Industry
Vol. 2, No. 1 (2022) pp 1-6
https://doi.org/10.31603/mesi.6850

Alternative fuels for transportation sector in Indonesia

Muji Setiyo

Department of Automotive Engineering, Universitas Muhammadiyah Magelang, **Indonesia**
✉ muji@unimma.ac.id

This article contributes to:
7 AFFORDABLE AND CLEAN ENERGY
SUSTAINABLE DEVELOPMENT GOALS

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.

Article info
Submitted: 2022-02-14
Edited: 2022-03-08
Published: 2022-02-12

Publisher
Universitas Muhammadiyah Magelang

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/m^2. 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.

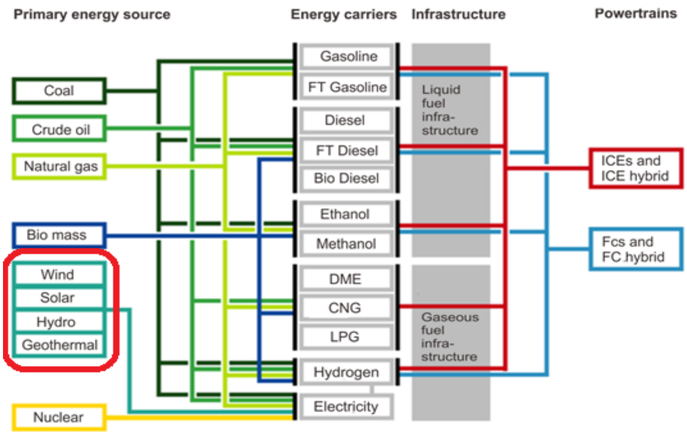

Figure 1. The fuel path for vehicles from natural energy

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 jatropa, 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.

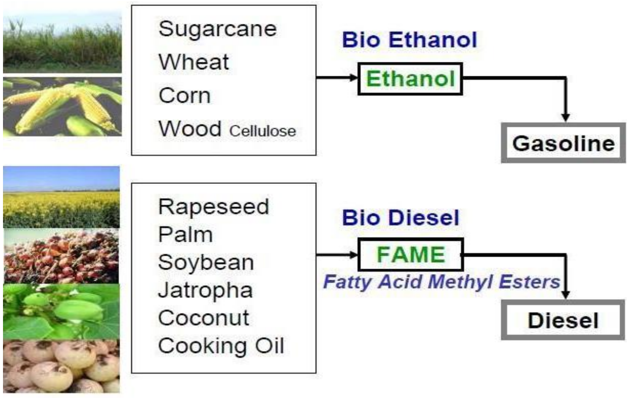

Figure 2. Biofuels for greenhouse gas emission reduction

Authors' Declaration

Funding – No funding information from the author.

Availability of data and materials - All data are available from the author.

Competing interests - The author declares no competing interest.

Additional information – This article is a part of the scientific oration script of the author's professorship inauguration, which was delivered on January 29, 2022, in Universitas Muhammadiyah Magelang.

References

[1] BP, "Statistical Review of World Energy globally consistent data on world energy markets . and authoritative publications in the field of energy," *BP Energy Outlook 2021*, vol. 70, pp. 8–20, 2021.

[2] E. L. Clark, "Coal as a source of automotive fuels," in *Future Automotive Fuels*, Springer, 1977, pp. 125–135.

[3] U. G. Akpan, A. A. Alhakim, and U. J. J. Ijah, "Production of ethanol fuel from organic and food wastes," *Leonardo Electronic Journal of Practices and Technologies*, vol. 7, no. 13, pp. 001–011, 2008.

[4] I. K. Adam, A. Galadima, and A. I. Muhammad, "Biofuels in the Quest for Sustainable Energy Development," *Journal of Sustainable Development*, vol. 4, no. 3, pp. 10–19, 2011, doi:

10.5539/jsd.v4n3p10.

[5] H. Carlsson and P. Fenton, “BioEthanol for Sustainable Transport - Results and recommendations from the European Best project,” Stockholm, 2010. doi: 10.13140/RG.2.1.4262.3442.

[6] IEA, “World Energy Outlook 2015,” Paris, 2015. doi: 10.1787/weo-2014-en.

[7] S. Sorrell, J. Speirs, R. Bentley, A. Brandt, and R. Miller, “Global Oil Depletion: An Assessment of the Evidence for a Near-term Peak in Global Oil Production,” London, 2009.

[8] Kementerian ESDM, “Ini Dia Sebaran Pembangkit Listrik Panas Bumi di Indonesia,” 2018. https://www.esdm.go.id/id/media-center/arsip-berita/ini-dia-sebaran-pembangkit-listrik-panas-bumi-di-indonesia#:~:text=JAKARTA - Sumber daya energi panas,panas bumi terbesar di dunia. (accessed Jan. 21, 2022).

[9] P3TEK, “Peta Potensi Energi Hidro Indonesia 2020,” 2021. https://p3tkebt.esdm.go.id/news-center/arsip-berita/peta-potensi-energi-hidro-indonesia-2020 (accessed Jan. 21, 2022).

[10] Kementerian ESDM, “Matahari Untuk PLTS di Indonesia,” 2012. https://www.esdm.go.id/id/media-center/arsip-berita/matahari-untuk-plts-di-indonesia (accessed Jan. 21, 2022).

[11] Kementerian ESDM, “Peta Potensi Energi Angin Indonesia dan Buku Integration of Wind Energy in Power Systems Diluncurkan,” 2017. https://www.esdm.go.id/en/media-center/news-archives/peta-potensi-energi-angin-indonesia-dan-buku-integration-of-wind-energy-in-power-systems-diluncurkan (accessed Jan. 21, 2022).

[12] Kementerian ESDM, “Tinjau Lokasi Pembangunan Pembangkit Arus Laut di Selat Larantuka, Menteri ESDM: Pertama di Indonesia, Terbesar di Dunia,” 2018. https://www.esdm.go.id/en/media-center/news-archives/tinjau-lokasi-pembangunan-pembangkit-arus-laut-di-selat-larantuka-menteri-esdm-pertama-di-indonesia-terbesar-di-dunia (accessed Jan. 23, 2022).

[13] A. Rahmanulloh, “Indonesia Biofuels Annual Report 2019,” Jakarta, 2019.

[14] F. Harahap, S. Silveira, and D. Khatiwada, “Cost competitiveness of palm oil biodiesel production in Indonesia,” *Energy*, vol. 170, pp. 62–72, 2019, doi: https://doi.org/10.1016/j.energy.2018.12.115.

[15] K. Siregar, A. H. Tambunan, A. K. Irwanto, S. S. Wirawan, and T. Araki, “A Comparison of Life Cycle Assessment on Oil Palm (Elaeis guineensis Jacq.) and Physic Nut (Jatropha curcas Linn.) as Feedstock for Biodiesel Production in Indonesia,” *Energy Procedia*, vol. 65, pp. 170–179, 2015, doi: https://doi.org/10.1016/j.egypro.2015.01.054.

[16] H. Kamahara *et al.*, “Improvement potential for net energy balance of biodiesel derived from palm oil: A case study from Indonesian practice,” *Biomass and Bioenergy*, vol. 34, no. 12, pp. 1818–1824, 2010, doi: https://doi.org/10.1016/j.biombioe.2010.07.014.

[17] A. S. Silitonga, A. E. Atabani, T. M. I. Mahlia, H. H. Masjuki, I. A. Badruddin, and S. Mekhilef, “A review on prospect of Jatropha curcas for biodiesel in Indonesia,” *Renewable and Sustainable Energy Reviews*, vol. 15, no. 8, pp. 3733–3756, 2011, doi: https://doi.org/10.1016/j.rser.2011.07.011.

[18] M. H. Jayed, H. H. Masjuki, M. A. Kalam, T. M. I. Mahlia, M. Husnawan, and A. M. Liaquat, “Prospects of dedicated biodiesel engine vehicles in Malaysia and Indonesia,” *Renewable and Sustainable Energy Reviews*, vol. 15, no. 1, pp. 220–235, 2011, doi: https://doi.org/10.1016/j.rser.2010.09.002.

[19] N. Indrawan *et al.*, “Palm biodiesel prospect in the Indonesian power sector,” *Environmental Technology & Innovation*, vol. 7, pp. 110–127, 2017, doi: https://doi.org/10.1016/j.eti.2017.01.001.

[20] R. Rosid, B. Sudarmanta, L. Atmaja, and S. Özer, “An Experimental Study of the Addition of Air Mass Flow Rate Using a 30% Emulsion-Fueled Diesel Engine at High Load,” *Automotive Experiences*, vol. 3, no. 2, 2020.

[21] E. Marlina, M. Basjir, M. Ichiyanagi, T. Suzuki, G. J. Gotama, and W. Anggono, “The Role of

Eucalyptus Oil in Crude Palm Oil As Biodiesel Fuel," *Automotive Experiences*, vol. 3, no. 1, pp. 33–38, 2020.

[22] D. Ayu, R. Aulyana, E. W. Astuti, K. Kusmiyati, and N. Hidayati, "Catalytic Transesterification of Used Cooking Oil to Biodiesel: Effect of Oil-Methanol Molar Ratio and Reaction Time," *Automotive Experiences*, vol. 2, no. 3, pp. 73–77, 2019, doi: 10.31603/ae.v2i3.2991.

[23] H. Y. Nanlohy, H. Riupassa, I. M. Rasta, and M. Yamaguchi, "An Experimental Study on the Ignition Behavior of Blended Fuels Droplets with Crude Coconut Oil and Liquid Metal Catalyst," *Automotive Experiences*, vol. 3, no. 2, 2020.

[24] H. Y. Nanlohy, I. N. G. Wardana, M. Yamaguchi, and T. Ueda, "The role of rhodium sulfate on the bond angles of triglyceride molecules and their effect on the combustion characteristics of crude jatropha oil droplets," *Fuel*, vol. 279, p. 118373, 2020, doi: https://doi.org/10.1016/j.fuel.2020.118373.

[25] A. C. Arifin, A. Aminudin, and R. M. Putra, "Diesel-Biodiesel Blend on Engine Performance: An Experimental Study," *Automotive Experiences*, vol. 2, no. 3, pp. 91–96, 2019, doi: 10.31603/ae.v2i3.2995.

[26] M. L. Sanyang, S. M. Sapuan, M. Jawaid, M. R. Ishak, and J. Sahari, "Recent developments in sugar palm (Arenga pinnata) based biocomposites and their potential industrial applications: A review," *Renewable and Sustainable Energy Reviews*, vol. 54, pp. 533–549, 2016, doi: https://doi.org/10.1016/j.rser.2015.10.037.

[27] P. A. Handayani, A. Abdullah, and H. Hadiyanto, "Biodiesel production from Nyamplung (Calophyllum inophyllum) oil using ionic liquid as a catalyst and microwave heating system," *Bulletin of Chemical Reaction Engineering & Catalysis*, vol. 12, no. 2, pp. 293–298, 2017.

[28] M. Fadhlullah, S. N. B. Widiyanto, and E. Restiawaty, "The potential of nyamplung (Calophyllum inophyllum L.) seed oil as biodiesel feedstock: Effect of seed moisture content and particle size on oil yield," *Energy Procedia*, vol. 68, no. 2015, pp. 177–185, 2015.

[29] S. Supriyadi and P. Purwanto, "Enhancing biodiesel from kemiri sunan oil manufacturing using ultrasonics," in *E3S Web of Conferences*, 2018, vol. 31, p. 2014.

[30] W. S. Wulandari, D. Darusman, and W. Cecep Kusmana, "Land suitability analysis of biodiesel crop Kemiri Sunan (Reutealis trisperma (Blanco) Airy Shaw) in the Province of West Java, Indonesia," *J. Environ. Earth Sci*, vol. 4, no. 21, pp. 27–37, 2014.

[31] N. A. Fauzan, E. S. Tan, F. L. Pua, and G. Muthaiyah, "Physiochemical properties evaluation of Calophyllum inophyllum biodiesel for gas turbine application," *South African Journal of Chemical Engineering*, vol. 32, pp. 56–61, 2020, doi: https://doi.org/10.1016/j.sajce.2020.02.001.

[32] A. S. Silitonga, H. H. Masjuki, H. C. Ong, T. Yusaf, F. Kusumo, and T. M. I. Mahlia, "Synthesis and optimization of Hevea brasiliensis and Ricinus communis as feedstock for biodiesel production: A comparative study," *Industrial Crops and Products*, vol. 85, pp. 274–286, 2016, doi: https://doi.org/10.1016/j.indcrop.2016.03.017.

[33] B. C. Purnomo, S. Munahar, Z. B. Pambuko, and H. Nasrullah, "Biodiesel Research Progress in Indonesia : Data from Science and Technology Index (Sinta)," *Technology Reports of Kansai University*, vol. 62, no. 06, pp. 45–52, 2020.

[34] M. Setiyo, D. Yuvenda, and O. D. Samuel, "The Concise Latest Report on the Advantages and Disadvantages of Pure Biodiesel (B100) on Engine Performance: Literature Review and Bibliometric Analysis," *Indonesian Journal of Science and Technology*, vol. 6, no. 3, pp. 469–490, 2021, doi: 10.17509/ijost.v6i3.38430.

[35] A. Kolakoti, M. Setiyo, and B. Waluyo, "Biodiesel Production from Waste Cooking Oil: Characterization, Modeling and Optimization," *Mechanical Engineering for Society and Industry*, vol. 1, no. 1, pp. 22–30, 2021, doi: 10.31603/mesi.5320.

[36] A. Kolakoti, B. Prasadarao, K. Satyanarayana, M. Setiyo, H. Köten, and M. Raghu, "Elemental, Thermal and Physicochemical Investigation of Novel Biodiesel from Wodyetia Bifurcata and Its Properties Optimization using Artificial Neural Network (ANN)," *Automotive Experiences*, vol. 5, no. 1, pp. 3–15, 2022.

[37] N. N. Clark, D. L. McKain, T. Klein, and T. S. Higgins, “Quantification of gasoline-ethanol blend emissions effects,” *Journal of the Air & Waste Management Association*, vol. 71, no. 1, pp. 3–22, Jan. 2021, doi: 10.1080/10962247.2020.1754964.

[38] M. K. Mohammed, H. H. Balla, Z. M. H. Al-Dulaimi, Z. S. Kareem, and M. S. Al-Zuhairy, “Effect of ethanol-gasoline blends on SI engine performance and emissions,” *Case Studies in Thermal Engineering*, vol. 25, no. May 2020, p. 100891, 2021, doi: 10.1016/j.csite.2021.100891.

[39] I. E. A. ETSAP, “Ethanol Internal Combustion Engines,” *Technology Brief T06*, no. June, pp. 1–6, 2010.