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Towards Alternative Energy Sources: Is it Time to Switch to Nyamplung?

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Abstract

Nyamplung *is one of the six priority non-timber forest products in Indonesia. This type of mangrove has a high yield of oil as a raw material biofuel with a 40-70% higher percentage than other plants, such as oil palm, whose percentage is only 46-54%. This article examines Indonesia's commitment to accelerate the transition to new and renewable energy through biofuels to meet the national electricity supply. In addition, it conducts an economic calculation of nyamplung as alternative energy for biofuels. The writing of this article reflects an economic analysis of law that combines legal analysis based on norms, guidelines, and plans as stipulated in Indonesian laws and regulations and international instruments and economic analysis referring to relevant data and sources. This article concludes that nyamplung may serve as an alternative energy source to fulfill future national energy needs, which aligns with efforts to achieve a sustainable environment. Despite laws and policies on national energy supporting any efforts to complement and substitute current energy sources, the utilization of nyamplung has yet to be optimized as a biofuel.*

Keywords: *Economic analysis of law; Environment sustainability; Indonesia; Nyamplung mangrove; National energy.*

1. INTRODUCTION

The increasing energy demand is generally influenced by rapid industrialization and economic development. This increase has an impact, especially on environmental issues and, in the broader scope, climate change. Most countries have made various efforts to address this issue by formulating environmentally friendly policies.[1]

Indonesia is one of the developing countries most vulnerable to climate change impacts.[2] For years, Indonesia has been criticized for its slow

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[1] Andreas Goldthau and Jan Martin Witte, *Global Energy Governance the New Rules of the Game* (Berlin: Policy Institute, 2010), 12.

[2] Diah Apriani Atika Sari and Rachma Indriyani, "Loss and Damage Due to Climate Change in Indonesia: An Overview of the ASEAN Cooperation Adapting to Global Warming," *Indonesian Journal of International Law* 12, no. 3 (2015): 396.

progress and lack of effort in dealing with climate change.[3] However, Indonesia is optimistic about mitigation and adaptation to climate change, to see the opportunities in law and regulation aspects and the various policies and regulations. Some of these opportunities include: first, government policy and some arrangements have existed and continue to be prepared in the context of climate change mitigation and adaptation; and second, laws and regulations have adopted climate change issues, such as institutional formation specialized on climate change; the National Action Plan for Greenhouse Gas Emission Reduction as a climate change mitigation; environmental license mechanism systems approach to climate change mitigation; national development plans with the approach to climate change adaptation and energy support; and opportunities for international cooperation with regard to climate change mitigation and adaptation.[4]

Natural resource based-energy is essential for controlling the lives of many people in Indonesia. The 1945 Constitution of the Republic of Indonesia (the 1945 Constitution) covers the economic aspects of energy in Chapter XIV concerning the National Economy and Social Justice. Article 33 (2) states that "Production sectors important for the state and vital for the livelihood of the people at large shall be controlled by the state."[5] Next, Article 33 (3) stipulates that "The land and waters and the natural wealth contained in it shall be controlled by the state and utilized for the optimal welfare of the people."[6] In the meantime, these constitutional provisions become the foothold of energy sovereignty. In addition, the 1945 Constitution determines that the national economy shall be conducted under economic democracy under some principles, among others, sustainability and environmental insight.[7] The establishment of a foothold for the meaning of energy sovereignty is built. The concern for a sustainable environment in the implementation of the national economy reflects the

[3] See Caroline Bulolo, "Indonesia's Cew Climate Plan: Slow Progress but Change Imminent," https://chinadialogue.net/en/climate/indonesias-new-climate-plan-slow-progress-but-change-imminent/

[4] See Maret Priyanta. "Intergrated Environmental Law System Strategies to Adapt Climate Change Impact from Energy Resilience in Indonesia," *Jurnal Dinamika Hukum* 17, no. 3 (2017): 298.

[5] The Constitutional Court has reviewed several laws regarding natural resources. According to the Constitutional Court, state control needs to be interpreted in depth which originates and is derived from the concept of people's sovereignty over all existing natural resources. It includes the notion of public ownership by the people's collectivity of natural resources. See Lego Karjoko, I Gusti Ayu Ketut Rachmi Handayani, and Willy Naresta Hanum, "Legal Policy of Old Wells Petroleum Mining Management Based on Social Justice in Realising Energy Sovereignty," *Sriwijaya Law Review* 6 no. 2 (2022): 287-288.

[6] Pursuant to the English version of the 1945 Constitution by The Constitutional Court of the Republic of Indonesia. See The Constitutional Court of the Republic of Indonesia, "The 1945 Constitution of the Republic of Indonesia and Law of the Republic of Indonesia concerning the Constitutional Court," https://www.mkri.id/public/content/infoumum/regulation/pdf/uud45%20eng.pdf

[7] The 1945 Constitution of the Republic of Indonesia, Art. 33 (4).

incorporation of the concept of a 'green constitution' in the 1945 Constitution.[8]

The development agenda contained in the 2016 National Legal Development Document desires harmony in managing both natural resources and the environment, especially concerning the energy sector. It underlines the need to strengthen supply, mix, and energy consumption efficiency.[9]

Indonesia is a country that has abundant natural resources, with an area of around 1.9 million KM^2 and a population currently reaching 278 million people with an average economic growth of 5% per year is faced with a trend of increasing needs and energy consumption.[10] Energy consumption, including in Indonesia, is highly dependent on fossil fuels, especially oil and coal.[11] The mass exploitation of fossil-based energy decreases the availability and reserves, leading to an effort to seek alternative energy as a substitution. The transition from fossil energy to new renewable energy on a large and rapid scale seems to be unavoidable.[12] The transitional policy will achieve at least three goals in a single action, i.e., to mitigate the adverse impact of climate change, encourage sustainable economic growth, and maintain national energy security.

The concept of New and Renewable Energy (*Energi Baru Terbarukan* /EBT) then seems to be relevant.[13] The use of EBT does not only aim at reducing the utilization of fossil energy but also as an embodiment of clean and environmentally sound energy.[14] This embodiment was supported by the Energy Trilemma (three pillars of energy management principles), which explains that to produce sustainable energy is based on 3 (three) index

[8] See I Gede Yusa dan Bagus Hermanto, "Implementation of Green Constitution in Indonesia: Guarantees of Constitutional Rights of Sustainable Enviromental Development," *Jurnal Konstitusi* 15, no. 2 (2018): 310-315. See also Sekar Anggun Gading Pinilih, "The Green Constitution Concept in the 1945 Constitution of the Republic of Indonesia," *Mimbar Hukum* 30, no. 1 (2018): 203-206.

[9] National Legal Development Agency, "National Legal Development Document", 70. https://www.bphn.go.id/dpage/reports/res_dphn

[10] Kompas, "Total Population of Indonesia," https://nasional.kompas.com/read/2022/04/27/03000051/jumlah-penduduk-indonesia-2022

[11] Muhammad Azhar, "The New Renewable Energy Consumption Policy of Rare Earth Metals to Build Indonesia's National Energy Security," *Conference Guidelines The 1st Sriwijaya International Conference on Environmental Issues* (2018): 84.

[12] Aditya Arso Perdana, Muhammad Ery Wijaya, and Ichsan, "Accelerating Renewable Energy Development toward Energy Security," *Jurnal Kebijakan Publik* 13, No.4, (2022): 405.

[13] Biro Komunikasi. "Layanan Informasi Publik dan Kerja Sama Kementerian Energi dan Sumber Daya Mineral." *Jurnal Energi: Program Strategis EBTKE dan Ketenagalistrikan, Edisi* 2 (2016): 9.

[14] Aan Jaelani, "Renewable Energy Policy in Indonesia: The Qur'anic Scientific Signals in Islamic Economics Perspective," *International Journal of Energy Economics and Policy* 7, no. 4 (2017): 193-204.

assessment dimensions, namely: the dimensions of energy security, energy equity (accessibility and affordability), and environmental sustainability.[15]

The utilization of EBT, also known as clean energy, has become a global concern.[16] The 21st Conference of the Parties (COP) of the United Nations framework for climate change (UNFCCC) in Paris on 30-13 December 2015, agreed upon a joint action that aims to stop global warming below 2°C.[17] The COP becomes a historic meeting as it concluded the first legally binding agreement since the Kyoto Protocol which was adopted at the 3rd COP meeting in 1997. This basis serves as a guide so that countries in the world are committed to presenting policies to reduce carbon emissions world.[18] A promising development was when Indonesia ratified the Paris Agreement to the United Nations Framework Convention on Climate Change through Law No. 16 of 2016. It then leads Indonesia to strive for a renewable energy transition by reducing carbon emissions.

Law No. 30 of 2007 concerning Energy (Energy Law) defines renewable energy as an energy source that is produced from sustainable energy resources if appropriately managed, including geothermal, wind, bioenergy, sunlight, water flows, and waterfalls, as well as the movement and temperature differences of the sea layers.[19] Energy transition efforts in Indonesia mandate the realization of energy management that is just, sustainable, and environmentally sound in the context of realizing national energy independence and national energy security based on energy sovereignty and fair economic values. In line with this, it directly mandates Indonesia to reduce the use of fossil energy by prioritizing fulfillment of new and renewable energy by 23% in 2025 and at least 31% in 2050.[20]

The fulfillment of the need for national energy has become an urgent matter in realizing national energy security.[21] The national energy policy is conducted based on the principles of justice, sustainability, and environmental insight to achieve self-reliance and security of energy.[22] The energy management effort referred to is the implementation of activities for supplying, exploiting, utilizing energy, providing strategic reserves, and

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[15] National Energy Council. *National Energy Mix* (Jakarta: National Energi Council, (2020), 83.

[16] National Energy Council, *op.cit.*,1.

[17] United Nations Climate Change, COP-21 Paris," https://unfccc.int/event/cop-21

[18] *Ibid.*

[19] Law No. 30 of 2007 concerning Energy, Art. 1(6).

[20] Grita Anindarini Widyaningsih, "Presidential Regulation Number 22 of 2017 concerning the National Energy General Plan," *Indonesian Journal of Environmental Law* 4, no. 1 (2017): 141.

[21] Gde Pradnyana, "Pemenuhan kebutuhan energi dalam rangka mewujudkan ketahanan nasional." *Jurnal Maksipreneur: Manajemen, Koperasi, dan Entrepreneurship* 5, no. 2 (2016): 67.

[22] Government Regulation No. 79 of 2014 concerning National Energy Policy, Art.2.

conserving energy resources.[23] The Energy Law mandates the government to formulate a National Energy Policy or *Kebijakan Energi Nasional* (KEN) as a guideline for national energy management. As an implementing regulation of the Energy Law, the Government Regulation No. 79 of 2014 concerning National Energy Policy (*Peraturan Pemerintah tentang Kebijakan Energi Nasional*/PP KEN) determines policies to be implemented from 2014 to 2050. [24] Further, Presidential Regulation No. 22 of 2017 concerning the National Energy General Plan (*Rencana Umum Energi Nasional*/RUEN) determines a RUEN for a period up to 2050 which includes among others current national energy conditions and future expectations; vision, mission, goals, and targets of national energy; and national energy management policy and strategy.[25]

The demand for energy in Indonesia is continuously increasing along with the progress of industrialized development which then places Indonesia facing the challenge of meeting its domestic energy consumption.[26] Energy consumption increased by an average of 2,6% per year, from approximately 99 million Tons of Oil Equivalent (Mtoe) in 1990 to 240 Mtoe in 2017. Besides, Indonesia's per capita energy consumption has also increased from 0.71 Tonnes of Oil Equivalent (toe)/per capita in 2010 to 0.76 toe/per capita in 2015, growing 1.5% per year. The increase has occurred in the need for energy consumption which so far has been chiefly met from fossil energy sources, ranging from petroleum, natural gas, and coal, which reached 91.45%.[27] This dependency reflects a challenge for Indonesia to diminish the availability of fossil energy reserves. Undeniably, Indonesia must strive an effort to replace the use of fossil energy with new and renewable energy.

In addressing this concern, the government introduced a biofuel policy that is expected to be a solution to meeting national energy needs and at the same time fulfilling international commitments to reduce global emissions amid the threat of climate change.[28] In Indonesia, biofuel is generally called *Bahan Bakar Nabati* (BBN). Utilization of biofuels in the form of biodiesel, bioethanol, and bio avtur is part of the direct utilization of energy which is expected to meet 23 Mtoe or 25% of the EBT contribution target in 2025. In

[23] *Ibid.*, Art. 1 (8). See also Savira Ayu Arista et al., "National Energy Policy Development and New and Renewable Energy in Indonesia," *Journal of Syntax Transformation* 2, no. 12 (2021): 1780.

[24] Government Regulation No. 79 of 2014 concerning National Energy Policy, Art. 4.

[25] Presidential Regulation No. 22 of 2017 concerning the National Energy General Plan, Art. 2 (1).

[26] Poppy Winanti, et.al., "Indonesian Energy Diplomacy," *Figshare* 25 (2020): 13.

[27] *Ibid.* See also Ministry of Energy and Mineral Resources, *Handbook of Energy and Economic Statistics of Indonesia* (Jakarta: Ministry of Energy and Mineral Resources, 2018), 18.

[28] Tiara Yasinta and Mahawan Karuniasa, "Palm Oil-Based Biofuels and Sustainability in Indonesia: Assess Social, Environmental and Economic Aspects," *IOP Conference Series: Earth and Environmental Science* 716 (2021): 1.

2018 the production of biodiesel increased by 36% compared to 2017. This positive trend was an impact of the Minister of Energy and Mineral Resources Regulation No. 41 of 2018 concerning the Provision and Procurement of Biodiesel Type, mainly under the framework of financing by Oil Palm Plantation Fund Management Agency (*Badan Pengelola Dana Perkebunan Kelapa Sawit* /BPDPKS) and Presidential Regulation No. 66 of 2018 concerning the Second Amendment to Presidential Regulation No. 61 of 2015 concerning the Collection and Use of Oil Palm Plantation Funds.

Until present, the use of biofuels as fuel substitutes is biodiesel obtained from the esterification of Crude Palm Oil (CPO) or Castor Oil. Palm oil has faced sharp criticism, especially for sustainability and food security.[29] In 2019, the phasing of biodiesel reached 20% (B20) for all sectors, with achievements that exceeded the target of RUEN. The blending of biodiesel is increased to a level of 30% (B30) in diesel fuel starting in 2020. The B20 program can run well because of the existence of palm oil plantation funds, one of whose functions is to supply and utilize biodiesel. However, if there is a difference in the price of CPO and the price of petroleum getting higher, funds for other activities related to the development of plantations and the palm oil industry will be disrupted. The massive use of CPO also has a particular impact on the scarcity on people's need for CPO based-cooking oil.

In this situation, *nyamplung* mangroves *(Calophyllum Inophyllum)* is proposed as a promising source of energy. As a type of mangrove tree, *nyamplung* is spread widely in almost all Indonesian coastal areas. It offers a high oil yield in the percentage of 40-70%, compared to other plants, such as oil palm, which percentage is only 46-54%. Therefore, *nyamplung* is very potential to be utilized.

This article aims to offer a solution to address Indonesia's energy problem by proposing using *nyamplung* mangroves to produce biodiesel. It will focus on two issues. First, it assesses Indonesia's commitment to accelerate the transition to new and renewable energy through biofuels to meet the national electricity supply. Second, it conducted an economic calculation of *nyamplung* mangrove as biofuel alternative energy. This article reflects an economic analysis of law.[30] It combines legal analysis based on

[29] Douglas Sheil, *et.al.*, *The Impacts and Opportunities of Oil Palm in Southeast Asia What Do We Know and What Do We Need to Know?* (Bogor: Center for International Forestry Research (CIFOR), 2009), 32.

[30] Economic analysis of law deploys the tools of micro-economic theory to study legal rules and institutions. It has been further developed by law scholars. For example, it assumes that every regulation is a economic arrangement that based on the idea of efficiency. See Stanford Encyclopedia of Philosophy, "Economic Analysis of Law," revised version January 7, 2022, https://plato.stanford.edu/entries/legal-econanalysis/. See also Fajar Sugianto, Velliana Tanaya, and Veronica Putri, "Penilaian Efisiensi Ekonomi Dalam Penyusunan Langkah Strategis terhadap Regulasi," *Jurnal Rechtsvinding* 10 no. 3 (2021): 447.

norms, guidances, and plans as stipulated in Indonesian law and regulations and international instruments and economic analysis that refers to relevant data and resources.

2. RESULT AND ANALYSIS

2.1. Indonesia's Commitment to Accelerate the Transition of New and Renewable Energy through Biofuels

In 2016, the government explicitly mentioned the need to accelerate the development of electricity infrastructure. Such an acceleration can be achieved through the construction of a 35,000 MW power plant and a 46,000 km transmission line by prioritizing the use of new and renewable energy in order to support efforts to reduce Greenhouse Gas (GHG) emissions.[31]

It becomes a general expectation that the Government of Indonesia can demonstrate a strong commitment to developing renewable energy, which requires achievable objectives and supporting policies.[32] This Section evaluates the commitment of the Indonesian government to accelerate the transition of EBT through biofuel. The assessment mainly refers to compliance with international agreements and the adoption of national law, regulation, and policy that support the excessive use of biofuel.

In the international context, the energy transition towards EBT is carried out to anticipate various activities that lead to an increase in GHG emissions. The massive increase in GHG emissions raised awareness of international society and triggers high-level meetings to adopt common measures as well as create programs to reduce it internationally,[33] including the United Nations Conference on the Human Environment which was held in Stockholm on 5-16 June 1972.[34] The implementation of this idea was then set forth in the United Nations Framework Convention on Climate Change (UNFCCC). In 2016, Indonesia ratified Paris Agreement to the UNFCCC,[35] which entails a commitment for Indonesia to reduce emissions

[31] Presidential Regulation No. 4 of 2016 concerning the Acceleration of Electricity Infrastructure Development, Consideration (a).

[32] Aditya Arso Perdana, Muhammad Ery Wijaya, and Ichsan, *loc.cit.*

[33] Katadata, "Energy Transition: Its Definition, Benefits, and Technology," http://universitaspertamina.ac.id/berita/detail/transisi-energi-pengertian-manfaat-dan-teknologinya

[34] This conference, among others, resulted in a common understanding that each person has fundamental rights to freedom, equality, and adequate conditions of the environment for the sake of life dignity, and prosperity. See Made Adhitya Anggriawan Wisadha and Grita Anindarini Widyaningsih, "Human Rights and the Environmental Protection: The Naïveté in Environmental Culture," *Udayana Journal of Law and Culture* 2, no.1 (2018): 74.

[35] Law No. 16 of 2016 concerning the Ratification of the Paris Agreement to the United Nations Framework Convention on Climate Change.

by 29% on its own and to 41% if there is international cooperation by 2030.[36]

Besides derived from international agreements, Indonesian law and regulations also indicate a commitment to shifting to EBT. The Energy Law mandates President to establish a National Energy Council or *Dewan Energi Nasional* (DEN) to be assigned to designing and formulating a national energy policy, to be stipulated by the Government with the approval of the House of Representatives, and stipulating a general national energy plan.[37] PP KEN emphasizes the strategy to ensure sustainability, security of supply, efficient use of energy, and the realization of an optimal energy mix by 2050. This policy further explains the country's goals, one of which is to reduce the final energy intensity by 1% per year until 2025 and increase the share of EBT in the energy mix by at least 23% in 2025 and at least 31% in 2050.[38]

Sustainable development is a crucial factor in achieving energy.[39] Indonesia is rich in renewable energy resources such as geothermal, biodiesel, solar, wind, and water. However, this potential is not yet optimal for meeting national energy needs. Among various types of new and renewable energy sources, biofuels are energy sources that have the opportunity to substitute fossil fuels.[40]

The global and Indonesia's national commitment to reducing GHG encourage the Indonesian government to increase the role of EBT in maintaining national security and energy. Table 1 shows Indonesia's potential to utilize EBT in order to achieve national energy security.

Table 1. New and Renewable Energy[41]

Energy Type	**Potential**
Hydro Power	94 GW
Geothermal	23.966 MWe
Bioenergy	32.654 MWe
Solar	1.385.988 MWe
Wind	60.650 MWe
Ocean Energy	4.294 MWe

*MWe (Megawatts of electricity)

[36] Dhysti Winyswara, "Alasan pemerintah Indonesia meratifikasi paris climate agreement tahun 2016." *eJournal Ilmu Hubungan Internasional* 6, no. 4 (2018): 1419.

[37] Law No. 30 of 2007 concerning Energy, Art. 12 (2).

[38] Maria Lauranti and Eka Afrina Djamhari. *Equal Energy Transition in Indonesia: Challenges and Opportunities* (Jakarta: Friendrich Ebert Stiftung, 2017), 5.

[39] Hayat Khan, Itbar Khan, and Truong Tien Binh, "The Heterogeneity of Renewable Energy Consumption, Carbon Emission and Financial Development in the Globe: A Panel Quantile Regression Approach," *Scientific Research* 9, no. 5 (2020): 860.

[40] Karna Wijaya, "The Role of Biofuel Research as New and Renewable Energy for Strengthening Chemical Literacy in Indonesia," *Proceedings of the Yogyakarta State University Chemistry National Seminar* (2017): 18.

[41] Directorate General of New Renewable Energy and Energy Conservation, 2020.

Data presented in Table 1 explains the potential of hydropower, geothermal, bioenergy, solar wind, and ocean energy to reduce the use of fossil energy. Even solar energy has a potential of 1.385.988 Mwe, while bioenergy has a potential of 32,654 Mwe. The utilization of EBT for electricity generation, both fossil and non-fossil, is 64.5 GW.[42] The minimal use of EBT in the electricity sector is due to several factors, one of which is the high cost of production from EBT-based power plants. This makes competition more complex against fossil energy such as coal.

Biofuels are fuels derived from vegetable materials and/or produced from other organic materials, which are traded as other fuels.[43] Biofuel may be formed in biodiesel (B100), bioethanol (E100), and pure vegetable oil (O100).[44] Among them, biodiesel has attracted wide public attention. Biodiesel is a product of *Fatty Acid Methyl Ester* (FAME) or *Mono Alkyl Ester,* which is produced from biological raw materials and other biomass through esterification.[45] Technically, biodiesel can be mixed with diesel to produce a higher cetane blend of biodiesel, and this can reduce dependence on imported diesel by 39%.[46] The mixture of biodiesel and diesel has been successfully carried out with mandatory B-20, where the fuel used consists of a mixture of 20% biodiesel and 80% diesel.[47] This is as explained in Presidential Instruction No. 1 of 2006 concerning the Provision and Utilization of Biofuels as Alternate Fuel.[48] This Presidential Instruction was further elaborated through the Minister of Energy and Mineral Resources Regulation No. 12 of 2015 concerning Mandatory Use of Biofuels which states that since 2016 the power generation sector has had to use B30 for PLTD engines that use diesel fuel/diesel oil.[49]

Biodiesel can be used as a substitute for diesel fuel if it meets the Indonesian National Standard or *Standar Nasional Indonesia* (SNI) 7182:2015 concerning the characteristics of biodiesel.[50] Biodiesel can be produced from palm oil, coconut, jatropha, kapok, and *nyamplung*.[51] Among

[42] Abdurrahman, S., Pertiwi, M. and Walujanto. *Indonesia Energy Outlook 2019* (Jakarta: Secretariat General of the National Energy Council, Ltd. 2019), 6.

[43] Regulation of Minister of Energy and Mineral Resources No. 32 of 2008 concerning the Supply, Utilization, and Trading of Biofuels as Alternate Fuel, Art. 1 (2).

[44] *Ibid.*, Art. 2 (2).

[45] *Ibid.,* Art. 1 (3).

[46] Wijaya, *loc.cit.*

[47] Arya Hadi Dharmawan, et.al., "Development of Bioenergy in Indonesia: Opportunities and Challenges for the Biodiesel Industry Policy," *CIFOR*, no. 242 (2018): 242.

[48] Presidential Instruction No. 1 of 2006 concerning the Provision and Utilization of Biofuels as Alternate Fuel, Art. 2.

[49] Minister of Energy and Mineral Resources Regulation No. 12 of 2015 concerning Mandatory Use of Biofuels, Art. 1.

[50] Edhi Sarwono, Nutfahryza Erzha, and Budi Nining Widarti, "Biodiesel Processing from nyamplung Seeds (Calophyllum Inophyllum L) Using KOH Catalyst," *Proceedings of the VI National Seminar on Technology* (2017): 34.

[51] Wijaya, *op.cit.*, 5.

the sources mentioned above of biodiesel, *nyamplung* (*Calophyllum Inophyllum* L), also known as *bintangur*, has not been very much utilized. It is a mangrove tree species spread throughout big Indonesian islands, i.e., Sumatra, Java, Kalimantan, Sulawesi, Papua, and other small islands. [52] The oil yield in *nyamplung* has 40-70% percentage, which is higher than other plants, such as oil palm, with only 46-54%. It indicates that *nyamplung* has the potential to provide a substitute for a mixture of diesel fuel.

2.2. Economic Calculation of *Nyamplung* Mangrove as Biofuel Alternative Energy

In terms of state development, forests play a significant role as it can provide maximum benefits for the prosperity and welfare of the people. Article 33 (3) of the 1945 Constitution determines the primary position of the state to control the utilization of natural resources in order to provide maximum benefits for the prosperity of the people.

One form of utilization of natural resources is the utilization of forests. Forests in Indonesia have provided significant benefits for various needs of the country, i.e., as the source of food, wood, and medicines, as well as the water storage, flood barrier, and soil reinforcement.[53] Natural resources in Indonesia are diverse, including forest natural resources. Forests in Indonesia have diverse ecosystem forests, freshwater swamps, and mangrove forests.[54] According to Law No. 41 of 1999 concerning Forestry, mangroves are included in the protected forest category.[55] Besides, Law No. 26 of 2007 concerning Spatial Planning includes mangroves in Other Protected Areas, which serves to protect coastal and marine life.[56]

Mangrove ecosystems are aquatic ecosystems with many environmental services, functions, and specific ecological conditions.[57] Mangroves have high economic and ecological values but are vulnerable to damage if they are not utilized wisely. Indonesia has the largest mangrove ecosystem in the world and has the highest biodiversity. With a coastline length of 95.181

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[52] See Budi Leksono, Eritrina Windyarini, and Tri Maria Hasnah. "Nyamplung, Superior Local Genetic Resources for Biofuel Development," *Proceedings of the National Seminar on Utilization of Local Genetic Resources in Supporting the Success of Breeding Programs* (2016): 529.

[53] Sum Mintarsih, "Socio-Economic Relations of Klanggon Forest Farmers in Towards Independence," *Patravidya: Historical and Cultural Research Publishing Series* 12, no. 4 (2011): 664.

[54] Abdhy Walid Siagian, "Mangrove Forest Protection Through Economic Valuation of Carbon Services as an Effort to Suppress Climate Change," https://rechtsvinding.bphn.go.id/?page=artikel&berita=638

[55] Law No. 41 of 1999 concerning Forestry, Art. 41(2).

[56] Law No. 26 of 2007 concerning Spatial Planning, Art. 5 (2).

[57] Haruni Krisnawati. *Mangrove Forests for Mitigation of Climate Change* (Jakarta: Agency for Research Development and Innovation Ministry of Environment and Forestry, 2017), 56.

km2,[58] based on data from the Ministry of Environment in 2021, Indonesia has mangrove forests with an area of 3,364,080 Ha. This area fills about 24% of the area of mangrove forests in the world.[59] From the area of mangroves in Indonesia, it is known that an area of 1,671,140.75 Ha is in good condition, while the remaining area of 1,817,999.93 Ha is in damaged condition.[60] If the data coverage is reduced, in Asia, mangroves are found in Indonesia, most of which are in the provinces of Papua, East Kalimantan, South Kalimantan, Riau, and South Sumatra.[61] As well as in Southeast Asia itself, around 75% percent of mangroves are found in Indonesia.[62]

As for the wide distribution of mangroves in Indonesia, one type of mangrove tree is *Calophyllum Inophyllum L*, which in Indonesian is known as *nyamplung*. Indications of the potential land area for sampling cultivation in Indonesia alone are divided into as many as 480,000 Ha spread across various provinces, from west to east Indonesia.[63] *Nyamplung* is one of the 6 (six) priority types of non-timber forest products in Indonesia which has a high yield as a raw material for biofuels, namely in the form of biokerosene as a substitute for kerosene, and biodiesel as a mixture of diesel with particular composition, which can 100% be used if the processing technology is proper.[64] The yield itself is the ratio of the dry weight of the product produced to the weight of the raw material.[65] The high percentage of oil yield contained in *nyamplung* shows its potential to be an alternative source of biofuels as a mixture of diesel, which supports programs to reduce the use of fossil-sourced energy.

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[58] Ministry of Environment and Forestry, "Indonesia Hosts 2017 International Mangrove Conference," http://ppid.menlhk.go.id/siaran_pers/browse/561

[59] Ministry of Environment and Forestry, "National Mangrove Rehabilitation Management Baseline," https://www.menlhk.go.id/site/single_post/4476/peta-mangrove-nasional-tahun-2021-baseline-pengelolaan-rehabilitation-mangrove-nasional

[60] Ministry of Environment and Forestry, "Own 23% of the World's Mangrove Ecosystem, Indonesia Hosts 2017 International Mangrove Conference," http://ppid.menlhk.go.id/siaran_pers/browse/561

[61] Hery Purnobasuki, "Utilization of Mangrove Forests as a Carbon Storage," https://www.researchgate.net/publication/236846548_Peuntungan_Hutan_Mangrove_As_Pendinding_Karbon

[62] *Ibid.*

[63] S. T Bustomi, et.al, "Nyamplung (Calophyllum inophyllum L): A Potential Biofuel Energy Source. Forestry Research and Development Agency, Ministry of Forestry, Jakarta, https://onesearch.id/Record/IOS3332.slims-1595/Details

[64] Budi Leksono, "Nyamplung Fruit (Calophyllum Inophyllum) for Energy Security, Feed and Medicines: Opportunities and Challenges," *National Seminar on the Role and Policy Strategy for Utilization of Non-Timber Forest Products (HHBK) in Increasing the Utilization of Forest Areas* (2014): 302.

[65] H. Yuniarifin, V.P. Bintoro, and A. Suwarastuti, ""Pengaruh berbagai konsentrasi asam fosfat pada proses perendaman tulang sapi terhadap rendemen, kadar abu dan viskositas gelatin." *Journal Indon Trop Anim Agric* 31, no. 1 (2006): 55.

Table 2. Comparison of Nyamplung Production with other Biodiesel[66]

Energy Sources	Oil Production (Liters/Ha)	Description
Corn	172	Staple Feed Ingredients
Soybean	446	Staple Feed Ingredients
Sunflower Seed (Canola)	1190	Staple Feed Ingredients
Jatropha	1892	Staple Feed Ingredients
Coconut	2689	Staple Feed Ingredients
Palm oil	5950	Staple Feed Ingredients
Microalgae 70%	136.900	Difficult to process
Microalgae 30%	58.700	Difficult to process
Nyamplung (*Calophyllum inophyllum* L)	4.500.000	Easy to process

Referring to Table 2, the economic advantage of utilizing *nyamplung* is very obvious: it contains high yield and is easy to be processed. It can also be economically compared with oil from palm, which is the basic ingredient of common vegetable oils. Palm oil itself is a food ingredient that is not only utilized in the energy sector. Besides, compared to other oils, the processing of *nyamplung* oil is more effective.

Furthermore, based on data from the Daily Chair of Biofuel, Paulus Tjakrawan, Indonesia still depends on palm oil as a mixture of biofuels to make biofuels. This can be seen in the data showing that the need for palm oil for biodiesel this year is 8.4 million tonnes. This amount is only around 16% of the total national palm oil production in 2022, which is projected to reach 52 million tonnes.[67]

So far, Indonesia still relies on palm oil or crude palm oil mixture biofuel,[68] from west to east Indonesia.[69] The utilization of *nyamplung* as a source of biodiesel has promising advantages, by looking at the need for energy, the availability of land that can be used as a place for cultivation, and the high yield contained in *nyamplung* itself. With the assumption that 1 liter of biodiesel requires 2.5 kg of *nyamplung* seeds, 2,691,920 liters of biodiesel will be obtained.[70] As indicated in PP KEN that the target for

[66] Suyono, Ninik Umi Hartanti, Agus Wibowo, and Naruto, "Biodiesel from nyamplung Mangrove Types (*Calophyllum inophyllum)* as an Alternative to Fossil Fuels," *Biosphere* 34, no. 3 (2017): 129.

[67] Wilda Asmarini, "Biodiesel Triggers Cooking Oil Controversy? Check the consumption of palm oil," https://www.cnbcindonesia.com/news/20220511164226-4-338245/biodiesel-pemicu-kisruh-oil-goreng-cek-konsumsi-sawitnya

[68] Directorate General of New, Renewable Energy, and Energy Conservation, "Understand the Terms B20, B30, B100, BBN in Bioenergy," https://ebtke.esdm.go.id/post/2019/12/18/2433/pahami.term.b20.b30.b100.bbn.dalam.bioenergi

[69] Bustomi, et.al, *loc. cit.*

[70] Abdul Muis Hasibuan, "Prospects and Feasibility of nyamplung (Calophyllum Inophyllum Linn) Farming," *Research Institute for Spices and Various Industrial Plants* (2019): 82.

biodiesel utilization in 2025 is 10.22 kiloliters, thus *nyamplung* can contribute to at least 25% of such target. If the policy is taken correctly, *nyamplung* may become a pillar in realizing the national energy policy.

The use of *nyamplung* seeds for biofuel seems to be very exclusive as it will not be traded for food purposes, which differs from the case of CPO.[71] Besides that, the cultivation of this type of plant is easy. Nyamplung has been planted as a windbreaker plant since half a century ago in coastal marginal areas and other degraded lands. The waste generated from the process of making *nyamplung* biofuel is quite a lot and has economic value, thus it can increase added value.[72] A correct technique of processing *nyamplung* into biofuel seems to be zero waste.[73] The oil from *nyamplung* offers excellent biodiesel. It is clean and carbon neutral with a yield of 95% under optimal conditions and meets the American Society for Testing and Materials (ASTM) standards.[74]

The Regulation of the Minister of Energy and Mineral Resources No. 12 of 2015 determines the phasing of the minimum mandatory utilization of biofuel as a mixture of fuel oil. This includes the obligation for power plants to use biodiesel (B100) by 30% and pure plant oil (O100) by 20% of the total demand in January 2025.[75]

Nyamplung waste can also be used as a mixture of biosolar,[76] a plant oil processed fuel specially formulated for diesel engines. Biosolar offers some advantages: it is renewable energy that is environmentally friendly; it has a complete combustion process with a lower cost of production than diesel fuel; and it can help reduce government subsidies for financing electricity.[77]

Despite all the advantages and potential of *nyamplung* as a source of biofuels, the utilization of *nyamplung* needs to be improved, particularly in processing it as an energy raw material. The challenge is significant considering the need for upstream-downstream integrative research between related fields of science that can support the efficiency and effectiveness of

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[71] *Ibid.*

[72] *Ibid.* See also Leksono, *op.cit.,* 303.

[73] Budi Leksono, Eritrina Windyarini, and Tri Maria Hasnah. *Cultivating Nyamplung Calophyllum Inophyllum L. For Bioenergy and Prospects for Other Utilization* (Bogor: IPB Press, 2014), 41.

[74] Center for International Forestry Research, "Energy from *Calophyllum inophyllum* Forest," https://www.cifor.org/id/feature/energi-dari-hutan/calophyllum-inophyllum-tamanu-tree/

[75] Minister of Energy and Mineral Resources Regulation No. 12 of 2015 concerning the Amendment of Minister of Energy and Mineral Resources Regulation No. 32 of 2008 concerning Supply, Utilization and Trading Procedure of Biofuel as Alternate Fuel, Annex.

[76] National Geographic Indonesia, "Limbah Tanaman Nyamplung untuk Bahan Biosolar, 21 May 2015, https://nationalgeographic.grid.id/read/13298782/limbah-tanaman-nyamplung-untuk-bahan-biosolar?page=all

[77] Billy J. Camerling, RA de Fretes, "Selection of Alternative Fuel Engines for PLTD Generators Using the Value Engineering Method," *Journal of Metrics* 1, no. 1 (2021): 46.

industrial processing so that the resulting product can be implemented on a production scale.[78] While further research is still needed towards the effective and efficient utilization of *nyamplung*, the current situation requires a pro-government policy to enable its use on a large scale.

3. CONCLUSION

The high demand for energy now and in the future has urged the Indonesian government to seek new renewable energy sources. Research on natural energy sources found several promising alternative energies. However, using new energy sources needs attention to some aspects, including economic efficiency. *Nyamplung* is a plant found in mangrove forests in coastal areas that meet aspects of economic efficiency when used as an energy source. Even compared to other biofuels, *nyamplung* has the advantage of being abundantly available and producing high energy with an easy processing process. Indonesian national laws and regulations in the energy, environment and forestry sectors allow the utilization of *nyamplung* as an environmentally friendly energy source in Indonesia. The use of *nyamplung* is also in line with the direction of the national energy policy, which has a vision for a sustainable environment to support the fulfillment of Indonesia's international commitments to reduce carbon emissions. Unfortunately, until now, no visible policy instrument supports the use of *nyamplung* on a large scale. It, therefore, certainly needs to be a consideration for the government in the future.

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[78] Leksono, *loc.cit.*

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