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ANALYSIS OF THE TRANSITION TO PALM-BASED BIOFUEL ON THE INDONESIAN MILITARY'S ENERGY SECURITY

by

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13. ABSTRACT (maximum 200 words)

Indonesia's petroleum oil production faces depletion within less than a decade, threatening its energy security. Further, Indonesia, as the world's largest palm oil producer, also faces the inevitable effects of climate change, which complicate the country's decision to rely more heavily on palm-based biofuel. Despite its abundant palm oil reserves, Indonesia's military faces a trilemma of energy security, operational readiness, and essential forces. This thesis qualitatively explores the expanded production and use of biofuel to address the effect of a potential fuel shortage on the Indonesian military. In addition, this study evaluates other renewable sources, such as jatropha and molasses, that might better serve the Indonesian military's fuel needs. The research finds that Indonesia's indigenous palm-based biofuel provides fuel supply redundancy for the military, whereas various economic factors hinder the other renewable sources serving as the primary source for biofuel. Based on this research, this thesis offers top-down recommendations for the government and military of Indonesia to address the potential cascading consequences of energy insecurity confronting Indonesia's armed forces. Eventually, Indonesia will need to establish a new sustainable biofuel program to guarantee its military's energy supply.

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ABSTRACT

Indonesia's petroleum oil production faces depletion in less than a decade, threatening its energy security. Furthermore, Indonesia, as the world's largest palm oil producer, also faces the inevitable effects of climate change, which complicate the country's decision to rely more heavily on palm-based biofuel. Despite its abundant palm oil reserves, Indonesia's military faces a trilemma of energy security, operational readiness, and essential forces. This thesis qualitatively explores the expanded production and use of biofuel to address the effect of a potential fuel shortage on the Indonesian military. In addition, this study evaluates other renewable sources such as jatropha and molasses, which might better serve the Indonesian military's fuel needs. The research finds that Indonesia's indigenous palm-based biofuel provides fuel supply redundancy for the military, whereas various economic factors hinder the other renewable sources serving as the primary source for biofuel. Based on this research, this thesis offers top-down recommendations for the government and military of Indonesia to address the potential cascading consequences of energy insecurity confronting Indonesia's armed forces. Eventually, Indonesia will need to establish a new sustainable biofuel program to guarantee its military's energy supply.

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LIST OF ACRONYMS AND ABBREVIATIONS

APROBI	*Asosiasi Produsen Biofuel Indonesia* (Indonesian Biofuel Producers Association)
Avtur	Aviation turbine fuel
BBL	Barrel (crude oil)
BPK	*Badan Pengawas Keuangan* (Audit Board of The Republic of Indonesia)
BRG	*Badan Restorasi Gambut* (Peatland Restoration Agency)
CPO	Crude Palm Oil
DOD	Department of Defense
EERC	Energy & Environmental Research Center
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FAME	Fatty Acid Methyl Ester
FFB	Fresh Fruit Bunches
FFV	Flexible Fuel Vehicle
GDP	Gross Domestic Product
GHG	Green House Gas
HVO	Hydrotreated Vegetable Oil
IDR	Indonesian Rupiah (currency)
ICAO	International Civil Aviation Organization
IEA	International Energy Agency
ITB	*Institut Teknologi Bandung* (Bandung Institute of Technology)
KEN	*Kebijakan Energi Nasional* (National Energy Policy)
KL	Kilo liters
LPG	Liquefied Petroleum Gas
MBSD	Thousand Barrels per Stream Day
MBOE	Thousand Barrels of Oil Equivalent
MEF	Minimum Essential Force
MEMR	Ministry of Energy, Mineral, and Resources
MoD	Ministry of Defense

MoU	Memorandum of Understanding
MTOE	Million Tons of Oil Equivalent
OECD	Organization for Economic Co-operation and Development
PLN	*Perusahaan Listrik Negara* (State Electricity Company)
RON	Research Octane Number
RUEN	*Rencana Umum Energi Nasional* (National Energy General Plan)
RUKN	*Rencana Umum Ketenagalistrikan Nasional* (General Plan of National Electricity)
RUPTL	*Rencana Umum Penyediaan Tenaga Listrik* (Electricity and Supply Business Plan)
SWOT	Strengths, Weaknesses, Opportunities, and Threats
TNI	*Tentara Nasional Indonesia* (Indonesian National Military)
USDA	U.S. Department of Agriculture

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I. INTRODUCTION

A. MAJOR RESEARCH QUESTION

Until 1996, Indonesia was self-sufficient in oil.[1] Since 2004, however, declining production rates have resulted in the country becoming a net energy importer.[2] Because of its need for uninterrupted oil supplies, Indonesia began looking for alternatives to imported oil. One option is biofuel, which can be made from palm oil, of which Indonesia has been the world's largest producer since 2008.[3] Despite the evidence for palm oil's potential, as mentioned by many scholarly works, the expanded use of palm-based biofuel for military energy could be undermined by environmental issues. Fortunately, other viable biofuel sources such as jatropha and molasses are readily available in Indonesia.[4]

This thesis seeks to examine the potential for improving Indonesian energy security through the expanded use of palm-based biofuel. In doing so, this study addresses the following questions: what are the distinct advantages and disadvantages associated with expanded production and military use of biofuel? Are there other renewable energy sources that might better serve the Indonesian military's needs? If not, can Indonesia exploit and harness palm oil to secure its national energy resilience?

B. SIGNIFICANCE OF THE RESEARCH QUESTION

Energy security is essential for military resilience. The multitude of military roles in domestic, regional, and international affairs requires abundant equipment and fuel to make the war machines serve their purposes. As Indonesia grows, the necessity to uphold its defense security is followed by the need to increase its inventories of combat vehicles,

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[1] Robert Mabro, *The Oil Price Crisis of 1998*, Special Papers - Oxford Institute for Energy Studies 10 (Oxford, UK: Oxford Institute for Energy Studies, 1998), 15.

[2] U.S. Energy Information Administration (EIA), "Indonesia Rejoining OPEC despite Being a Net Importer of Petroleum - Today in Energy" October 15, 2015, https://www.eia.gov/todayinenergy/detail.php?id=23352.

[3] Jim Crutchfield, "Indonesia Palm Oil Production," United States Department of Agriculture, December 31, 2007, https://ipad.fas.usda.gov/highlights/2007/12/Indonesia_palmoil/.

[4] Yanuandri Putrasari et al., "Resources, Policy, and Research Activities of Biofuel in Indonesia: A Review," *Energy Reports* 2 (November 2016): 238, https://doi.org/10.1016/j.egyr.2016.08.005.

ships, and aircraft, as well as for the fuel to operate them. Therefore, the availability of fuel serves as the core of and is directly related to Indonesia's military readiness.

As of 2021, Indonesia continues to be a net importer of fossil fuel because its domestic oil production cannot meet the national demand.[5] Indonesia has growing fuel needs and currently meets those needs by importing fossil fuel. Since fossil fuel is a limited and non-renewable resource, not having sufficient fuel would affect the Indonesian military's role. This pattern of net fossil fuel importation is taking place not only in Indonesia and in other countries in the Southeast Asia region but is also likely to occur for countries across the world.[6] The risk from the inability to preserve fuel availability for military readiness is unquestionable. One could imagine how national security would be compromised if Indonesia's expensive military machines, such as its multi-billion-dollar F-16 jets, Sigma-class frigates, and Leopard tanks, were rendered useless without fuel readiness. Therefore, the availability of fuel defines the military's energy security status. Against this backdrop, Indonesia is well positioned as the biggest palm oil producer globally and possesses other potential sources for biofuel.[7] Therefore, investment in palm-based biofuel is likely to give Indonesia better energy security and sovereignty since it already has a substantial production foundation and capability.

This study's inquiry into the advantages and disadvantages of using palm oil as an alternate fuel for war machines can give Indonesian stakeholders a clear assessment upon which to decide whether to pursue palm-based biofuel development. The variety of biofuels or other renewable energy sources that might serve the military's needs will help distinguish the feasibility of palm oil development for biofuel in the future. Ultimately, the investigation into Indonesia's energy security in the context of palm oil as biofuel can help shape the stakeholders' policies to secure Indonesia's national resilience through its military energy security.

[5] EITI, "Indonesia Report," March 31, 2021, https://eiti.org/es/implementing_country/53.

[6] IRENA, *Renewable Energy Market Analysis: Southeast Asia* (Abu Dhabi, UAE: IRENA, 2018), 35. https://www.irena.org/media/Files/IRENA/Agency/Publication/2018/Jan/IRENA_Market_Southeast_Asia_2018.pdf.

[7] IRENA, 75.

C. LITERATURE REVIEW

This section reviews the relevant literature to provide an overview of Indonesia's energy security in the context of palm oil as a possible energy source for the military. Three important areas of research that contribute to this thesis are as follows: the concept of energy security and its correlation to the military's energy security, the concept of Indonesia's energy security, and the notion of palm oil as an alternative to petroleum-based fuels. Defining energy security facilitates an understanding of its correlation to military readiness. Furthermore, this literature review explains Indonesia's energy security and how it affects the Indonesian government in executing its biofuel policy to uphold national energy resilience. Finally, after examining the aforementioned areas, the last part discusses the situation of palm oil as an alternative to petroleum-based fuels. It also provides a body of knowledge concerning the likelihood for palm oil to emerge as a potential source for biofuel since there are some other sources at present.

1. The Concept of Energy Security and Its Correlation to the Military Energy Security

Defining the concepts of energy security and military energy security are important aspects of a country's policy. Yet, this thesis finds that the energy security definitions described by scholars are like an open architecture of ideas. Christian Winzer has declared that many scholars could not define the concept of energy security firmly.[8] He then mentions that fellow scholars, starting from Loschel et al., argue that the concept of "security of energy supply," or in short form "energy security," seems somewhat blurred.[9] Furthermore, Winzer also mentioned that the same argument is echoed by others such as Checchi, Kruyt, Mitchell, and Chester et al.[10]

Nevertheless, there are many organizational and scholarly approaches to define energy security. In 2007, the Asia Pacific Research Centre defined it as the country's

[8] Christian Winzer, "Conceptualizing Energy Security," *Energy Policy* 46 (July 2012): 36, https://doi.org/10.1016/j.enpol.2012.02.067.

[9] Winzer, 36.

[10] Winzer, 36.

economic ability to sustainably maintain the supply chain of energy resources on time and cost without compromising its economy.[11] The International Energy Agency (IEA) also supported the same notion in 2019, defining energy security as the sustainability in acquiring energy sources at an affordable cost.[12] In defining energy security, however, Aleh Cherp suggested "two epistemologically different approaches."[13] The first is to examine the mechanism of getting energy so that it can reveal the mechanism's weaknesses.[14] The second approach is to examine the way to overcome the weaknesses of the first approach by looking into the perception or interest of many countries.[15] Cherp described how Sovacol experimented with the second approach; his experiment has expanded the dimension and indicators of energy security, making the concept less rigorous than those derived from the first approach.[16] Furthermore, Winzer tried to deliver a quantifiable approach by narrowing down the concept as an energy supply continuum.[17] His approach originated from Joskow in 2009, who argued that because of the openness of ideas, one needs to understand the rationale and necessary reasoning in defining energy security, which has linked many political agendas with energy security.[18]

By building upon the concepts of energy security just mentioned, from the epistemological down to the operational concepts, this thesis draws a connection between energy and the military. In fact, energy security concepts must be synergized with the conceptual framework of military energy security since both energy and military security are directly related to national security. The theory in energy security that emphasizes

[11] Asia Pacific Energy Research Centre, ed., *A Quest for Energy Security in the 21st Century: Resources and Constraints* (Tokyo, Japan: Inst. of Energy Economics, Japan, 2007), 6.

[12] IEA, "Energy Security - Areas of Work," December 2, 2019, https://www.iea.org/areas-of-work/ensuring-energy-security.

[13] Aleh Cherp, "Defining Energy Security Takes More Than Asking Around," *Energy Policy*, Special Section: Frontiers of Sustainability, 48 (September 1, 2012): 841, https://doi.org/10.1016/j.enpol.2012.02.016.

[14] Cherp, 841.

[15] Cherp, 841.

[16] Cherp, 842.

[17] Winzer, "Conceptualizing Energy Security," 36.

[18] Winzer, 36.

military energy security can be categorized as classical realism theory, and among the modern approaches, can be explained by the resilience theory. These theories are suitable for defining energy security, which determines a country's defense posture survivability.

Realism is one of the general concepts that can correlate energy to the military framework, emphasizing the importance of putting energy security as the capstone of a country's national interest. Hans J. Morgenthau's argument about realism can portray the landscape of energy security and the military's role in that landscape. He observed that some global problems, such as the distribution of raw material (energy source) and its relation to the countries that "have" and "have not," would always be precarious.[19] Morgenthau's analysis of the international relations associated with energy security arguments is logical and undoubtedly similar to realism. Therefore, a country will always compete to secure as many energy sources as it needs to survive; thus, the competition for energy security behaves according to the principles of realism. The competition outlined in realism theory can create dramatic effects, resulting not only in environmental issues but also in violence such as that which occurs in war, threatening a country's defense security.

Many scholars emphasize the realism theory in energy and military security; one profound argument by Mark Whitehead, Rhys Jones, and Martin Jones reveals that wars fought over natural resources often arise out of competition over energy resources.[20] They underscore Klare's term "resources wars" and claim that the core of resource conflicts is related to increasing national security.[21] Therefore, when a war is necessary and inevitable to protect energy security, the concept of military security will come into play and take over national security as the top priority. Some scholars have emphasized this realistic position to put defense security at the top of the national agenda. They have argued that the concept of defense should become the capstone of a country's national interest, whereas energy security is one of the supporting pillars. In the end, one takeaway perspective is that

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[19] Hans J. Morgenthau, *Politics among Nations: The Struggle for Power and Peace* (Boston, Massachusetts, USA: McGraw Hill, 1993), 43.

[20] Mark Whitehead, Rhys Jones, and Martin Jones, *The Nature of the State: Excavating the Political Ecologies of the Modern State*, Oxford Geographical and Environmental Studies (Oxford ; New York: Oxford University Press, 2007), 5.

[21] Whitehead, Jones, and Jones, 7.

a country's survivability may be defined by its energy and military security policies. Cherp and Jewell also state that the reality in the 20th-21st century is that energy sustainability has become an increasingly fundamental factor for military security because it is a vital prerequisite to conduct military functions, which are a translation of national political interest.[22]

Moreover, Gawdat Bahgat has implied that the synergy between energy and military security is needed since the concept of energy security should reflect all concerned parties' interests, including the military, in the global context.[23] He claimed that an energy security policy could be established in a "win-win situation" by cooperation among countries as the key strategy in pursuing energy security.[24] Baghat revealed that the interdisciplinary approach is supported by many scholars and should be taken to address the energy security problem since the global interdependency environment has created a multi-dimensional concept of energy security.[25] Baghat's interdisciplinary approach discovered the fragility of energy security; hence, a fraction of disruption in energy security would create a ripple effect globally, and one of the disruptions takes the form of military actions. Consequently, military superiority is needed to secure a country's influence over its energy sources, just as it needs the energy to conduct security.

As for the resilience theory, it gives the perspective that energy security could be understood by examining a country's survivability. C. S. Holling first defined the resilience theory in 1973: "Resilience determines the persistence of relationships within a system and is a measure of the ability of these systems to absorb changes of state variables, driving variables, and parameters, and persist."[26] In 2019, Jesse Berhard-Johannes, Heidi Ursula Heinrichs, and Wilhelm Kuckshinrichs revealed that many scholars are progressively using

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22 Aleh Cherp et al., "Energy and Security," *Global Energy Assessment: Toward a Sustainable Future*, 2012, 329.

23 Gawdat Bahgat, *Energy Security: An Interdisciplinary Approach* (Chichester, UK: John Wiley & Sons, Ltd, 2011), 17, https://doi.org/10.1002/9780470980170.

24 Bahgat, 17.

25 Bahgat, 3.

26 C. S. Holling, "Resilience and Stability of Ecological Systems," *Annual Review of Ecology and Systematics* 4, no. 1 (November 1973): 17, https://doi.org/10.1146/annurev.es.04.110173.000245.

resilience for energy systems, but the approach utilized is not identical in each circumstance.[27] They mentioned three types of resilience theory: engineering, ecological, and adaptive resilience.[28] Some scholars have tried to correlate this theory to defense energy resilience, such as Scott Thomas and David Kerner, who claimed that the ecological and adaptive resilience approach may offer a new paradigm to recommend energy security policy. The resilience approach offers a set of outlooks on planning, whereas the adaptive approach examines how to shape better energy security by scrutinizing the institutions' methods.[29] They define "defense energy security" as a way to guarantee the military energy demands by sufficient energy resources.[30] They argued that the resilience approach could reveal that military operational sustainability will uphold the national security because the military functions are ensured against the uncertainty of energy availability.[31]

Finally, one profound connection between the military function and its energy security can be derived from Gen. James N. Mattis, who in 2003, during the advance on Baghdad in Operation Iraqi Freedom, said "unleash us from the tether of fuel" to challenge the U.S. Department of Defense (DOD).[32] Many scholars echoed Mattis, such as Andrew Bochman, who in 2009 claimed that the DOD was aware of the problem of energy cost but undervalued the importance of fuel development.[33] Furthermore, Constantine Samaras, William J. Nuttall, and Morgan Bazilian , in 2019, asserted that energy security not only becomes the enabler for military action but also can be a weapon.[34] They also observed

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[27] Jesse Bernhard-Johannes, Heidi Ursula Heinrichs, and Wilhelm Kuckshinrichs, "Adapting the Theory of Resilience to Energy Systems: A Review and Outlook," *Energy, Sustainability and Society* 9, no. 1 (July 2019): 11, http://dx.doi.org.libproxy.nps.edu/10.1186/s13705-019-0210-7.

[28] Bernhard-Johannes, Heinrichs, and Kuckshinrichs, 6.

[29] Scott Thomas and David Kerner, *Defense Energy Resilience: Lessons from Ecology*, Letort Papers, no. 39 (Carlisle, Pennsylvania, USA: Strategic Studies Institute, U.S. Army War College, 2010), viii.

[30] Thomas and Kerner, 7.

[31] Thomas and Kerner, 7.

[32] Constantine Samaras, William J. Nuttall, and Morgan Bazilian, "Energy and the Military: Convergence of Security, Economic, and Environmental Decision-Making," *Energy Strategy Review* 26 (November 1, 2019): 3, https://doi.org/10.1016/j.esr.2019.100409.

[33] Andrew Bochman, "Measure, Manage, Win the Case for Energy Operational Metrics," *Joint Force Quarterly*, no. 55 (October 2009): 114.

[34] Samaras, Nuttall, and Bazilian, "Energy and the Military," 1.

that the historical link between energy and war had pushed the military to adapt and evolve the old perception of energy supply as mission-critical into broader defense planning dimensions such as energy research, development, and independence.[35] The contemporary energy security competition can be seen within the recent global power energy plan. While, Indonesia and other developed countries pursue energy independence, Russia, China, and the U.S. engage in energy dominance. For instance, Russia's Nord Stream 2 project created geopolitical tension of energy dependency perspectives over European countries.[36] Moreover, China currently is the leading country of renewable energy plants by 2020, with a capacity reaching 895 gigawatts.[37] Lastly, The U.S. during Trump's administration sought "energy dominance" by becoming a major oil and gas producer that surpassed OPEC by 2019.[38]

2. Energy Security Overview of Indonesia and Its Military

The Indonesian government has an adequate and complete set of concepts and policies in defining its energy security. The government stipulated the term of energy security in Law No. 30/2007 and defined it as "a condition of ensuring the availability of energy and access of people to energy at affordable prices in the long term regarding the protection of the environment."[39] The law was then followed by the "National Energy General Plan" (RUEN) in Presidential Regulation No. 22/2017 that established the energy management plan. It constitutes the "National Energy Policy" (KEN), which set up the targets for "applying energy policy across sectors." The RUEN is "a reference document for the development of inter alia, national and local government planning documents 'General Plan of National Electricity' (RUKN) and 'Electricity and Supply Business Plan'

[35] Samaras, Nuttall, and Bazilian, 4.

[36] Jeronim Perović and Maria Shagina, "Nord Stream 2: It's Time to Change Perspective," CSS Policy Perspectives 9, no. 6 (April 2021), 4, https://doi.org/10.3929/ethz-b-000479318.

[37] Statista, "Renewable Energy Capacity Worldwide by Country 2020," Statista, 2021, https://www.statista.com/statistics/267233/renewable-energy-capacity-worldwide-by-country/.

[38] Farid Guliyev, "Trump's 'America First' Energy Policy, Contingency and the Reconfiguration of the Global Energy Order," *Energy Policy* 140, (May 1, 2020): 4, https://doi.org/10.1016/j.enpol.2020.11143

[39] Indonesian Ministry of Law and Human Rights, "Law No. 30/2007," August 10, 2007), https://www.dpr.go.id/dokjdih/document/uu/UU_2007_30.pdf.

(RUPTL)."[40] Also, the government already enacted the foundational policy for developing biofuel as alternate fuel in Presidential Instruction No.1/2006 on The Biofuel Provision and Utilization as an Alternate Fuel.[41] Furthermore, it was followed by Government Regulation No. 79/2014 on National Energy Policy. This policy was intended to reform Indonesia's energy independence by identifying uncharted energy resources. It also projected the energy mix by utilizing Indonesian-made energy supplies from renewables. The policy mandated the renewable energy mix targets to be at least 23% by 2025 and 31% by 2050.[42] As for biofuel, the Minister of Energy and Mineral Resources enacted a policy of biodiesel supply and utilization framework by Law No.41/2018.[43] The regulation mandated the domestic ministries as of January 1, 2020, to use the B-30 fuel (biofuel 30%) mixture from palm oil in their transportation units.

From the military side, in 2014–2015 Indonesia's Defense White Book indicated the alarming depletion of fossil fuel due to global demand, which could compromise military readiness in 2025–2030.[44] Then in 2019, the military signed an MoU with the Special Task Force for Upstream Oil and Gas Business Activities (SKK *Migas*) to secure upstream oil and gas business.[45] Recently, in 2021, The Ministry of Defense (MoD)

[40] Ministry of Energy and Mineral Resources (MEMR), "Indonesia Energy Outlook 2019," 2019, 1, https://www.esdm.go.id/assets/media/content/content-indonesia-energy-outlook-2019-english-version.pdf.

[41] "Presidential Instruction No.1/2006 of Biofuel Provision and Implementation as an Alternate Fuel," Deputy Cabinet Secretary for Legal Affairs, January 25, 2006, https://jdih.esdm.go.id/storage/document/inpres_01_2006.pdf

[42] Ministry of Energy and Mineral Resources (MEMR), "Indonesia Energy Outlook 2019," 2019, 48, https://www.esdm.go.id/assets/media/content/content-indonesia-energy-outlook-2019-english-version.pdf.

[43] Ministry of Energy and Mineral Resources (MEMR), "Ministrial Regulation No.41/2018 of Biodiesel's Supply and Utilization to Finance the Palm Oil Plantation Agency" August 23, 2018, https://jdih.esdm.go.id/peraturan/Permen_ESDM_Nomor_41_Thn_2018.pdf.

[44] *The White Book of Indonesia's Defense 2015*, 1st ed. (Jakarta, Indonesia: Indonesian Ministry of Defense, 2008), 25; *The White Book of Indonesia's Defense 2014*, 1st ed. (Jakarta, Indonesia: Indonesian Ministry of Defense, 2008), 16.

[45] Liputan6, "SKK Migas Gandeng TNI Amankan Kegiatan Operasional dan Aset Migas," [SKK Migas Collaborates with TNI to Secure Operational Activities and Oil and Gas Assets] November 13, 2019, https://www.liputan6.com/bisnis/read/4109696/skk-migas-gandeng-tni-amankan-kegiatan-operasional-dan-aset-migas.

decided to project a decentralized energy supply concept based on each major island.[46] In addition, the Indonesian Air Force Chief of Staff recently echoed that fuel supply is the key factor in transforming the national air force to have modern warfare capability.[47] From these concerns, it can be inferred that the defense stakeholders agreed that energy security is fundamental. Nevertheless, the current energy strategy revolves only around distribution and assets security.

In 2018, Yoesgiantoro observed that Indonesia's government policies on energy security are complete, and the policies also anticipate the future assessment by mandating the energy mix including renewable energy for diversification.[48] Some scholars, such as Erkata Yandri, Ratna Ariati, and Riki Firmandha Ibrahim, in 2018, also supported the Indonesian government energy policy, arguing that the plans were ambitious, which was in line with the projection of the rising population.[49] One approach that identifies Indonesia's energy resilience status is the energy trilemma approach (energy equity, energy security, and environmental sustainability), which as Yandri et al. reported, Gunningham observed as early in 2013.[50] He claimed that Indonesia started suffering from energy poverty, such that Indonesia ranked 75th out of 125 nations in the World Energy Council's energy trilemma index in 2017.[51] Indonesia's energy policies are considered to be derived from the realism and resilience approaches. The government realized the future challenges and so set ambitious targets as well as became adaptive to achieve resilience by diversifying its energy sources, pursuing renewable energy.

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[46] Biro Humas Setjen Kemhan, *Kebijakan Umum Pertahanan Negara 2020–2024*, 1st ed. [2020-2024 National Defense Policy] (Jakarta, Indonesia: 2021), 9, https://www.kemhan.go.id/wp-content/uploads/2021/06/wira-master-jan-feb2021-rev-jakumhaneg-19april2021indonesiakomplit.pdf.

[47] Fadjar Prasetyo, *Plan Bobcat: Transformasi Kekuatan Udara Di Era Modern*, 1st ed. [Plan Bobcat: Air Power Transformation in the Modern Age] (Jakarta, Indonesia: Elex Media Komputindo, 2021), 81.

[48] Arie Widiarto, "Pemerintah Perlu Tegas soal Energi Terbarukan," [The Government Needs To Be Firm About Renewable Energy] Suara Merdeka, August 19, 2018.

[49] Erkata Yandri, Ratna Ariati, and Riki Firmandha Ibrahim, "Meningkatkan Keamanan Energi Melalui Perincian Indikator Energi Terbarukan dan Efisiensi Guna Membangun Ketahanan Nasional Dari Daerah," [Improving Energy Security Through Detailed Indicators of Renewable Energy and Efficiency to Build National Resilience from the Regions] *Jurnal Ketahanan Nasional* 24, no. 2 (August 7, 2018): 242, https://doi.org/10.22146/jkn.30999.

[50] Yandri, Ariati, and Ibrahim, 243.

[51] Yandri, Ariati, and Ibrahim, 243.

3. Palm Oil as a Replacement for Petroleum-Based Fuels

According to Joel Schmitigal and Jill Tebb, the contemporary petroleum-based fuels for military equipment are divided into three major sources for internal combustion engines: kerosene, gasoline, and diesel.[52] Kerosene in the form of aviation turbine fuel (avtur) is primarily required for aircraft jet engines, gasoline for low-level drones and cars, whereas diesel fuel is used mainly for ground combat vehicles or vessels. The notion of using palm oil as a replacement for petroleum-based fuels has been examined and supported by many scholars. As early as 1996, S. M. Sapuan, H. H. Masjuki, and A. Azlan revealed that the first attempt to use palm oil as a biofuel in vehicles was carried out by a Malaysian research group in 1983.[53] They also mentioned that the group's Japanese and Australian counterparts had conducted successful scientific research to use 100% palm-based biofuel for running conventional engines.[54] Sapuan et al. further observed palm oil's properties and how its impact on the environment could significantly reduce carbon emissions.[55] Furthermore, according to Dilip Khatiwada, Carl Palmén, and Semida Silveira, in 2018, Indonesia had the ecological foundation to produce and develop biofuels from palm oil.[56]

As for the economic aspect, Fumi Harahap, Semida Silveira, and Dilip Khatiwada, in 2019, optimistically noted that the palm's biological traits for biofuel could provide economic prospects for Indonesia.[57] In 2017, the International Civil Aviation Organization (ICAO) proposed a regulation that mandates airliners across the globe to have a mix of

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[52] Joel Schmitigal and Jill Tebbe, *JP-8 and Other Military Fuels* (Warren, Michigan, USA: U.S. Army TARDEC, December 1, 2011), 2, https://apps.dtic.mil/dtic/tr/fulltext/u2/a554221.pdf.

[53] S. M. Sapuan, H. H. Masjuki, and A. Azlan, "The Use of Palm Oil as Diesel Fuel Substitute," *Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy* 210, no. 1 (February 1996): 48, https://doi.org/10.1243/PIME_PROC_1996_210_007_02.

[54] Sapuan, Masjuki, and Azlan, 50.

[55] Sapuan, Masjuki, and Azlan, 52.

[56] Dilip Khatiwada, Carl Palmén, and Semida Silveira, "Evaluating the Palm Oil Demand in Indonesia: Production Trends, Yields, and Emerging Issues," *Biofuels* 12, no. 2 (February 7, 2021): 137, https://doi.org/10.1080/17597269.2018.1461520.

[57] Fumi Harahap, Semida Silveira, and Dilip Khatiwada, "Cost Competitiveness of Palm Oil Biodiesel Production in Indonesia," *Energy* 170 (March 2019): 43, https://doi.org/10.1016/j.energy.2018.12.115.

50% biofuel by 2050.[58] At the same time, the ICAO's report put palm oil into the spotlight as the most viable source to support the regulation.[59] Finally, a report from the Indonesian Navy stated that it has been using biofuels from palm oil with a mix of 20% on its warships since 2018, but with a record replacement of fuel filters.[60] Based on the literature, the use of palm oil for military energy is viable since the military uses the same engines as its civilian counterparts.

On the other hand, there is a lack of scholarly literature that directly gives solid research on, and evidence for, palm-based biofuel usage in the military. One possible explanation for this lack of study may come from the environmental constraints and from palm oil's "status quo" as food stock, which hinders biofuel's full potential. The lack of attention can be explained by James T. Bartis and Lawrence Van Bibber's research on alternative fuels for military applications in 2011, in which they suggested palm oil is not an option because of the environmental issue.[61] Claudio Bertelli shared that view; he noted that since the promotion of "green aviation" in 2009, no aviation industry has used biofuel from palm oil, despite palm oil's superior availability.[62] In addition, Putrasari et al. revealed that as of 2005, other biofuel sources such as jatropha and molasses were developed in Indonesia, which competes with palm oil hegemony and could be considered a potential source.[63]

As promising as it could be, some scholars underscore that the palm oil strategy has already been under critique and challenges due to environmental issues, mainly from

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[58] ICAO, "Proposed ICAO Vision on Aviation Alternative Fuels," October 2017, 3, https://www.icao.int/Meetings/CAAF2/Documents/CAAF.2.WP.013.4.en.pdf.

[59] Andrea Springer, "ICAO Sustainable Aviation Fuels Guide," International Civil Aviation Organization (ICAO), 2017, 35, https://www.icao.int/environmental-protection/knowledge-sharing/Docs/.

[60] M. Nur Safrudin, "Biofuel B-20 Effect on Diesel Engine," October 1, 2020, 11, https://www.tnial.mil.id/assets/majalah/PDF-20201105-174846.pdf.

[61] James T. Bartis and Lawrence Van Bibber, *Alternative Fuels for Military Applications* (Santa Monica, CA: RAND, 2011), 28.

[62] Claudio Bertelli, "Current Status of Biofuels Production and Use for Commercial Aviation," Universal Oil Products LLC, 2009, 21, http://extranet.olade.org/wp-content/uploads/2015/11/S4-B2010_C_Bertelli_UOP_USA.pdf.

[63] Putrasari et al., "Resources, Policy, and Research Activities of Biofuel in Indonesia," 241.

greenhouse gas (GHG) and deforestation issues. Fargione, in 2008, argued that an increase in palm oil production would likely cause severe rainforest deforestation, which in turn would increase GHG emissions.[64] Similarly Ausilio Bauen et al., in 2009, emphasized that the use of palm oil as a bio-jet fuel source could create a large amount of GHG emissions due to direct or indirect land-use change.[65] Finally, in 2012, the U.S. Environmental Protection Agency (EPA) agreed that the palm oil used for biodiesel production is expected to be limited in the European Union and the United States, as it is not suitable for the renewable fuel program due to high GHG emissions.[66]

D. POTENTIAL EXPLANATIONS AND HYPOTHESES

This thesis primarily addresses Indonesian energy security policy, the country's palm-based biofuel development programs, and how they could help the country achieve energy security for its military readiness. Building on the available literature presented in the previous section, this thesis advances three hypotheses related to the research question:

First, I hypothesize that palm-based biofuel production in Indonesia for military use could have advantages in energy supply resilience. On the other hand, its disadvantages could emerge from the possible increase in the cost of crude palm oil due to the diversion of crude palm oil as a cash commodity in the export market to the effort in biofuel conversion for domestic needs, especially for military energy security.

Second, I hypothesize that other renewable sources for biofuel with lower environmental impact could complement palm oil and represent a small percentage in Indonesian biofuel production. Jatropha and molasses, which are non-food stock plants, would balance the palm oil market demand.

Third, I hypothesize that Indonesia's energy policies on palm oil could establish a new sustainable commodity that supports the country's economic energy security and

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64 Bartis and Van Bibber, *Alternative Fuels for Military Applications*, 28.

65 Ausilio Bauen et al., "Review of the Potential for Biofuels in Aviation: Final Report," August 2009, 59. https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.170.8750&rep=rep1&type=pdf.

66 Mark Drajem, "EPA Said to Be Close to Limiting U.S. Greenhouse-Gases," Bloomberg, March 27, 2012, https://www.bloomberg.com/news/articles/2012-03-26/epa-said-to-be-close-to-tightening-u-s-greenhouse-gas-limits.

environmental sustainability, producing a more profitable export commodity: indigenous palm-based biofuel. Thus, Indonesia's excess biofuel production would be a potential export good and decrease energy importation.

E. RESEARCH DESIGN

First, the thesis examines Indonesia's energy situation in the context of supporting its military energy security. The thesis then examines ongoing programs in Indonesia's palm oil and biofuel strategy, as well as the implications of this strategy for Indonesia's military energy security. Furthermore, the thesis examines the compatibility and viability of the other potential biofuel sources in Indonesia to serve the military energy demand by offering strengths, weaknesses, opportunities, and threats analysis. The thesis research is based on data and sources from national and international agencies, as well as from the contemporary scholarly research. Finally, several recommendations are provided for improving Indonesia's military energy security.

F. THESIS OVERVIEW

This thesis is divided into five chapters. This first chapter has provided background on Indonesia's energy security concepts and perspectives on palm-based biofuel development to achieve the military's energy security. Chapter II provides an overview of Indonesia's military energy situation. Chapter III examines sources of biofuel in Indonesia that are capable to support the military. Chapter IV explores the compatibility of biofuel sources in supporting Indonesia's military energy needs and assesses the challenges these sources pose with regard to climate change. Finally, Chapter V synthesizes the previous chapters' findings to assess how Indonesia's energy policy and biofuel development efforts could help the country achieve greater military energy security. The chapter concludes by offering recommendations on how Indonesia could effectively consolidate its military energy security.

II. INDONESIA'S MILITARY ENERGY SECURITY SITUATION

In the last two decades, Indonesia's energy consumption has increased significantly, in line with the consistent growth of its population. Therefore, the national energy demands, especially for military energy, require adequate energy production. Moreover, the storage capacity and the reserve must withstand any contingency or emergency such as natural disasters and military conflicts. Therefore, the view of the actual energy situation in Indonesia serves as the fundamental principle for state policies, and the most important is the policy for military energy.

Indonesia's energy security status can be seen from the energy trilemma index (see Figure 1). The trilemma consists of energy security, energy equity, and environmental sustainability.[67] Energy security is defined as the energy capacity to satisfy the current and future demands, while energy equity is a measure of the nation's energy affordability and accessibility.[68] Lastly, environmental sustainability is a reflection of the energy system's impact on the environment and climate change.[69] Indonesia's trilemma score has improved over the last two decades, with a significantly higher energy security index score. Its performance improved due to higher energy storage capacity, improved access to modern energy, and clean cooking facilities. Reducing emissions, however, remains a key challenge to improve its sustainability score given Indonesia's heavy reliance on fossil fuels. In 2020–2021, Indonesia reached a balance grade of ACC (A for energy security, C for energy equity and environmental sustainability), and its global rank is 56 to 58 out of a score of 66.80 to 61.10 due to a decline in energy security-environment sustainability scores.[70]

[67] World Energy Council (WEC), "World Energy Trilemma Index," 2021, https://www.worldenergy.org/transition-toolkit/world-energy-trilemma-index.

[68] WEC.

[69] WEC.

[70] WEC, "WEC Trilemma: Country Profile: Indonesia," 2021, https://trilemma.worldenergy.org/#!/country-profile?country=Indonesia&year=2021.

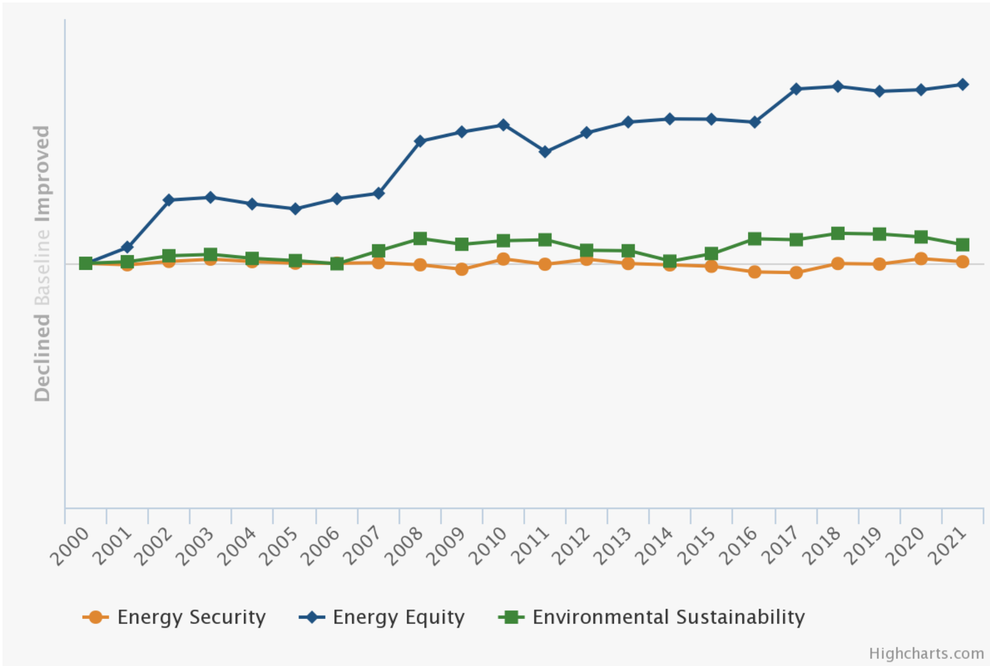

Figure 1. Indonesia's energy trilemma index.[71]

This chapter further describes the Indonesian energy situation specifically as it relates to military energy security. To begin with, it discusses the country's non-renewable and renewable energy sources, followed by an overview of the military energy situation. Next, the chapter outlines Indonesia's ambitions for energy security, especially in military energy security. Finally, this chapter concludes with findings on the connection between national energy and the Indonesian military energy situation.

A. NON-RENEWABLE ENERGY

The form of non-renewable energy related to Indonesian military energy security is crude oil (fossil fuel) since the military's equipment primarily requires petroleum-based fuel to operate. In order to provide an understanding of the current military energy-security situation, this section examines Indonesia's crude oil status through the following factors: crude oil resources (reserves), oil production, and problem-related to oil.

[71] Source: WEC, "2021 Indonesia Trilemma Index," 2021, https://trilemma.worldenergy.org/reports/countryProfile/2021/Indonesia.pdf.

Indonesia's crude oil reserves are alarmingly low. Fundamentally, Indonesia's commercial oil reserves declined 42.3% between 2010 and 2020 from 4.23 to 2.44 billion barrels (proven) (see Table 1).[72] Moreover, a report from British Petroleum (BP) and the Organization for Economic Co-operation and Development (OECD) in 2018–2019 predicted that the reserves would be entirely depleted in nine years.[73] This is an alarming condition that the Indonesian government has been fully aware of.

Table 1. Indonesia's crude oil reserves, in billion barrels.[74]

Year	Reserves			Contingent Resources		Unrecoverable[5)]
	Proven[2)]	Potential[3)]	Total	Low Estimates[4)]	Best + High Estimates[4)]	
2010	4.23	3.53	7.76	-	-	-
2011	4.04	3.69	7.73	-	-	-
2012	3.74	3.67	7.41	-	-	-
2013	3.69	3.86	7.55	-	-	-
2014	3.62	3.75	7.37	-	-	-
2015	3.60	3.70	7.31	-	-	-
2016	3.31	3.94	7.25	-	-	-
2017	3.17	4.36	7.53	-	-	-
2018	3.15	4.36	7.51	-	-	-
2019[1)]	2.48	1.29	3.77	0.33	0.38	3.03
2020[1)]	2.44	1.73	4.17	0.29	0.34	2.71

Source : Directorate General of Oil and Gas
Note: 1) Based on new parameter of Petroleum Resources Management System 2018 (it was considered as an oil reserves, however part of oil reserves has not been developed, it has been categorized as contingent resources since 2019)
2) Proven reserves = P1
3) Potential reserves = P2 + P3
4) Contingent resources = low estimate (C1) + best estimate (C2) + high estmate (C3)
5) Needs further assessment

[72] Ministry of Energy and Mineral Resources (MEMR), "Handbook of Energy and Economy Statistics of Indonesia 2020," 2021, 67, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2020.pdf.

[73] G20 2019 Peer-Review Team, "Indonesia's Effort to Phase Out and Rationalise Its Fossil-Fuel Subsidies," Organisation for Economic Co-operation and Development, 2019, 13, https://www.oecd.org/fossil-fuels/publication/G20_peer_review_Indonesia_Final-v2.pdf.

[74] Source: "Ministry of Energy and Mineral Resources (MEMR)," 67.

According to Indonesia's Ministry of Energy and Mineral (MEMR), the declines in national oil extraction are due to a faster-than-projected rate of production decline at the largest and primary oil wells, which are old (mature) wells.[75] The Secretary of Special Task Force For Upstream Oil and Gas (SKK Migas), Taslim Yunus, in June 2021, explained that even though the new oil fields such as in Rokan and Mahakam have started to operate, their production is relatively limited due to late investment to maximize output, drilling execution delays, aging facilities, and onstream delays from the new wells.[76]

Furthermore, scholars argue that the old oil wells, which have been operating since the 1970s, are just one problem. According to Hidayat Amir, scholars argue that Indonesia's oil potential is still relatively large, especially in deep-sea areas of eastern Indonesia; although the potential may be economically viable and technically recoverable, it cannot be explored and exploited optimally because of some obstacles.[77] These unrecoverable or unexplored oil fields comprise around 68 basins with an amount equal to around 3.6 billion barrels; however, due to lack of capital or investment, limited technology capability and the less attractive investment climate persist as roadblocks to tapping this potential (see Figure 2). SKK Migas has identified and reported these findings since 2010. The promise represented by these unrecoverable/unexplored oil sources remains unfulfilled more than a decade later; therefore, growth in Indonesia's oil production taken from the contingent resources may encounter many challenges.

Another potential energy source Indonesia has is shale oil. According to the U.S. Energy Information Administration's (EIA) report based on Advanced Resources International (ARI)'s research in 2013, Indonesia may have adequate shale oil potential. EIA reported that Indonesia's shale oil deposits, which are located in Sumatra, Kalimantan,

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[75] Ministry of Energy and Mineral Resources (MEMR), "Indonesia Energy Outlook 2019," 2019, 2, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf.

[76] CNBC Indonesia, "SKK Migas: Ada 4 Penyebab Turunnya Produksi Minyak Q1-2021," [The 4 Causes of Lower Oil Production in Q1-2021] CNBC Indonesia, June 17, 2021, https://www.cnbcindonesia.com/market/20210617102550-19-253801/skk-migas-ada-4-penyebab-turunnya-produksi-minyak-q1-2021.

[77] Rofyanto Kurniawan and Hidayat Amir, eds., *Aspek Fiskal Bisnis Hulu Migas*, 1st ed. (Jakarta: Naga Media, 2017), 233, https://fiskal.kemenkeu.go.id/data/document/buku/Aspek_Fiskal_Bisnis_Hulu_Migas.pdf.

and Papua, are technically recoverable.[78] The EIA estimated around 2.8 billion barrels of shale oil as the most promising shale oil potential, which is located in Central Sumatra Basin.[79] The government of Indonesia also has been conducting resource assessments on the shale oil basin since 2014 to confirm these findings (see Figure 2).[80] Yet, unconventional oil has been left untouched to date because of the current difficulties in conventional oil exploration and exploitation.

Eventually, facing this reality, Indonesia began importing crude oil, mainly from the Middle East, which brought Indonesia's dependency on oil importation to a peak of 45% in 2016, but it was at its lowest level of 26% in 2020 (see Figure 3).[81] This reduction came from the rebalancing of oil supply and demand in 2018–2019. Therefore, in 2019, Indonesia significantly reduced oil imports from 113,055 to 75,296 and exports from 74,472 to 25,716 (in thousand barrels) (see Table 2).[82] It can be inferred that Indonesia may encounter trade deficit if continues to import crude oil, however maximizing revenue by exporting its crude oil is always be a lucrative option to gain profit. On the other hand, Indonesia is desperate to meet the increasing national demand for crude oil. Surprisingly, fuel shortages at the pumps in many cities are not a new event in Indonesia. The Google Trends shows that the most acute fuel shortage in Indonesia was in 2005, which was aligned with the conflicts in Middle East that spike the oil price to be around $60-70 per barrel.[83]

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78 EIA, "Technically Recoverable Shale Oil and Shale Gas Resources: Indonesia," September 2015, XXIII–1, https://www.eia.gov/analysis/studies/worldshalegas/pdf/Indonesia_2013.pdf.

79 EIA, XXIII–9.

80 Ministry of Energy and Mineral Resources (MEMR), "Update Indonesia Shale Hydrocarbon Mapping," presentation at UC Project, Vientiane, Laos, May 2016, 37, http://ccop.asia/uc/data/40/docs/3-INDONESIA.pptx.pdf.

81 Ministry of Energy and Mineral Resources (MEMR), "Indonesia Energy Outlook 2019," 2019, 2, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf.

82 "Handbook of Energy and Economic Statistics of Indonesia 2019," Ministry of Energy and Mineral Resources (MEMR), 2020, 69, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf.

83 "Keyword 'BBM Langka' [Fuel Shortage] in Indonesia 2004–2021," Google Trends, accessed November 16, 2021, https://trends.google.com/trends/explore?date=all&geo=ID&q=bbm%20langka; BBC News United Kingdom, "Why the Oil Price Keeps Rising," June 6, 2008, http://news.bbc.co.uk/2/hi/business/7431805.stm.

Figure 2. Indonesia's upstream oil and gas reserves map in 2021.[84]

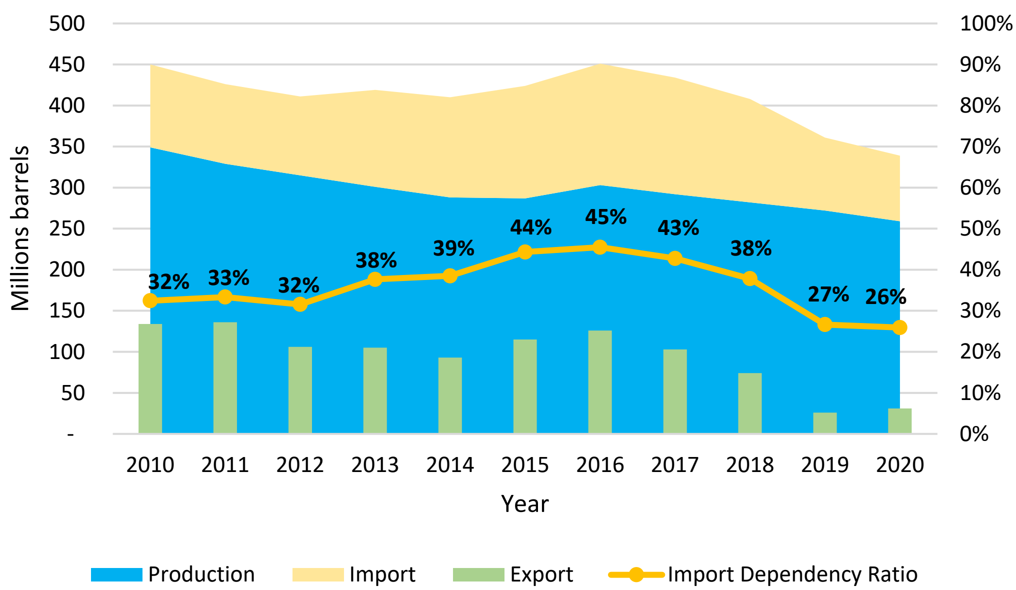

Figure 3. Indonesia's crude oil energy balance.[85]

[84] Source: David Pratama, "Fakta Umum Industri Hulu Migas," [General Facts of Upstream Oil and Gas Industry] Satuan Kerja Khusus Pelaksana Kegiatan Usaha Hulu Minyak dan Gas Bumi, February 2021, http://www.skkmigas.go.id/infografis/fakta-umum-industri-hulu-migas.

[85] Adapted from : Ministry of Energy and Mineral Resources (MEMR), "Handbook of Energy and Economy Statistics of Indonesia 2020," 2021, 69, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2020.pdf.

Table 2. Indonesia's crude oil production, exports, imports, and refinery input.[86]

Year	Production	Export	Import	Oil Refinery Input	
	Thousand bbl	Thousand bbl	Thousand bbl	Crude (thousand bbl)	Crude (Thousand bpd)
2010	344,888	134,473	101,093	299,116	819
2011	329,265	135,572	96,862	321,002	879
2012	314,666	106,485	95,968	299,257	820
2013	300,830	104,791	118,334	300,134	822
2014	287,902	93,080	121,993	309,445	848
2015[1)]	286,814	115,063	136,666	271,372	743
2016[1)]	303,336	125,541	148,361	401,541	1,100
2017[1)]	292,374	102,723	141,616	323,142	885
2018[1)]	281,780	74,472	126,082	334,281	916
2019[1)]	272,025	25,971	89,315	334,963	918
2020	259,247	31,448	79,685	302,344	826

Source : Directorate General of Oil and Gas
Note : 1) Revised data for export and import

From Figure 3 and Table 2, it is evident that Indonesia is facing a gradual decline in its oil supply. The data shows that Indonesia's high energy demands may possibly be due to domestic factors such as excessive energy consumption and inefficiency that led to wasted energy. The increase in energy consumption is due to the sustained increase in Indonesia's total population, which has continued growing at a rate of 1.1%, followed by a GDP growth rate of 5.6% in the past five years.[87] Indonesia's problem with energy efficiency was also confirmed by the American Council for an Energy-Efficient Economy (ACEEE) in 2018, which stated that Indonesia's energy efficiencies were still under the

[86] Source: MEMR, 69.

[87] Channelchek, "Energy Sector in Rapidly Growing Indonesia," accessed August 4, 2021, https://www.channelchek.com/news-channel/id/fBIm1W0TuZ.

median except for the industrial sector due to the establishment of energy management policies, mandates for energy sectors, and energy audit requirements.[88] ACEEE concluded that Indonesia's buildings or infrastructures are the most inefficient energy users (see Figure 4).

Therefore, it can be inferred that Indonesia has been pushed to extract more from its oil reserves or find alternative fuel sources since budget constraints limit Indonesia's ability to import enough oil import. This dilemma arises from deficient oil production to satisfy the domestic need, which forces Indonesia to import more oil, thus causing a trade deficit for Indonesia. The budget constraints can be confirmed from the World Bank's 2019 trade data, showing Indonesia's petroleum products imports in total were around 11% and caused a trade deficit of 2.4% ($3.593 million).[89] Facing this unfavorable condition, Indonesia eventually switched to producing indigenous palm-based biofuel to cater to the country's fuel demands. According to MEMR, Indonesia's biodiesel saved $3.35 billion in 2019 and an estimated $4.8 billion in 2020 of foreign exchange reserve by reducing oil imports.[90]

Pertamina has planned to revamp biofuel production in its refineries. In 2020, Pertamina chose Honeywell to revamp Palembang and Cilacap refineries with biofuel daily production capacity of 20,000 barrels of JXX and BXX, bio-LPG as well as 6,000 barrels of advanced *green fuels*.[91] The biodiesel production is expected to be started in December 2021 and bioavtur in next year.[92] It can be inferred that Pertamina has decided to combine

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[88] Fernando Castro-Alvarez et al., "The 2018 International Energy Efficiency Scorecard," June 2018, 111, https://www.aceee.org/sites/default/files/publications/researchreports/i1801.pdf.

[89] World Bank, "Indonesia Trade," 2021, https://wits.worldbank.org/countrysnapshot/en/IDN/textview.

[90] Ministry of Energy and Mineral Resources (MEMR), "Pemerintah Serius Capai Target Pemanfaatan Biofuel, Dampaknya Luar Biasa," [Government Seriously Reaching Target for Biofuel Utilization, The Impact is Tremendous] February 6, 2020, https://ebtke.esdm.go.id/post/2020/02/07/2470/pemerintah.serius.capai.target.pemanfaatan.biofuel.dampaknya.luar.biasa.

[91] Tehani Manochio, "Pertamina to Use Honeywell UOP Technologies," Honeywell UOP, September 28, 2020, https://uop.honeywell.com/content/uop/en/us/home/news-events/2020/09/pertamina-to-use-honeywell-uop-technologies.html.

[92] "Pertamina Aims To Start Green Refinery Operations By End 2021," *Reuters*, March 6, 2021, sec. Oil and Gas, https://www.reuters.com/article/indonesia-palmoil-biodiesel-idUSL2N2L4028.

the outsourcing of advanced biofuel refinery technology with the capacity of a national biofuel joint venture.

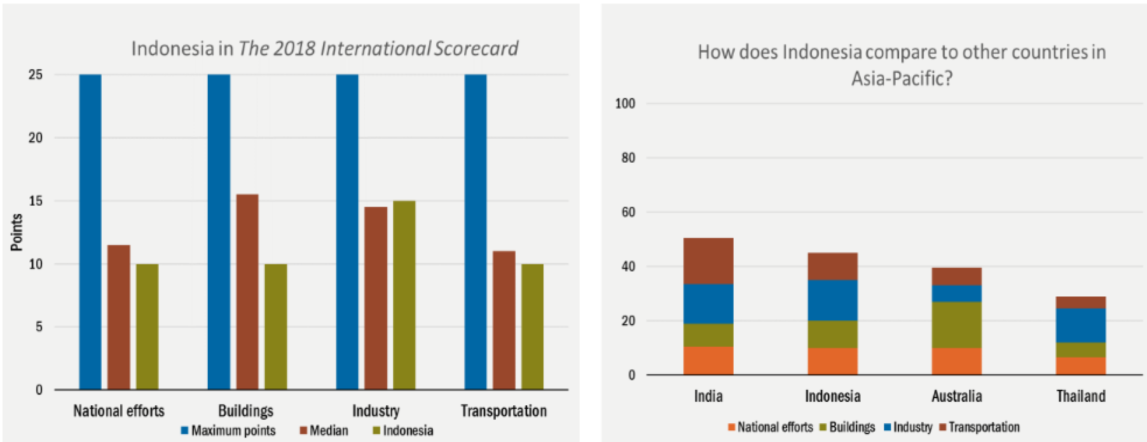

Figure 4. Indonesia's energy efficiency score in 2018.[93]

To sum up the latest status, between 2010 and 2020, Indonesia's crude oil production trend has been decreasing, with a margin that reached a low of 259,247 MBOE (thousand barrels of oil equivalent) in 2020 and a high of 344,888 MBOE in 2010, and with exports at a maximum of 135,572 MBOE (2011) and a minimum of 26,716 MBOE (2019).[94] Indonesia also imported crude oil at a rate as high as 148,361 MBOE (2016) and 79,685 MBOE at the lowest (2020).[95] The significant reduction in oil importation in 2020 can be related to the mandatory use of indigenous biofuel, specifically, the palm-based biodiesel (B20/30), which at that time had come into effect, thus relieving a substantial burden on the national oil supply. In 2018, the president himself stated that "the mandatory

[93] Source: Castro-Alvarez et al., "The 2018 International Energy Efficiency Scorecard," 111, https://www.aceee.org/sites/default/files/publications/researchreports/i1801.pdf.

[94] MEMR, "Handbook of Energy and Economic Statistics of Indonesia 2019," Ministry of Energy and Mineral Resources (MEMR), 2020, 69, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf.

[95] MEMR.

biodiesel program cannot be bargained any longer, since it is related to the trade balance, and we could save up to $21 million per day if the program is implemented successfully."[96]

On the other hand, other problems came from Indonesia's oil refinery sector, which suffered reduced production capacity and setbacks caused by repetitive fire accidents at almost all its refineries during that same period. In 2019, the MEMR reported that Indonesia's refineries capacity was 1,169.10 MBSD (thousand barrels per stream day), around 426 MBOE, comprising nine refineries (see Table 3).[97] Since 2010, crude oil production has only reached around an average of 295–300 MBOE, as depicted in Table 2. Therefore, Indonesia's oil refineries have been only producing around 70% of the country's total capacity.

In 2019, Indonesia imported as much as 141 MBOE, which is around 50% of the domestic refineries' production output.[98] This limited production may be due to technical issues within the refineries systems. Moreover, according to Pertamina, Indonesia's refineries' total capacity may be less than the stated one, which is around 1,051.10 MBSD excluding the Tri Wahana Universal Ltd (TWU) in Bojonegoro and the Trans-Pacific Petroleum Indotama Ltd (TPPI) in Tuban, which are private refinery companies. Pertamina, the sole national petroleum company, built in the 1950s, has a refinery capacity of 1,046.70 MBOE, from its six refinery units (see Table 3).[99]

[96] Cabinet Secretariat of the Republic of Indonesia, "Pengantar Presiden Joko Widodo pada Rapat Terbatas tentang Percepatan Pelaksanaan Mandatori Biodiesel, 20 Juli 2018, di Kantor Presiden, Jakarta," Sekretariat Kabinet Republik Indonesia, July 20, 2018, https://setkab.go.id/pengantar-presiden-joko-widodo-pada-rapat-terbatas-tentang-percepatan-pelaksanaan-mandatori-biodiesel-20-juli-2018-di-kantor-presiden-jakarta/.

[97] MEMR, "Handbook of Energy and Economic Statistics of Indonesia 2019," Ministry of Energy and Mineral Resources (MEMR), 2020, 68, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf.

[98] MEMR, 17.

[99] Pertamina, "Pertamina Refinery Overview," 2021, https://www.pertamina.com/en/.

Table 3. Indonesia's oil refinery capacity (in MBSD).[100]

No	Refinery	Capacity	Year built	Latest upgrade/ revamp	Products
1	Bojonegoreo-TWU Ltd	18	2010	n/a	(Inactive since Jan 2018)
2	Dumai – Pertamina unit II	177	1971	n/a	Avtur, Diesel, Kerosene, LPG, Biofuel
3	Musi – Pertamina unit III	127.30	1904	1982, 1992 (revamped)	Gasoline, Diesel, LPG, Biofuel
4	Cilacap – Pertamina unit IV	348	1974	1981 (expanded) 1988 (expanded)	Asphalt, Biofuel, Toluene
5	Balikpapan – Pertamina unit V	260	1922	1980 (expanded) 1995 (upgraded)	Gasoline, Diesel, Kerosene, Avtur
6	Balongan – Pertamina unit VI	125	1994	2003, 2008 (revamped) 2005, 2013 (expanded)	Gasoline, Diesel, Avtur, LPG
7	Cepu - Pertamina	3.80	1894	2000s (rebuilt)	Solvent, Diesel
8	Kasim – Pertamina unit VII	10	1997	n/a	Gasoline, Diesel, Kerosene
9	Tuban-TPPI Ltd	100	1995	n/a	Under construction to merge with the national project
Total		**1,169.10**			

The reduced capacity results from the TWU not being in operation since January 2018 due to financial constraints caused by the rise of crude oil prices (Brent).[101] As for TPPI refinery, which is a private petrochemical company that merged with government-owned Pertamina in 2019, it is still under construction to be revamped and integrated with

100 Adapted from "Handbook of Energy and Economic Statistics of Indonesia 2019," Ministry of Energy and Mineral Resources (MEMR), 2020, 68, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf.

101 Martha Warta Silaban, "Sandiaga Prihatin Kilang Minyak Di Bojonegoro Ditutup, Apa Sebab?," Tempo, February 15, 2019, https://bisnis.tempo.co/read/1176040/sandiaga-prihatin-kilang-minyak-di-bojonegoro-ditutup-apa-sebab.

Pertamina's new grassroots refinery project and is projected to be completed in 2026.[102] For 2020, however, the MEMR reported that Indonesia's oil refinery capacity was at 1,151.10 MBSD, excluding the TWU Ltd.[103] By contrast, in 2021, British Petroleum (BP) has reported that Indonesia's refinery capacity is at 1,127 MBSD with throughput at around 826–918 MBSD.[104]

Furthermore, Indonesia's operational refineries have been overshadowed by a number of accidents. As early as 2007, the Balongan refinery and other large refineries have been prone to fires, with the most recent case on November 13, 2021.[105] There have been around 13 notable cases of accidents involving fire at oil refineries across Indonesia since 2008 (see Table 4).[106] These accidents have disrupted Indonesia's domestic energy security, forcing the government to import refined fuel from other countries. Eventually, Arifin Tasrif, the Minister of MEMR, underscored some factors that need to be evaluated, such as the safety protocols, especially with regard to the fire hazard, the refineries' standard operating procedures, and lastly, the updating or upgrading of the aging refinery equipment.[107]

[102] Wilda Asmarini, "Proyek Rp 2,6 T Kilang TPPI Ditargetkan Tuntas Q1 2022," CNBC Indonesia, Spetember 24, 2020, https://www.cnbcindonesia.com/news/20200924160636-4-189227/proyek-rp-26-t-kilang-tppi-ditargetkan-tuntas-q1-2022.

[103] Ministry of Energy and Mineral Resources (MEMR), "Handbook of Energy and Economy Statistics of Indonesia 2020," 2021, 68, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2020.pdf.

[104] BP, "Statistical Review of World Energy – All Data, 1965–2020," July 2021, https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html.

[105] Liputan6, "Kilang Minyak Pertamina Balongan Sudah 3 Kali Terbakar, Simak Rentetannya," March 29, 2021, https://www.liputan6.com/bisnis/read/4518017/kilang-minyak-pertamina-balongan-sudah-3-kali-terbakar-simak-rentetannya.

[106] Ayomi Amindoni, "Insiden kebakaran berulang di fasilitas migas, Pertamina didesak benahi 'sistem pengamanan yang tidak andal,'" BBC News Indonesia, March 31, 2021, https://www.bbc.com/indonesia/indonesia-56579399.

[107] Ministry of Energy and Mineral Resources (MEMR), "Investigasi Kebakaran Di Kilang Balongan, Lembaga Internasional Dilibatkan," April 3, 2021, https://migas.esdm.go.id/post/read/investigasi-kebakaran-di-kilang-balongan-pemerintah-libatkan-lembaga-internasional.

Table 4. Indonesia's oil refineries' accidents.

No	Date	Refinery Unit	Casualty and Estimated Loss
1	March 9, 2008	Cilacap	3 deaths, ≥ $1 Million[108]
2	October 28, 2008	Balongan	6 injured, 1 residual catalytic tank[109]
3	June 3, 2009	Cilacap	2 pipes crude distillation unit[110]
4	July 19, 2009	Balongan	1 residual catalytic cracking tank[111]
5	April 2, 2011	Cilacap	$30 Million[112]
6	February 16, 2014	Dumai	Pipes and heater, ≥ $1 Million [113]
7	October 5, 2016	Cilacap	1 asphalt tank[114]
8	January 4, 2019	Balongan	Boiler line[115]
9	August 15, 2019	Balikpapan	A section pipe lines[116]
10	April 9, 2020	Cepu	Central processing plant facility[117]
11	June 19, 2020	Balikpapan	Hydrocracker unit[118]
12	March 29, 2021	Balongan	2 deaths, 20 injured, 4 fuel tanks, $78 Million[119]
13	November 13, 2021	Cilacap	1 gasoline tank (3,000 barrels capacity)[120]

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[108] Detik, "Kebakaran Kilang Minyak Cilacap Bukan yang Pertama," April 2, 2011, https://news.detik.com/berita/d-1607012/kebakaran-kilang-minyak-cilacap-bukan-yang-pertama;Pertamina.

[109] Okezone, "Kilang Balongan Meledak," https://news.okezone.com/, October 29, 2008, https://news.okezone.com/read/2008/10/29/1/158522/kilang-balongan-meledak-6-pekerja-terluka.

[110] Kompas Cyber Media, "Terbakar, Kilang Cilacap Berhenti Operasi," June 3, 2009, https://properti.kompas.com/read/2009/06/03/16054398/terbakar.kilang.cilacap.berhenti.operasi.

[111] "Satu Tangki Di Kilang Balongan Terbakar," Tempo, July 19, 2009, https://nasional.tempo.co/read/187989/satu-tangki-di-kilang-balongan-terbakar.

[112] Viva, "Kerugian Kebakaran Kilang Cilacap Rp270 M," May 23, 2011, https://www.viva.co.id/arsip/222157-kerugian-kebakaran-kilang-cilacap-rp270-m.

[113] Liputan6, "Kebakaran Kilang Minyak Pertamina Dumai," February 17, 2014, https://www.liputan6.com/news/read/828933/kebakaran-kilang-minyak-pertamina-dumai.

[114] Vindy Florentin, "Pertamina Selidiki Kebakaran Di Kilang Cilacap," Tempo, October 5, 2016, https://bisnis.tempo.co/read/809908/pertamina-selidiki-kebakaran-di-kilang-cilacap.

[115] Arie Dwi Budiawati, "Pertamina Balongan Kebakaran, Tak Ada Korban Jiwa," Dream, February 4, 2019, https://www.dream.co.id/dinar/pertamina-sebut-kebakaran-kilang-balongan-sudah-padam.html.

[116] BBC, "Kebakaran di kilang Pertamina Balikpapan," August 15, 2019, https://www.bbc.com/indonesia/indonesia-49355608.

[117] Anisatul Umah, "Sempat Terbakar, Kilang Gas Pertamina Cepu Setop Operasi," CNBC Indonesia, accessed July 7, 2021, https://www.cnbcindonesia.com/news/20200409123402-4-150872/sempat-terbakar-kilang-gas-pertamina-cepu-setop-operasi.

[118] Bisnis, "Kilang Balikpapan Alami Kebakaran," June 19, 2020, https://ekonomi.bisnis.com/read/20200619/44/1255236/kilang-balikpapan-alami-kebakaran.

[119] Agung Filemon and Wahyu T. Rahmawati, "Ini Potensi Kerugian Kebakaran Kilang Balongan," Kontan, March 31, 2021, https://industri.kontan.co.id/news/ini-potensi-kerugian-kebakaran-kilang-balongan.

[120] Detik, "Detik-detik Kebakaran Tangki Kilang Pertamina Cilacap," November 14, 2021, https://news.detik.com/berita/d-5810523/detik-detik-kebakaran-tangki-kilang-pertamina-cilacap.

On the other hand, Indonesia's oil consumption has increased significantly each year alongside the 1.1% increase in its population per annum, reaching 270 million people in 2019, thus putting it fourth among the world's largest populations.[121] The largest consumers of oil in Indonesia are the industry and transportation sectors, each accounting for at least 30% of Indonesia's total energy consumption from 2009 to 2019.[122] The burden on an imbalance in oil supply and demand has led to a trade deficit. Since 2004, the net energy importation resulted in a substantial oil trade deficit, reaching 3.3% of the GDP in 2014.[123] Despite the reduction in oil export, the trend continued and was confirmed in January 2021 when the deficit increased slightly from $0.46 billion in December 2020 to $0.67 billion because of the lower rates in oil and gas exports and higher number of oil and gas imports.[124]

The heavy demand for oil from the large population may also be exacerbated by the government policy on fossil fuel subsidy reform. The government has been extending the fuel subsidy to help low-income households with energy consumption since the early 2000s during the Asian financial crisis.[125] According to IEA, Indonesia allocated approximately $22.7 billion in 2017 and gradually reduced that amount to $19.2 billion in 2019.[126] The agency estimates that the target to help low-income households may have only been achieved in 5% of these cases; conversely, as many as 70% of wealthy

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[121] World Bank, "Population, Total - Indonesia," 2021, https://data.worldbank.org/indicator/SP.POP.TOTL?locations=ID&most_recent_value_desc=true.

[122] "Handbook of Energy and Economic Statistics of Indonesia 2019," Ministry of Energy and Mineral Resources (MEMR), 2020, 23, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf.

[123] G20 2019 Peer-Review Team, "Indonesia's Effort to Phase Out and Rationalise Its Fossil-Fuel Subsidies," 12, https://www.oecd.org/fossil-fuels/publication/G20_peer_review_Indonesia_Final-v2.pdf

[124] BI, "No. 23/40/DKom, Trade Surplus Maintained in January 2021," February 15, 2021, https://www.bi.go.id/en/publikasi/ruang-media/news-release/Pages/sp_234021.aspx.

[125] IEA, "Oil and Electricity Consumption Subsidies, 2013–2019," accessed June 1, 2021, https://www.iea.org/data-and-statistics/charts/oil-and-electricity-consumption-subsidies-2013-2019.

[126] IEA.

households may have benefited from consuming subsidized fuels.[127] MEMR supported this claim by stating that "the outcome was inevitable, due to the characteristic of the fuel subsidy itself, which is a blanket subsidy that reduces the price paid at the pump by all customers, rich or poor."[128] Moreover, according to the ministry of finance, due to the poorly targeted beneficiaries, the rich households now can have cheaper fuel.[129] Therefore, it can be inferred that the fuel subsidies policy has been a problematic political option originally intended to offer affordable fuel to poor people. Pushing down the fuel price at the pump, which is available to all people, may earn politicians favorable support from the people and may foster energy equity, but it discourages energy security.

Currently, the Indonesian government has gradually reduced its fuel subsidies. As of now, it only supports up to 15.8 million kiloliters of diesel fuel, 7.8 metric tons of 3 kilogram bottles of liquified petroleum gas (LPG) for the poor households, and 0.5 million kiloliters of kerosene.[130] Although the subsidies for energy in 2021 have increased around 6.3% of GDP as compared to 5.6% in 2020, the overall growth has been decreasing from -4.8% to -8.7% (see Figure 5).[131] The reason for the cut is to boost infrastructure projects and public facilities; however, due to the volatility of oil prices, which affected the fiscal burden, the government was forced to reform the fuel subsidies that resulted in an increase in prices at the pump.[132] The government would likely continue the fuel subsidies that burden the GDP balance while possibly implementing some gradual reductions due to the combination of pressures related to social-political support and the alarming depletion of Indonesia's oil reserves.

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127 Kathryn Chelminski, "Fossil Fuel Subsidy Reform in Indonesia: The Struggle for Successful Reform," in *The Politics of Fossil Fuel Subsidies and Their Reform*, ed. Harro van Asselt and Jakob Skovgaard (Cambridge, UK: Cambridge University Press, 2018), 194, https://doi.org/10.1017/9781108241946.013.

128 Ministry of Finance, "Indonesia G20 Self-Report IFFS," 2019, 13, https://www.oecd.org/fossil-fuels/publication/Indonesia_G20_Self-Report_IFFS.pdf.

129 Ministry of Finance, 13.

130 Ministry of Finance, "APBN Indonesia 2021," 2021, 31, https://www.kemenkeu.go.id/media/16835/informasi-apbn-2021.pdf.

131 Ministry of Finance, 7.

132 Chelminski, "Fossil Fuel Subsidy Reform in Indonesia," 202.

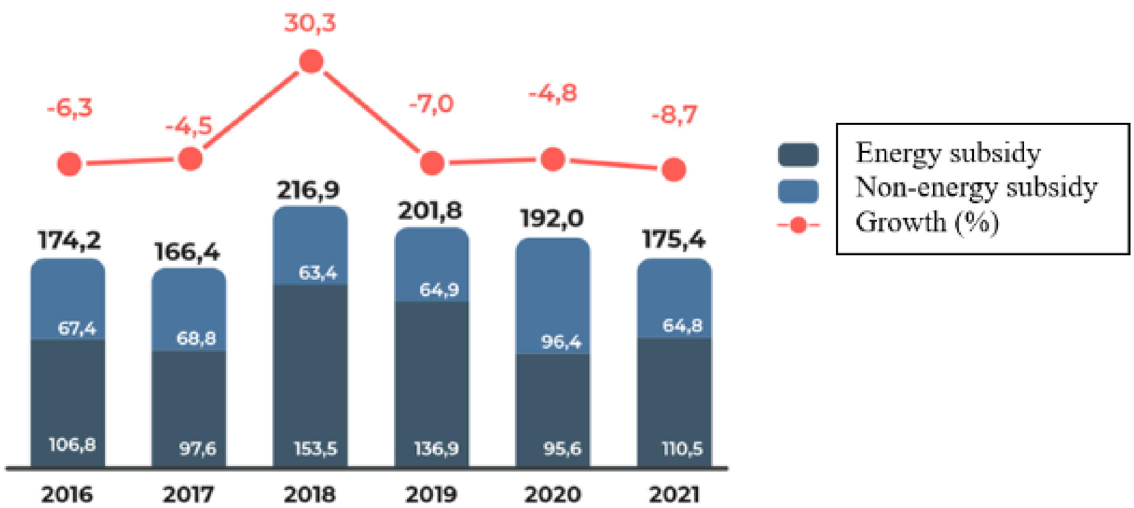

Figure 5. Indonesia's subsidies allocation 2013–2019 (in trillion IDR).[133]

B. RENEWABLE ENERGY SOURCES

Indonesia's special geographical factors provide the country with a wide array of natural resources and the potential to leverage renewable energy. Renewable energies consist of hydropower, solar energy, geothermal, marine energy, wind energy, and bioenergy (biofuel).[134] This section defines renewable energy related to Indonesia's military energy security as biofuel, a fuel produced from plants or biomass, divided into two categories. The first one is the blended fuels of biofuel and petroleum (biodiesel, bioavtur, biogasoline), which have similar physical properties to petroleum fuels.[135] *Green fuels* or drop-in fuels are pure biofuels with similar chemical properties to petroleum fuels.[136] These biofuels could supply military energy as an alternative fuel in times of scarcity or availability and as cheaper fuel, which Indonesia's defense budget can better afford. As stated earlier, Indonesia's military needs sustainable energy that comes from an

[133] Source: Ministry of Finance, "APBN Indonesia 2021," 31.

[134] IRENA, "IRENA Overview of Renewable Energy," 5, https://www.irena.org/-/media/Files/IRENA/Agency/Data-Statistics/2-Overview-of-renewable-energy.pdf.

[135] EIA, "Biofuels Explained," August 2020, https://www.eia.gov/energyexplained/biofuels/.

[136] Advanced BioFuels USA, "What's the Difference between Biodiesel and Renewable (Green) Diesel?," March 2011, https://advancedbiofuelsusa.info/whats-the-difference-between-biodiesel-and-renewable-green-diesel/.

undisturbed fuel supply to meet its operational demands, which means that Indonesia's fossil fuel resources may be depleted soon. Therefore, this section investigates the potential of Indonesia's biofuel to supply the military.

According to MEMR, Indonesia has produced a significant amount of biofuel from palm oil (see Table 5).[137] As reported in 2020, since 2010, Indonesia's palm-based biofuel consumption share reached 21%, catching up with petroleum fuel at 26% (see Table 6).[138] The biofuel production has doubled, peaking at 225% in 2016 at 8,399 thousand kiloliters.[139] The military and MoD have not disclosed the data regarding the consumption of biofuels; however, due to their policy to follow the government's biofuel use mandate, it is expected that the military will accept the lowest-cost government-provided fuel since the budget for fuel is limited. MEMR stated that the military normally uses gasoil (red-dyed diesel fuel) CN 48 (cetane number 48), or High-Speed Diesel (HSD/CN 45), which is the lowest grade and price of petroleum-based diesel fuel.[140]

MEMR established Indonesia's biofuel products nomenclature in 2020.[141] As mentioned earlier, Indonesia's blended fuel consists of biodiesel and bioethanol. The biodiesel is made of Fatty Acid Methyl Ester (FAME), produced from esterification/ transesterification. Biodiesel is a blend of pure palm-based biodiesel in the form of B100 with gasoil, which is coded as BXX (B10, B20, etc.).[142] This biodiesel has a higher cetane number (>49.3), which gives better combustion performance than conventional petroleum

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[137] MEMR, "Handbook of Energy and Economic Statistics of Indonesia 2019," Ministry of Energy and Mineral Resources (MEMR), 2020, 105, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2019.pdf

[138] MEMR, 16–17.

[139] MEMR, 105.

[140] MEMR, 70.

[141] EBTKE, "Tingkatkan Penggunaan Energi Bersih, Pemerintah Dorong Pengembangan Green Diesel," July 20, 2020, https://ebtke.esdm.go.id/post/2020/07/21/2589/ tingkatkan.penggunaan.energi.bersih.pemerintah.dorong.pengembangan.green.diesellangen.

[142] EBTKE.

fuel.[143] Bioethanol, which is produced by fermentation from molasses (a byproduct of sugar cane), is coded as E with the same numbering mixture as biodiesel.[144]

Table 5. Indonesia's production of palm-based biofuel (pure biodiesel/ B100).[145]

Year	Production (Thousand KL)	Export (Thousand KL)	Domestic (Thousand KL)
2010	243	20	223
2011	1,812	1,453	359
2012	2,221	1,552	669
2013	2,805	1,757	1,048
2014	3,961	1,629	1,845
2015	1,620	328	915
2016	3,656	477	3,008
2017	3,416	187	2,572
2018	6,168	1,803	3,750
2019	8,399	1,319	6,396
2020	8,594	36	8,400

143 Iman K. Reksowardojo et al., "An Investigation of Laboratory and Road Test of Common Rail Injection Vehicles Fueled with B20 Biodiesel," *Energies* 13, no. 22 (November 22, 2020): 3, https://doi.org/10.3390/en13226118.

144 EBTKE, "Tingkatkan Penggunaan Energi Bersih, Pemerintah Dorong Pengembangan Green Diesel," July 20, 2020, https://ebtke.esdm.go.id/post/2020/07/21/2589/ tingkatkan.penggunaan.energi.bersih.pemerintah.dorong.pengembangan.green.diesellangen.

145 Source: Ministry of Energy and Mineral Resources (MEMR), "Handbook of Energy and Economy Statistics of Indonesia 2020," 2021, 105, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2020.pdf.

Table 6. Share of final energy consumption by type (%).[146]

(%)

Year	Coal	Natural Gas	Fuel	Biofuel	Biogas	LPG	Electricity
2010	20.55	13.00	43.94	4.17	n.a	4.79	13.55
2011	19.17	12.49	44.37	6.07	n.a	4.91	12.99
2012	15.05	11.91	47.53	7.24	n.a	5.24	13.03
2013	5.72	13.15	50.46	8.95	n.a	6.38	15.34
2014	7.23	12.77	47.68	9.55	n.a	6.81	15.96
2015	9.25	12.55	42.56	12.09	0.02	7.16	16.37
2016	8.62	10.49	44.59	10.67	0.02	7.67	17.94
2017	7.64	11.54	42.96	12.17	0.02	7.95	17.73
2018	11.57	11.00	36.92	15.00	0.02	7.42	18.07
2019	17.67	9.99	28.12	20.25	0.02	6.99	16.95
2020	13.44	11.53	26.36	21.21	0.02	8.24	19.19

Table 3 shows the publicly published data of Indonesia's oil refineries. Pertamina designated three refineries to develop and produce biofuels. The palm-based biodiesel (BXX) production has been carried out by two refineries, Musi and Cilacap, whereas *green diesel* (DXX) has been under development by the Dumai refinery.[147] As for *green avtur* (JXX), it is still under research and development by the Center for Research and Development of Oil and Gas Technology, or *Pusat Penelitian dan Pengembangan Teknologi Minyak dan Gas Bumi* (LEMIGAS), and Bandung Institute of Technology, or

[146] Source: Ministry of Energy and Mineral Resources (MEMR), "Handbook of Energy and Economy Statistics of Indonesia 2020" 2021, 27, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2020.pdf.

[147] EBTKE, "Tingkatkan Penggunaan Energi Bersih, Pemerintah Dorong Pengembangan Green Diesel," EBTKE, July 20, 2020, https://ebtke.esdm.go.id/post/2020/07/21/2589/ tingkatkan.penggunaan.energi.bersih.pemerintah.dorong.pengembangan.green.diesellangen.

Institut Teknologi Bandung (ITB).[148] Biodiesel needs methanol, and bioethanol needs yeast in the production, both of which are cheap and abundant products. As for *green fuel*, it needs a particular catalyst, which Indonesia has imported and is expensive. The refineries for *green fuels* use the catalytic reactor in its process, with the help of petrochemical plants, to provide the catalyst necessary for biofuel production.

Green fuel is a pure alternative fuel produced by the hydrotreating process with the help of a catalyst, as just mentioned. The first type of *green fuel* is *green diesel*/D100, a hydrocarbon fuel with no oxygen content for a high-speed diesel engine and derived from biofuels through various specific process technologies. Next, *green gasoline*/G100 is a fuel oil intended for gasoline engines; it is composed of straight-chain hydrocarbons, ranging from C5 to C11, with an octane number or Research Octane Number (RON) of at least 90.[149] Lastly, bioavtur/biojet/jet-biofuel/J100, an alternative fuel for turbine-engine aircraft, is made with raw materials from renewable sources through various specific process technologies. Currently, Indonesia has successfully developed and utilized biodiesel (BXX).[150]

Indonesia has an excellent start to *green fuel* production due to the successful indigenous catalyst capable of processing crude palm oil (CPO) made by the ITB supported by Pertamina and the government. The catalyst is called *Merah-Putih* (red-white), symbolic of the Indonesian national flag (see Figure 6). The catalyst itself was researched and pioneered in 2004 by Subagjo, Makertihartha, and Melia Laniwati.[151] Indonesia's catalyst has many advantages. The MEMR Minister Arifin stated that Indonesia spent $500 million importing catalysts for its refineries' operation in 2007 and up to $595.5 million in 2020; therefore, creating the indigenous catalyst greatly helps the effort and reduces

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[148] Ministry of Energy and Mineral Resources (MEMR), "Kunjungan Lapangan Pengujian Statis (Test Cell) Bioavtur Untuk Pesawat Terbang," May 29, 2021, https://litbang.esdm.go.id/news-center/arsip-berita/kunjungan-lapangan-pengujian-statis-test-cell-bioavtur-untuk-pesawat-terbang.

[149] EBTKE, "Tingkatkan Penggunaan Energi Bersih, Pemerintah Dorong Pengembangan Green Diesel."

[150] EBTKE.

[151] Astra Agro Lestari, "Formula Katalis 'Merah Putih,'" *Astra Agro Lestari* (blog), May 2019, https://www.astra-agro.co.id/2019/05/20/formula-katalis-merah-putih/.

Indonesia's reliance on imports.[152] Moreover, the *Merah-Putih* catalyst improves the cetane number, lowers emissions, and boosts mileage.[153] In July 2020, the government promoted a joint venture involving ITB, Pertamina, and several petrochemical companies to secure and support the *Merah-Putih* catalyst and its implementation in oil refineries (see Figure 6).[154] From 2011 to 2019, no less than 140 tons of these hydrotreating catalysts were produced and used in eight reactors at five Pertamina refineries.[155]

Figure 6. The Merah-Putih Catalyst.[156]

According to Subagjo, the *Merah-Putih* catalyst material comes from mineral rocks based on sulfide from nickel, cobalt, and molybdenum with an alumina buffer.[157] The catalyst helps produce green diesel from DHDT (distillate hydrotreating) Unit 220 at Pertamina Refinery Unit (RU) II Dumai refinery. Nandang Kurnaedi, General Manager of RU II Dumai, said that "In the unit coprocessing was done, namely mixing RBDPO and

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152 Astra Agro Lestari.

153 APROBI, *2020 Buletin Bioenergy* (Jakarta, Indonesia: 2020), 9, https://www.aprobi.or.id/wp-content/uploads/Bulletin-202008.pdf.

154 ITB, "Perdana, Factory 'Katalis Merah Putih' Starts to Be Built End of the Year – (Indonesian) Program Studi Teknik Kimia," July 2020, https://www.che.itb.ac.id/en/2020/07/29/perdana-pabrik-katalis-merah-putih-mulai-dibangun-akhir-tahun/.

155 "Tim Katalis Merah-Putih ITB Mendapatkan Apresiasi Langsung Dari Presiden RI Joko Widodo - ," ITB, February 4, 2020, https://www.itb.ac.id/berita/detail/57407/tim-katalis-merah-putih-itb-mendapatkan-apresiasi-langsung-dari-presiden-ri-joko-widodo.

156 Source: CNN Indonesia, "Pabrik Katalis Ditargetkan Beroperasi Mulai 2020," May 1, 2019, https://www.cnnindonesia.com/ekonomi/20190430164019-92-390909/pabrik-katalis-ditargetkan-beroperasi-mulai-2020.

157 Astra Agro Lestari, "Formula Katalis 'Merah Putih.'"

LCGO (composition 20:80) to produce *green diesel oil*."[158] RBDPO (refined, bleached, deodorized palm oil) is refined palm oil (CPO) refined to whiten or brighten the color and eliminate odors.[159] LCGO (light coker gas oil) is a gas oil produced from the processing of residual oil.[160] This gas oil can be further processed into light oil products like gasoline, avtur, and diesel.[161] This oil mixture undergoes a hydrotreating reaction in DHDT reactors to reduce the sulfur, oxygen, and other impurities until it becomes a high purity *green diesel*.[162] The oxygen content of *green diesel* is 0%, sulfur content is below two parts per million (ppm), and the color is clearer than ordinary diesel, and its cetane number is between 75 and 90.[163] In comparison, the ordinary diesel oxygen content is 11%, and the cetane number is 40–65, indicating that *green diesel* has better oxidation stability than petroleum-based diesel and biodiesel.[164] Over time, Indonesia has acquired many instruments to create biodiesel and *green diesel*. ITB researched the catalyst as early as 1983, which Subagjo and his colleagues carried out.[165] Nevertheless, the government has only recently recognized the importance of this indigenous capability for the national refineries and eventually put this matter into the spotlight just in 2020 by signing the joint venture.

C. INDONESIA'S MILITARY ENERGY SECURITY

As mentioned earlier, the author defines military energy security as the assurance that military energy logistic capacity can rely on a sustainable energy supply to support the military's multi-mission and be guaranteed sufficient energy to meet future challenges. This section examines Indonesia's military energy security condition and its connection to

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158 Astra Agro Lestari.

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the state's energy agencies. Therefore, the problems within their interlinked energy supply can be highlighted.

Indonesia's military relies on the defense budget to obtain its fuel, which it purchases solely from Pertamina's state-owned petroleum company. Although the defense budget has shown a significant increase in the last several years, it has also shown a gradual reduction in terms of percentage of the GDP (see Figure 7).[166] Nevertheless, the increased defense budget is not enough to cover the cost of the military's fuel needs. For example, in 2020, the defense budget was IDR 127,357.6 billion, of which IDR 5,597.6 billion or 4.4 % of the budget was used to purchase fuel.[167] Then in 2021, the defense budget reached IDR 136,995.9 billion, with IDR 6,112.7 billion for fuel supply (4.5% from the defense budget).[168] Therefore, from the budget allocation just described, it is evident that the military only allots a small amount of its budget for energy, which is around 4–5 %.

The current oil depletion rate and trade deficit referred to in section B have worsened, with the indications of fuel debt in the Indonesian military (TNI). As early as 2008, the Corporate Secretary of Pertamina (the Indonesian oil mining company) Sudirman Said stated that the military's fuel debt had reached IDR 4 trillion, and it has been sustained each subsequent year because the military's budget could not cover its fuel demand.[169] The condition forced the government to reduce some portion of the debt, which had reached $432 million or around IDR 6 trillion in December 2019 (see Figure 8).[170] From these reports, the military has been one of the biggest debtors in terms of fuel and electricity. The debt accounted for almost half of Pertamina's credit income from government-related

166 Macrotrends, "Indonesia Military Spending/Defense Budget 1974–2021," 2021, https://www.macrotrends.net/countries/IDN/indonesia/military-spending-defense-budget.

167 Ministry of Finance, "2020 RKAKL," Ministry of Finance, 2020, 13, https://www.academia.edu/40097162/Himpunan_RKA_K_L_Tahun_Anggaran_2020_Buku_III.

168 Ministry of Finance, "2021 RKAKL," 2021, 39, https://www.kemenkeu.go.id/media/15867/buku-iii-himpunan-rka-kl-ta-2021.pdf.

169 Detik, "Garuda dan TNI Utang BBM Rp 4,9 Triliun," August 31, 2008, https://finance.detik.com/berita-ekonomi-bisnis/d-997629/garuda-dan-tni-utang-bbm-rp-49-triliun.

170 Pertamina, "2019 Pertamina Annual Report," 2019, 328, https://www.pertamina.com///Media/File/Pertamina_AR_2019_Final_Indo_Hires.pdf.

entities in 2013 and 2016, whereas in 2020–2021, it reached around 20%.[171] Therefore, the military's energy security problem also affects the state's economic enterprises and cash flow performance, affecting Indonesia's state income.

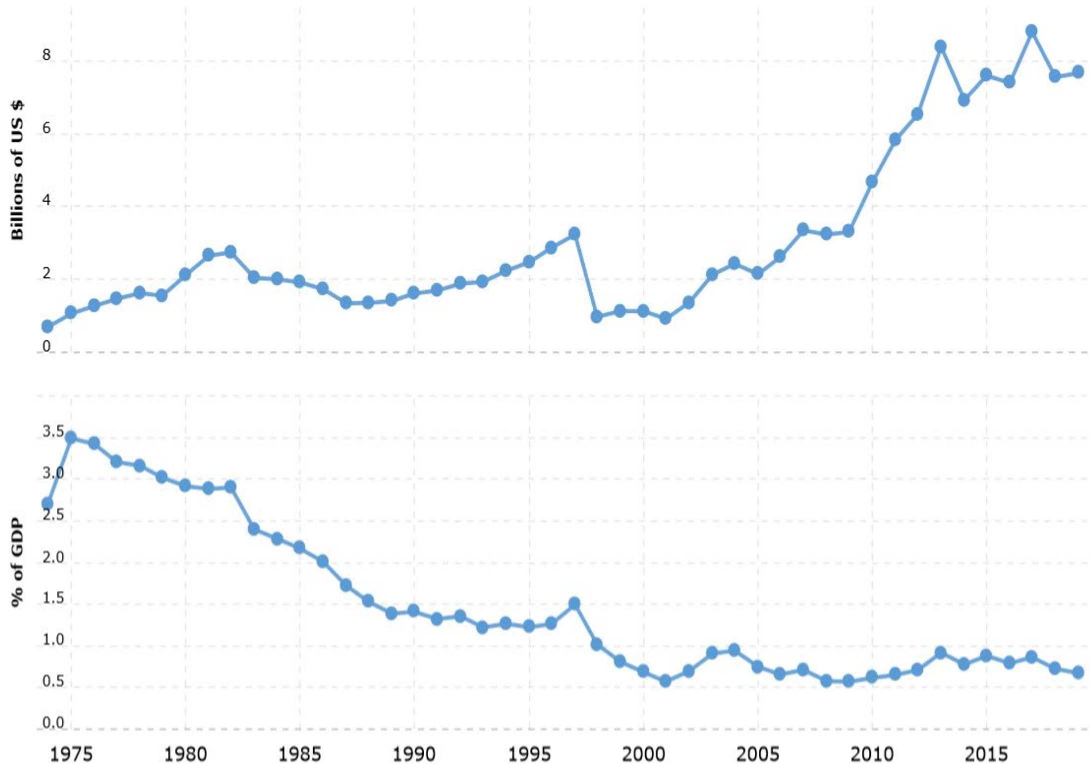

Figure 7. Indonesia's defense budget 1975–2019.[172]

[171] Pertamina, "Laporan Tahunan," 2021, https://www.pertamina.com/id/dokumen/laporan-tahunan.

[172] Source: Macrotrends, Macrotrends, "Indonesia Military Spending/Defense Budget 1974–2021," 2021, https://www.macrotrends.net/countries/IDN/indonesia/military-spending-defense-budget.

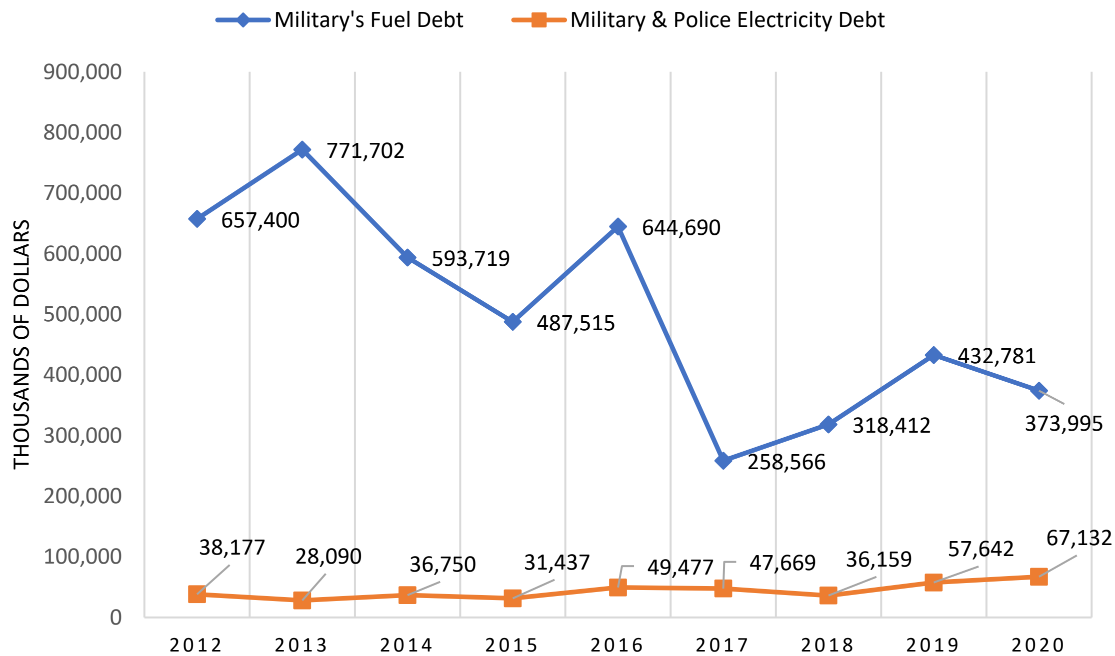

Figure 8. Fuel debt to Pertamina and electricity debt to PLN by the military and police.[173]

Moreover, during a hearing with the House of Representatives (DPR) in 2014, the Head of Downstream Oil and Gas (BPH Migas), Andy Noorsaman Sommeng asserted that Indonesia's strategic fuel reserves could only last for 21 to 23 days.[174] Yet, Indonesia, as one of the associated members of IEA, was obliged to hold oil stocks for at least 90 days.[175] Another problem indicated by the Audit Board of The Republic of Indonesia (BPK) was that since 2017–2019 the military had not been conducted fuel management as referred to in the regulations.[176] The publicized problem of military fuel-related debt and mismanagement may be perceived as arising from the lack of budget to cover the

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[173] Adapted from Pertamina, "Laporan Tahunan," accessed May 30, 2021, www.pertamina.com; PLN, "Annual Report PT PLN Persero," 2021, http://web.pln.co.id/hubungan-investor/laporan-keuangan.

[174] BPH Migas, "National Fuel Buffer Ideally 90 Days, Indonesia Still Not Have," *BPH* (blog), February 25, 2014, https://www.bphmigas.go.id/en/news/national-fuel-buffer-ideally-90-days-indonesia-still-not-have/.

[175] IEA, "Data Overview," 2021, https://www.iea.org/data-and-statistics.

[176] BPK, "BPK Serahkan LHP Atas Laporan Keuangan Tahun 2019 Dan 3 LHP PDTT Pada Kementerian Pertahanan," July 30, 2020, https://www.bpk.go.id/news/bpk-serahkan-lhp-atas-laporan-keuangan-tahun-2019-dan-3-lhp-pdtt-pada-kementerian-pertahanan.

operational demand. As stated in 2014 by Chief of Staff of the Navy Admiral Marsetio, the ideal fuel needs for navy patrol boats had reached 5.6 million kiloliters per year.[177] Even now, conditions are far from ideal, as the budget for fuel only covered 13% of the total needed.[178] Therefore, only 7–15 ships can be fueled for operation per day, whereas there are 60–70 ships in the full combat-ready position.[179]

Indonesia's military fuel consumption from 2014 to 2018 was estimated to have increased significantly related to its progress on completing the Minimum Essential Force (MEF) (see Figure 9). Thus, it is projected that the military will further increase its fuel demand in the next decade, especially when the MoD has confirmed purchasing new fighter jets and new frigates in 2021.[180] Indonesia's defense budget seems robust enough to procure new equipment. However, compared to increasing military fuel debts and the small allocation to purchase that fuel, it can be inferred that the debt has grown due to inadequate budget allocation to cover fuel costs for the military. In 2017, the Director-General of Budget of the Ministry of Finance, Askolani, revealed that the government would repay the military fuel debts by allocating them into the state budgetary plan.[181] Therefore, Pertamina indeed may encounter financial setbacks due to military fuel debt, which in turn may hinder Pertamina's performance and investment to increase oil production, especially since exploration and exploitation of new oil wells are long-term projects (30 years), and the revenue will always be at the end of the line. Eventually, it can be inferred that Indonesia's military budget could be sufficient to purchase all the fuel needed; however to achieve that, the military will not be able to catch up with the MEF completion if funds are redirected from such efforts in order to increase the budget for fuel from the current 4.5%.

[177] Hendra Gunawan, "Tak punya BBM, TNI utang Rp 6 triliun ke Pertamina," Kontan, November 17, 2014, https://nasional.kontan.co.id/news/tak-punya-bbm-tni-utang-rp-6-triliun-ke-pertamina.

[178] Gunawan.

[179] Gunawan.

[180] Andrew McLaughlin, "Indonesia to Order FREMM Frigates and Rafale Fighters," *ADBR* (blog), June 21, 2021, https://adbr.com.au/indonesia-to-order-fremm-frigates-and-rafale-fighters/.

[181] Liputan6, "Pemerintah Lunasi Utang BBM TNI Ke Pertamina Tahun Ini," July 6, 2017, https://www.liputan6.com/bisnis/read/3013847/pemerintah-lunasi-utang-bbm-tni-ke-pertamina-tahun-ini.

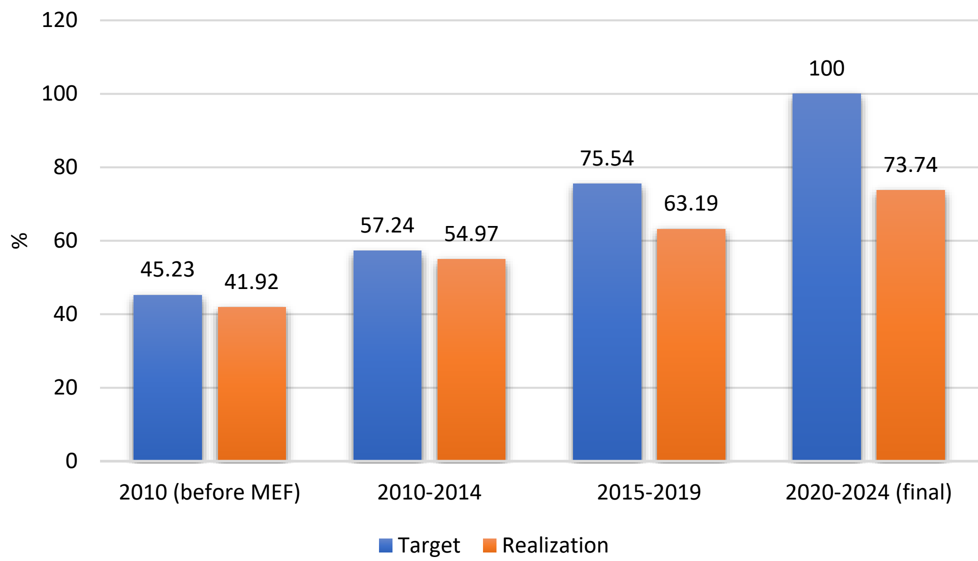

Figure 9. Indonesia's military Minimum Essential Force progress.[182]

Indonesia's military petroleum fuel consumption as it relates to the military's operational readiness is mainly from the avtur/jet fuel (aviation turbine fuel/ATF) and diesel, whereas gasoline is only used by commuters. Both avtur and diesel for the military can be replaced by biofuels; however, while Indonesia currently manages to provide biodiesel (BXX) as an alternate fuel for diesel, *green avtur* (J100) is still under development. It should be noted, though, the military has not disclosed any of its data regarding its specific fuel consumption.

In 2013, Pertamina, as the sole supplier for Indonesia's military, had signed an MoU with MoD regarding the affirmation of support to provide fuel for the military, whose need is expected to increase annually along with the new military equipment that will be bought to meet the MEF.[183] According to Pertamina, they will provide fuel supply in a quantum of no less than 425 million liters per year and projecting for a 5% growth rate for

[182] Adapted from Ervita L Zahara and Arjun Rizky M.N., "Anggaran Pertahanan Indonesia," Pusat Kajian Anggaran Badan Keahlian DPR RI, April 2020, 4, https://berkas.dpr.go.id/puskajianggaran/analisis-ringkas-cepat/public-file/analisis-ringkas-cepat-public-28.pdf.

[183] Ahmad Baiquni, "Alutsista Baru Buat Konsumsi BBM TNI Membengkak," Merdeka.com, December 18, 2013, https://www.merdeka.com/uang/alutsista-baru-buat-konsumsi-bbm-tni-membengkak.html.

Indonesia's military and police needs; therefore, when compared to the national fuel consumption and production rates, Indonesia's military consumes only a fraction (0.7–1%) of the national fuel consumption (see Figure 10).[184] Not only does the military account for only a small fraction of Indonesia's total fuel consumption, it has similarly received little benefit from the fuel subsidy. In 2013, the Minister of MoD, Purnomo Yusgiantoro, criticized the fuel subsidy noting that the military received the fuel subsidy only in one specific budget; consequently, the military's operational capability has been reduced to at least 40%.[185] He suggested that the military needs to have the fuel subsidy in terms of fuel quantum since the military's fuel expenses account for only 1.2% of the state budget used for the national fuel subsidy.[186]

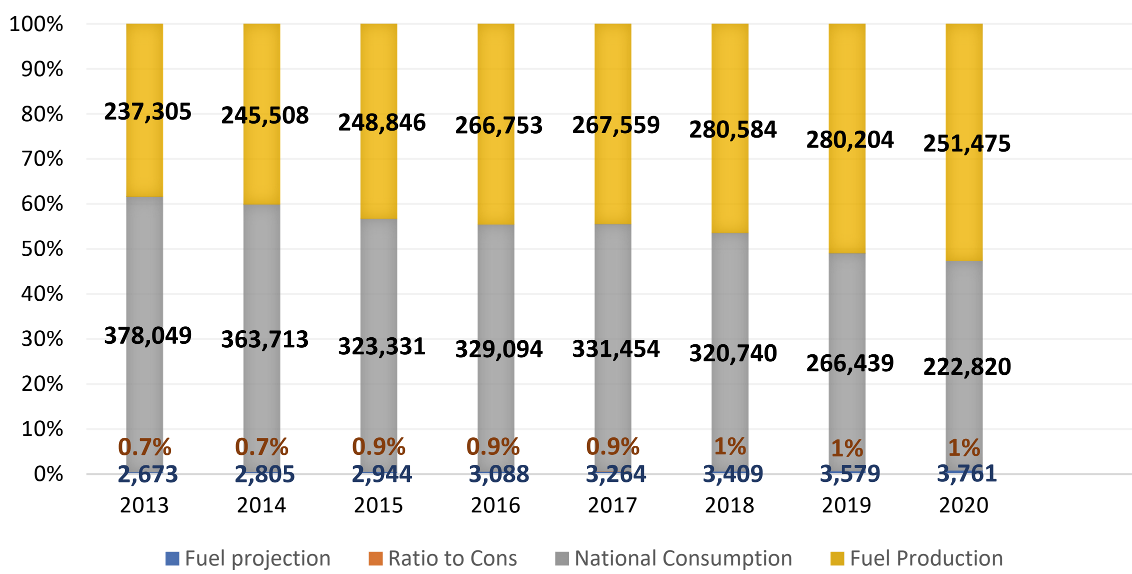

Figure 10. Projected fuel demands of the military (in thousand barrels).[187]

[184] Baiquni.

[185] Baiquni, "Alutsista Baru Buat Konsumsi BBM TNI Membengkak."

[186] Baiquni.

[187] Adapted from Ministry of Energy and Mineral Resources (MEMR), "Handbook of Energy and Economy Statistics of Indonesia 2020," 2021, https://www.esdm.go.id/assets/media/content/content-handbook-of-energy-and-economic-statistics-of-indonesia-2020.pdf.

In order to see whether the indigenous palm-based biofuel could help address Indonesia's military energy requirements, one can examine the recent and projected prices for the indigenous biodiesel compared with petroleum fuel. Military fuels are not subsidized according to Presidential Regulation No.191/2014; therefore, the military purchases fuels at the same price as everyone else at the pump.[188] Moreover, the military is also given a "relaxation" or flexibility to not use biofuels for its combat system equipment. According to the Directorate General of Oil and Gas, Djoko Siswanto, on August 24, 2018, the government declared a temporary relaxation for three sectors: the National Electricity Company or *Perusahaan Listrik Negara* (PLN), Freeport Co., and Indonesian Armed Forces equipment.[189] Therefore, the military uses the current biofuel product only for transportation and ground vehicles. Furthermore, the biofuel price at the pump is influenced by the crude palm oil market price to keep palm-based biofuel costs lower or at least competitive with petroleum.

The government and Indonesia's palm oil producer, and the downstream company, must control or even intervene in the palm oil market. In 2019, as stated by the Coordinating Minister of Maritime and Investment Affairs, Luhut Binsar P, it is important to keep the palm oil price at $800–$1,000 per ton to give producers a positive incentive.[190] However, in 2021 the CPO price had increased to $1,280 per ton from $1,030 in 2020.[191] In addition, Indonesia has progressed from B20 to B30 in 2020, and the government only gives biodiesel subsidies for its latest biofuel (B30) for the essential sector, excluding the military.[192]

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[188] Pertamina, "Konsumen Yang Berhak Menggunakan Biosolar (B30) Subsidi," accessed July 28, 2021, https://pertamina.com/id/www.pertamina.com.

[189] Anastasia Arvirianty, "Tiga Sektor Ini Tak Harus Ikuti Aturan Bahan Bakar Nabati B20," CNBC Indonesia, August 24, 2018, https://www.cnbcindonesia.com/news/20180824080757-4-29973/tiga-sektor-ini-tak-harus-ikuti-aturan-bahan-bakar-nabati-b20.

[190] Dhean News, "Gandeng ITB, Menko Luhut Percepat Program B30 Dan Kembangkan Green Diesel," January 31, 2019, https://www.dhean.news/2019/01/gandeng-itb-menko-luhut-percepat.html.

[191] GAPKI, "Harga Komoditas," *Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI)* (blog), 2021, https://gapki.id/posisi-harga-komoditas.

[192] Erric Permana, "Pemerintah Resmi Luncurkan Program Biodiesel B30," December 23, 2019, https://www.aa.com.tr/id/ekonomi/pemerintah-resmi-luncurkan-program-biodiesel-b30-/1681307.

Indonesia's biofuel and petroleum fuels are both influenced by crude oil and crude palm oil prices. Meanwhile, the government still enacts subsidies for both petroleum and biodiesel in order to increase affordability. However, the CPO price has been higher than crude oil since 2017, which has made biodiesel more expensive than petroleum diesel (see Figure 11). The wide gap between CPO and crude oil prices will give biodiesel a higher price than diesel. The government has also revised the export tax on palm oil and its derivative as a progressive tax, which became effective in July 2021. The export tax was initially fixed without referring to any CPO price at $55 per ton and a $15 increment for every $25 increase in CPO price.[193] Finance minister Sri Mulyani stated that "the export tax begins when the reference CPO price is at $750 per ton, with a $20 increase for every $50 rise in the price; in addition, the maximum tariff for when CPO prices are above $1,000 will be flat at $175."[194] This tax's purpose is to increase the government's revenue to support the subsidy and ongoing domestic biofuel project, especially with the pressure from the wide gap between CPO and crude oil prices. By imposing a higher export tax on Indonesia's CPO, the demand for CPO may decrease, which may, in turn, decrease the price. On the other hand, the government may revise the export tax again when the CPO's price becomes economical enough to support Indonesia's biofuel.

The current wide gap in prices between CPO and crude oil is the main problem that may stall the full implementation of the mandatory biofuel program. The military is likely to hesitate to consume expensive fuel with lesser performance. In turn, the government relies on biofuel subsidies to suppress the price at the pump. Therefore, introducing the current biodiesel to Indonesia's military may not help alleviate the problem in the fuel budget because the same amount allocated to the fuel budget in 2020–2021 seems to be a fixed allocation. This indicates that the MoD's policy to cater to military fuel needs is tied to a fixed budget. Thus, Indonesia's biofuel will help MoD purchase more fuel if the price is lower than the price of petroleum. This difference can improve MoD's energy security strategically. At the same time, it may also help the government repay the military fuel debt

[193] Christina Bernadette, "Indonesia's New Palm Oil Levy Likely to Lift Exporters' Profit Margin," Reuters, June 22, 2021, sec. Commodities News, https://www.reuters.com/article/us-indonesia-palmoil-tax.

[194] Bernadette.

in the long term since palm oil and biodiesel have generated revenue to save the trade balance.

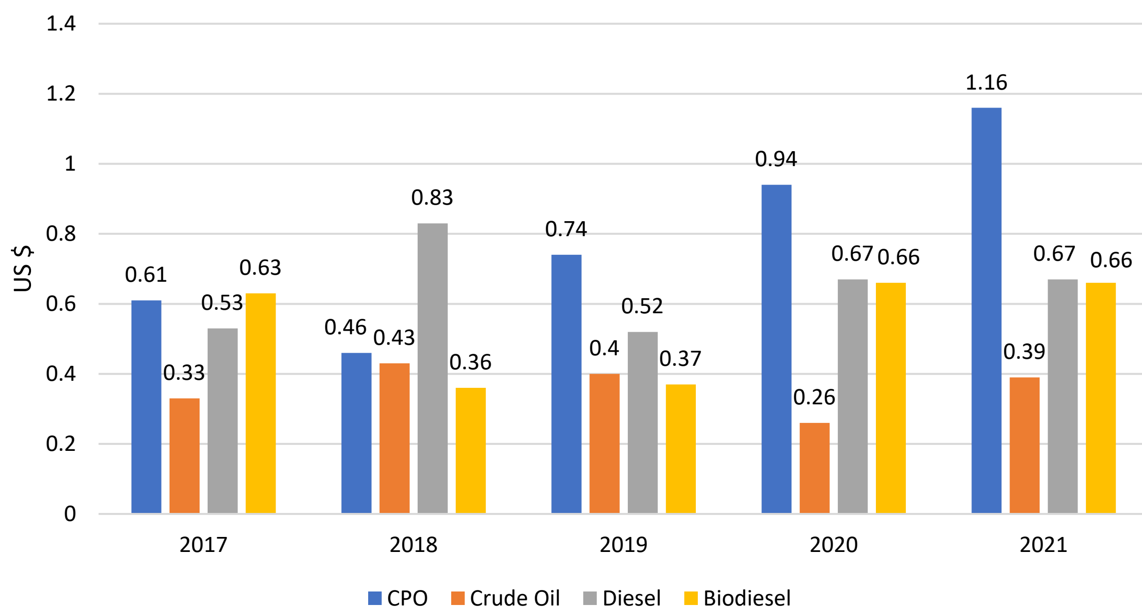

Figure 11. Prices/liter of CPO, crude oil, diesel (Dexlite), and biodiesel (B20/30).[195]

The military is mandated to use the current biofuel (B30), which the government is pushing to maximize its demand. On the other hand, the conventional diesel product is still available for the military to use for its combat system. Therefore, it can be inferred that the military will have redundancy for equipment that uses diesel fuel. The military has indeed limited its budget to purchase its fuels, and yet the fuel debts grow annually. Nevertheless, it also suffers from limited fuel supply due to Indonesia's declining fuel production.

D. AMBITIONS

With the establishment of Presidential Regulation No.79 of 2014 of the National Energy Policy, Indonesia set a primary energy supply target for 2025 of around 400 MTOE

[195] Adapted from GAPKI, "Harga Komoditas."; Pertamina, "Pengumuman," accessed July 28, 2021, https://www.pertamina.com/id/news-room/announcement/www.pertamina.com.

(million tons of oil equivalent) and by 2050 around 1,000 MTOE, with an optimal primary energy mix, as listed in Table 7.[196] Moreover, according to MEMR Regulation No.12 of 2015, Indonesia set up three energy scenario targets consisting of a Business as Usual (BaU) scenario, *Rendah Karbon* (RK) or Low Carbon scenario, and *Pembangunan Berkelanjutan* (PB) or sustainable development scenario. BaU is a normal scenario that assumes a GDP growth rate of 5.6%. RK is a "green" scenario that focuses on reducing GHGs. PB is a "middle" scenario that assumes the GDP and GHG factors. According to the National Energy Council, the target has yet to be reached, even with a substantial increase for the recent 2020 target (see Figure 12). As for crude oil as the primary source of military energy, it only reached 33.55 MTOE in 2019, whereas the target was 81.4 MTOE.[197]

Table 7. Indonesia's primary energy supply targets.[198]

No	Energy	2025	2050
1	Primary energy supply (MTOE)	>400	>1000
2	Energy mix (%)		
	a. Renewables (as long as the economy is fulfilled)	>23	>31
	b. Crude oil	<25	<20
	c. Coal	>30	>25
	d. Natural Gas	>22	>24

196 National Energy Council, "National Energy Council-Strategic Plan of 2020–2024," 2020, 3, http://www.den.go.id.

197 National Energy Council, 4.

198 Adapted from Cabinet Secretariat of the Republic of Indonesia, "Presidential Regulation No.22/ 2017," March 13, 2017, https://www.esdm.go.id/assets/media/content/content-rencana-umum-energi-nasional-ruen.pdf.

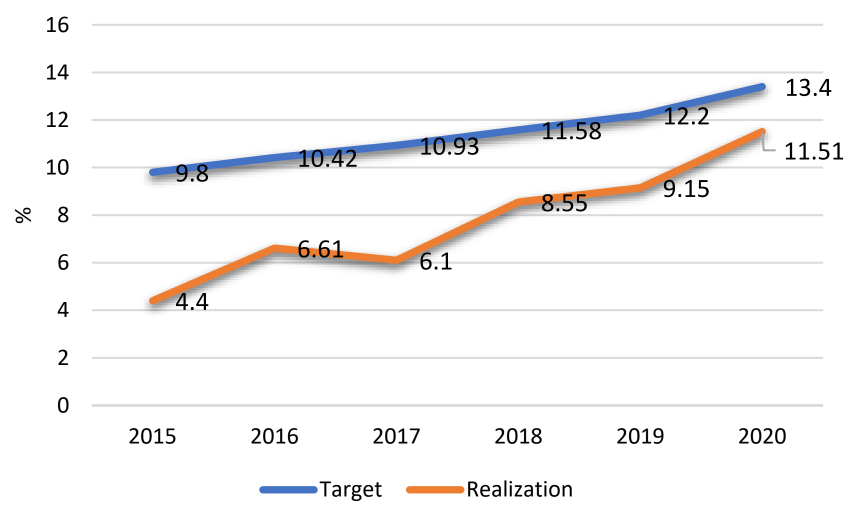

Figure 12. Target-realization of the renewable energy mix in primary energy.[199]

Furthermore, as for military energy security, the MoD and armed forces branches do not have specific plans or targets. The short-term plan inferred from the evidence is to keep applying the same policy of incurring fuel debt to Pertamina, which will be paid later directly from the state budget outside the defense budget. With around only 4% of its budget for fuel supply and the pattern in which the government has paid the fuel debts, the defense stakeholders perceive the fuel supply problem as a national burden that should be waived by giving the military a designated fuel quantum according to its demand. This has been echoed since 2013 by MoD—that the military only needs 1.2% of the GDP for its entire fuel supply and that it can be provided by the government, which has only a fraction of the national supply.

E. FINDINGS

There are essential findings about Indonesia's energy security from the evidence mentioned earlier that directly relate to its military energy security. To begin with, Indonesia has limited military energy security. Indonesia's income from oil and gas is

199 Adapted from National Energy Council, "National Energy Council-Strategic Plan of 2020–2024," 4, http://www.den.go.id.

substantial at around 40% of GDP in 2021; in contrast, the military's fuel needs only cost 1.2% of GDP in 2013 and are estimated at 1.68% in 2021.[200]

Indonesia has taken steps to respond to its dire energy situation, which motivated its pursuit of a renewable energy mix to keep the energy balance. Yet, the government has provided the leading figure of energy security matters, the MEMR, with the smallest budget of around 0.5% of GDP in 2021.[201] This contradicts the presidential regulation in 2014, which established a new paradigm that energy is the basis for national development. Moreover, with its ambitious energy mixture targets for 2025 and 2050, the government and other stakeholders have just realized that the targets should be re-evaluated and revised, especially due to the Covid-19 pandemic. As reported in March 2021, the National Energy Council was devising a new grand strategy and renewable energy law with a set of adjustments in RUEN, which was expected to be completed in October 2021.[202] Therefore, Indonesia is expected to implement a wider and more massive renewable energy mixture that expands on the enacted mandate for biofuel use due to its proven effectiveness and efficiency to compensate for the energy deficiency from fossil fuel.

As for military energy security, the absence of strategic policy has thrown the military into a fragile state in which it relies on fuel debt to cover fuel supply. The MoD's only strategy was the fuel quantum proposal to replace the fuel budget, which has been sounded since 2013. It may increase the military's operational readiness due to the fuel availability and affordability being covered and confirmed. Thus, the MoD would have more space from its allocated budget to purchase the remaining fuel demand and repay its fuel debts. Prior to the biofuel mandate in 2019, this proposal would not have been favorable for the government and Pertamina due to declining petroleum production rates and Indonesia's increase in imports. The introduction of biodiesel and its mandated use, however, have relaxed the heavy demand for diesel fuel in all the consumer sectors,

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200 Ministry of Finance, "APBN Indonesia 2021," 2021, https://www.kemenkeu.go.id/media/16835/informasi-apbn-2021.pdf.

201 Ministry of Finance, "APBN Indonesia 2021."

202 Listrik Indonesia, "Sidang Paripurna Ke-5 DEN, Grand Strategi Energi Nasional Penyempurna RUEN," 2021, https://listrikindonesia.com/sidang_paripurna_ke-5_den_grand_strategi_energi_nasional_penyempurna_ruen_7074.htm.

especially those of transportation and industry, which are the largest consumers. Therefore, the military has the luxury or greater opportunity to use petroleum fuel due to the decreased demand from other sectors.

The increased defense budget does little to relieve the military's fuel debt. Rather, if focuses on covering the requirement to procure and obtain military equipment to reach the MEF, which should be accomplished in 2025. Yet, the realization of MEF could only reach half of the target. Previously, the military has not had adequate energy security due to the combination of fuel availability and limited budget. Indonesia's current energy security position is to invest in biofuel, with the successful biodiesel program. Palm-based biofuels have proven their capability as alternate fuels. Nonetheless, their potential for use with other important aspects of Indonesia's military equipment needs to be investigated further. Given the fact that Indonesia's military fuel is less prioritized, the military's operations are similarly hampered due to limited budget allocation and the need to compete with major public sectors such as transportation. Consequently, it can be inferred that the important factors for its military energy security are availability and affordability of fuel.

The mandatory biodiesel program can support the military's energy availability due to its ability to mitigate the effects of Indonesia's declining petroleum fuel production. As for affordability, the B20/30 price is slightly lower than petroleum fuel, which may not greatly affect the military's fuel purchasing power and may not help alleviate the military's fuel debts. From these facts, it can be inferred that the military has faced a trilemma in its energy security, operational readiness, and MEF completion. On paper, the military may have adequate equipment by 2025, but if its energy security cannot be supported and its fuel debt is likely to increase, the military's overall actual operational readiness may decrease. The aspect of military operation most affected is duration, which will be reduced due to limited fuel availability. As for military fuel affordability, since the government is responsible for repaying fuel debts, the military may be forced to limit its fuel demand to help reduce the outstanding debt. In the end, this chapter finds that Indonesia's military energy security poses not only internal risks but threatens Indonesia financially.

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III. SOURCES OF BIOFUEL FOR MILITARY ENERGY IN INDONESIA

Indonesia has abundant potential to develop biofuel because the fertility of the land supports plantations for biofuel. According to the U.S. Department of Agriculture (USDA), in 2019, Indonesia by far was the largest producer of palm oil in the world and produces 58% of world production, or around 42,500 thousand metric tons.[203] Indonesia was also one of the largest jatropha producers as early as 1942–1945, especially during World War II, as the Japanese occupation force was mandated to support the war-time effort.[204] In addition, according to the Observatory of Economic Complexity (OEC), between 2018–2019, Indonesia is the second-largest exporter of molasses, accounting for 9.65% of the world's exports and reaching $94.2 million.[205] These three products are the most significant and most viable resources for biofuel in Indonesia. Indonesia already had experience in cultivating these crops, but each plantation business has faced different situations and challenges, which have shaped the biofuel environment in Indonesia.

To distinguish the best crop to serve Indonesia's military energy security, this chapter investigates each of the three resources. It looks upon the general overview, production, and suitability of the crops to support military equipment in particular. The expected outcome is evidence of biofuel's suitability for Indonesia's military energy security, which prioritizes availability and affordability, as revealed in the previous chapters. Finally, this chapter concludes with the findings to point out the most favorable source that fits the military needs.

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203 USDA, "Palm Oil Explorer," 2021, https://ipad.fas.usda.gov/cropexplorer/cropview/commodityView.aspx?cropid=4243000&sel_year=2019.

204 Suraya Afiff, "Engineering the Jatropha Hype in Indonesia," *Sustainability* 6 (April 1, 2014): 1690, https://doi.org/10.3390/su6041686.

205 "Molasses Product Trade, Exporters and Importers," OEC - The Observatory of Economic Complexity, 2021, https://app-bee.oec.world/en/profile/hs92/molasses.

A. PALM

Palm oil is extracted from the palm tree *(Elaeis guineensis),* which originates from Africa. The oil is divided into two types: crude palm oil (CPO), which is extracted out of the fruit's flesh, and palm kernel oil, which is taken from the inner flesh of the seed (see Figure 13). Palm oil yields more fluid per fruit than palm kernel oil, but the latter contains more saturated fat. Palm oil is traditionally used for edible purposes (cooking oil, food), whereas palm kernel oil is generally used for non-edibles (cosmetics, soaps). Palm kernel oil can only be produced from about 12% of the palm fruit, and it can also be used as bioavtur from its palm fatty acid distillate (PFAD).[206]

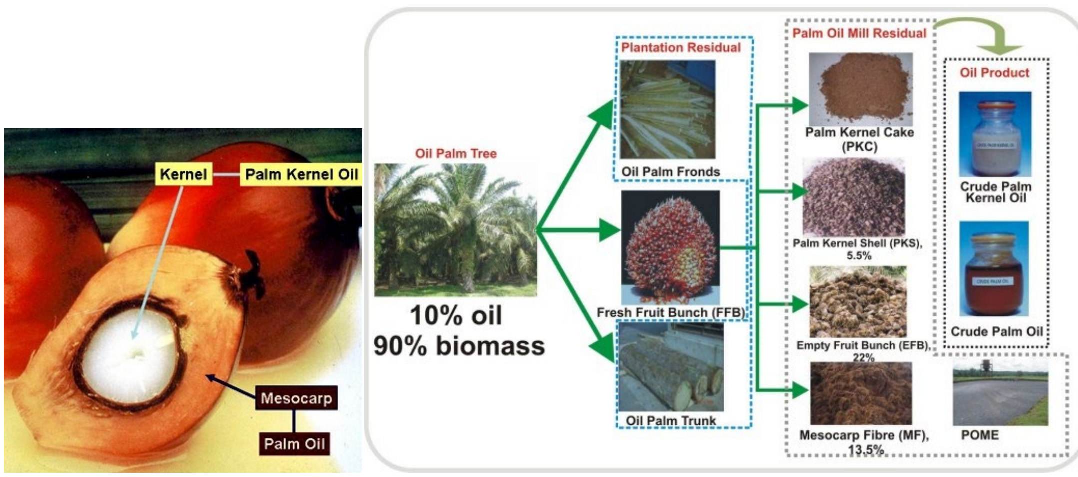

Figure 13. Palm-kernel oil extraction.[207]

Palm was introduced by the Dutch into Indonesia in 1848 when the seed from Africa was planted at the Bogor botanical garden, which then thrived and is cultivated across Indonesia.[208] Palm-based biofuel was developed in the early 1990s by several

206 F. Sulaiman et al., "The Oil Palm Wastes in Malaysia," in Biomass Now: Sustainable Growth and *Use* (Croatia: InTech, December 24, 2013), 78.

207 Source: Salman Zafar, "National Biofuel Policy," *BioEnergy Consult* (blog), October 1, 2020, https://www.bioenergyconsult.com/tag/national-biofuel-policy/.

208 Joko Supriyono, "Sejarah Kelapa Sawit Indonesia," *Gabungan Pengusaha Kelapa Sawit Indonesia (GAPKI)* (blog), November 28, 2017, https://gapki.id/news/3652/video-sejarah-kelapa-sawit-indonesia.

national research institutes such as the Center for Research and Development of Oil and Gas Technology, or *Pusat Penelitian dan Pengembangan Teknologi Minyak dan Gas Bumi* (LEMIGAS); Assessment and Application of Technology Agency, or *Badan Pengkajian dan Penerapan teknologi* (BPPT); Palm Oil Research Center, or *Pusat Penelitian Kelapa Sawit* (PPKS); Indonesian Plantation Research, or *Institute Lembaga Riset Perkebunan Indonesia* (LRPI); and Bandung Institute of Technology, or *Institut Teknologi Bandung* (ITB).[209] Each institute pioneered creating a palm-based biofuel, focused on alternative fuel for diesel; each institute followed identical parallel paths and succeeded in producing the 30% mixture fuel known as B30 (30% biofuel, 70% diesel).[210] These biofuel products have been successfully tested and produced on a limited scale; however, it was not until 2005 when the crude oil prices increased 100% to $148/barrel, creating energy insecurity, that the government of Indonesia enacted Presidential Regulation No.5/2006 and Instruction No.1/2006 for biofuel development.[211] Palm-based biofuel is mainly created by transesterification or hydrotreating methods. Transesterification produces glycerin and biodiesel fuel, or FAME (fatty acid methyl esters), whereas hydrotreating produces the "green" fuel or drop-in fuel that is equivalent to petroleum fuels.[212] Currently, Indonesia produces biodiesel (BXX) by using transesterification due to its higher production rate and cheaper process. *Green fuels* have been under development and testing (see Figure 14).

In 2002, the Indonesian Biodiesel Forum, or *Forum Biodiesel Indonesia* (FBI), was established. In 2006, the forum included biodiesel in the Indonesian National Standard, or *Standar Nasional Indonesia* (SNI). The latest update for Indonesia's biodiesel was in 2015 as SNI 7182:2015, consisting of several parameters.[213] After the successful biofuel pioneering in the 2000s, biofuel industries emerged and started the commercialization of

209 Supriyono, 2.

210 Faridha et al., *Biodiesel Jejak Panjang Perjuangan*, 1st ed. (Jakarta, Indonesia: Ministry of Energy and Mineral Resources (MEMR), 2021), 16, https://www.esdm.go.id/assets/media/content/content-buku-biodiesel-jejak-panjang-perjuangan-.pdf.

211 Faridha et al., 16.

212 U.S. Departement of Energy, "Alternative Fuels Data Center: Renewable Hydrocarbon Biofuels," accessed July 23, 2021, https://afdc.energy.gov/fuels/emerging_hydrocarbon.html.

213 Faridha et al., 22.

biofuels in Indonesia, mainly when Pertamina supported and joined the projects in 2006, which strengthened palm-based biofuel development. In 2006, these industries formed the Indonesian Biofuel Producers Association, or *Asosiasi Produsen Biofuel Indonesia* (APROBI), which consisted of 24 biodiesel companies and one ethanol company.[214] Indonesia's palm-based biofuel has been tested in the transportation sector as it is the most significant fuel consumer. The national road test for B20 was carried out since 2014–2015 for car producers such as Toyota, Mitsubishi, Ford, Chevrolet, and Hino, with a range up to 40,000 km, whereas the locomotives rail test was done in February–August 2018, reaching around 65,454 km.[215]

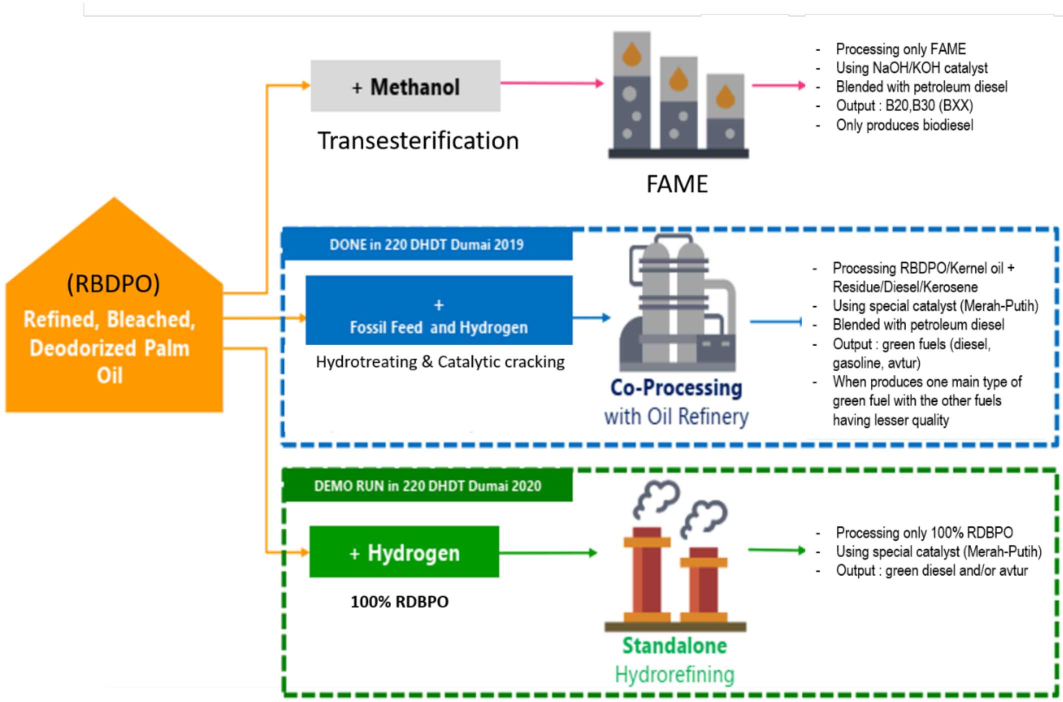

Figure 14. Indonesia's biofuel production process.[216]

214 Faridha et al., 31.

215 EBTKE, "Kebijakan Dalam Implementasi Biofuel" September 25, 2018, 19, https://btbrd.bppt.go.id/images/downloads/2018/Dialog-Nasional-Biofuel_2_Dirjen-EBTKE.pdf.

216 Source: J. S. Sabarman et al., "Bioavtur Synthesis from Palm Fatty Acid Distillate through Hydrotreating and Hydrocracking Processes," *Indonesian Journal of Energy* 2, no. 2 (August 30, 2019): 7, https://doi.org/10.33116/ije.v2i2.40.

Eventually, Indonesia successfully harnessed the capability of B20 (biodiesel). On January 1, 2020, the president implemented the mandatory use of B30 biofuel. At that point, Indonesia became the largest producer of biodiesel in the world.[217] Indonesia's next target is to reach the B40, or 40% mixture (30% FAME, 10% *green diesel*/HVO, 60% gasoil) that was projected to be implemented in 2022. This blending is expected to have higher cetane and to be more compatible with commercial vehicle specifications.[218] In January 2021, however, the government decided to postpone the B40 program due to economic factors, such as the expected higher cost to support the program than the B30.[219] The government has projected that it will need an incentive of nearly IDR 46 trillion with a quota of 9.2 million kiloliters to support the B40.[220] Since B40 is composed of three different fuel components, each requiring its own technology, the cost to support the development of B40 may be higher than the current B30. Nevertheless, the research and development for *green diesel* are continuing, especially by Pertamina. Pertamina has decided to advance from FAME biofuel to *green fuel*.[221] The main reason is that *green fuel* is expected to be more compatible than FAME with the current technology in automotive, aviation, and naval transportation, which may increase its economic value.

Furthermore, due to its well-established market and industrial chain, Indonesia can achieve a sustainable production chain for palm-based biofuel. In 2019, as reported by Statista based on USDA data, Indonesia became the world's largest palm oil producer, with up to 42.50 million metric tons (see Figure 15). The increasing palm oil supply is followed

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[217] Christina Bernadette, "Indonesia Launches B30 Biodiesel to Cut Costs, Boost Palm Oil," Reuters, December 23, 2019, sec. Commodities, https://www.reuters.com/article/us-indonesia-biodiesel-idUSKBN1YR0D2.

[218] FAO, "Indonesia Biofuel Detail," July 2020, http://www.fao.org/economic/est/est-commodities/commodity-policy-archive/detail/en/c/755318/.

[219] Kompas Cyber Media, "Pemerintah Tunda Program B40 Tahun Ini, Ini Alasannya," [The Government Postpones the B40 Program This Year, Here's The Reason] April 6, 2021, https://otomotif.kompas.com/read/2021/04/06/185500015/pemerintah-tunda-program-b40-tahun-ini-ini-alasannya.

[220] Kompas Cyer Media.

[221] APROBI, *2020 Buletin Bioenergy*, 2020, 8, https://www.aprobi.or.id/wp-content/uploads/Bulletin-202008.pdf.

by demand, with 77 million metric tons in 2020–2021.[222] Moreover, palm oil has become a valuable trade commodity for Indonesia, contributing 10–15% to the total export goods and 4.5% to the GDP.[223] Therefore, it can be inferred that palm oil, a significant food source, has become a modest cash commodity and a strategic commodity due to its intrinsic value as an alternative for petroleum-based fuel used for military equipment. By contrast, the price of palm kernel oil is significantly lower, at $0.26 per kilogram (IDR 3,655) compared to CPO at $0.48 (IDR 6,751) per kilogram.[224] This price gap may direct biofuel development efforts toward palm kernel oil, which could create surge pricing.

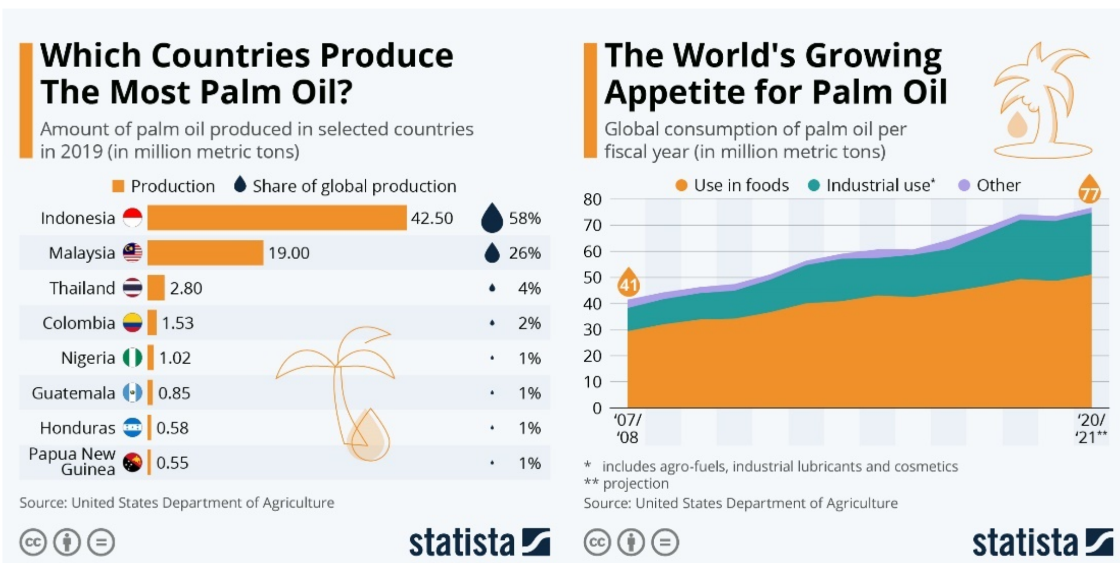

Figure 15. World's palm oil producers and demand.[225]

[222] Statista, "The World's Growing Appetite for Palm Oil," 2021, https://www.statista.com/chart/20114/global-consumption-of-palm-oil/.

[223] UNDP, "Indonesia At A Glance," Green Commodities, May 2019, https://www.greencommodities.org/content/gcp/en/home/resources/at-a-glance-country-guides/indonesia-at-a-glance.html.

[224] Bisnis, "Harga Inti Sawit di Jambi Naik 3 Persen, Picu Kenaikan Harga CPO Rp6 per Kilogram," June 22, 2020, https://market.bisnis.com/read/20200622/94/1255898/harga-inti-sawit-di-jambi-naik-3-persen-picu-kenaikan-harga-cpo-rp6-per-kilogram.

[225] Source: Statista, "The World's Growing Appetite for Palm Oil," 2021, https://www.statista.com/chart/20114/global-consumption-of-palm-oil/.

In order to reach the 2025 renewable energy target, the government has set up 9.2 million kiloliters of B30 for 2021.[226] APROBI is even more optimistic regarding the target, stating that biofuel production might reach 10 million kiloliters by 2021.[227] Furthermore, APROBI predicts that there will be a 16% growth rate for the following year due to the boost given by the government to palm-based biofuel producers.[228] In addition, Indonesia's biodiesel production capability has surpassed the domestic demand. The increasing supply and the subsidy may stabilize or decrease the price in the following years; therefore, it can also be a profitable export commodity.

Moreover, Indonesia had increased palm oil production by 49.12 million tons by 2020, which was dispersed around the major islands, with Sumatra and Kalimantan as the primary producers (see Figure 16). As depicted in Figure 16, CPO production has increased due to the expansion of palm plantations, with an average increase of 4–5% per year. With a large production capacity, Indonesia may produce even more CPO for the following decades, and thus, securing the palm-based biofuel capacity. Compared to Indonesia's projected defense and security fuel demands which will be at around 3,949 thousand barrels in 2021, biofuel production will secure the fuel availability aspect. On the other hand, it may not help the affordability if the price is at par with petroleum-based fuel.

[226] Suparjo Ramalan, "Airlangga: Target Penyaluran B30 Di 2021 Sebesar 9,2 Juta Kiloliter," SINDO News, February 6, 2021, https://ekbis.sindonews.com/read/326918/34/airlangga-target-penyaluran-b30-di-2021-sebesar-92-juta-kiloliter-1612616554.

[227] Andi M. Arief, "Produksi Biofuel Naik Di Masa Pandemi, Aprobi: Kami Juga Heran," Bisnis, October 30, 2020, https://ekonomi.bisnis.com/read/20201030/257/1311596/produksi-biofuel-naik-di-masa-pandemi-aprobi-kami-juga-heran.

[228] Arief.

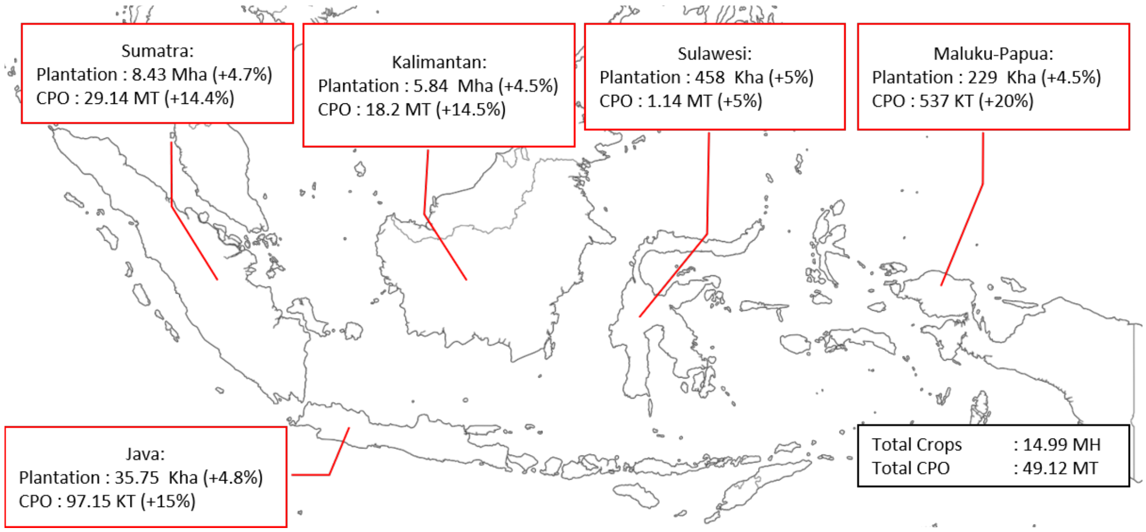

Figure 16. Indonesia palm plantation and CPO production map in 2020.[229]

B. JATROPHA

Jatropha, or *jarak (Jatropha curcas),* was introduced to Indonesia by the Japanese during the occupation in 1942 as a mandatory crop for the war effort when it was used as lubricants and biofuel for Japanese tanks and aircraft (see Figure 17). As the war ended in 1945, jatropha cultivation in Indonesia was abandoned; however, it revealed that jatropha-based biofuel is feasible.[230] In addition, jatropha oil is non-edible, which eliminates the conflicting supply-demand of fuel against food stock. Jatropha originated from the Subtropical American continent and has many advantages. It is resistant to drought, can be grown in arid land, has a life expectancy of up to 50 years, and most importantly, can be produced into biofuel.[231]

[229] Adapted from Directorate General of Estates, "2018–2020 Palm Crop Estate Statistics of Indonesia," 2019, 37, https://ditjenbun.pertanian.go.id/?publikasi=buku-publikasi-statistik-2018-2020.

[230] Afiff, "Engineering the Jatropha Hype in Indonesia," 1690.

[231] A. S. Silitonga et al., "A Review on Prospect of Jatropha Curcas for Biodiesel in Indonesia," *Renewable and Sustainable Energy Reviews* 15, no. 8 (October 1, 2011): 3743, https://doi.org/10.1016/j.rser.2011.07.011.

Figure 17. Jatropha fruit, seeds, and crude biofuel.[232]

Indonesia experienced jatropha hype in 2005 when the government significantly invested in biofuel and incorporated it into the national framework. The government did not specifically mention crop types in its policies; however, the spotlight landed on jatropha since many influential scholars supported it. As a result, Indonesia set aside around $244 million for several projects with support from Japan.[233] Due to financial losses and an unprepared industrial chain, after 2006 there was a rapid decline in interest in jatropha and growing doubt among the stakeholders.[234] At that time, people were attracted to growing jatropha since it was easier and did not require large amounts of land compared to palm trees. Eventually, palm oil thrived and became the leader for biofuel due to its experienced industrial and market chain establishment. Currently, the production of jatropha is carried out by private companies. By 2010, the Ministry of Agriculture stated that Indonesia's jatropha production reached 50,106 hectares, with a total production of 7,081 tons.[235]

Jatropha-based biofuel production has the same process and output as palm-based biofuel. Biofuel has different properties for every variant of jatropha. Compared to palm-based biofuel, jatropha has at least one significantly better property, which is a lower cloud

[232] Source: Silitonga et al., 3744.

[233] Afiff, "Engineering the Jatropha Hype in Indonesia," 1696.

[234] Silitonga et al., "A Review on Prospect of Jatropha Curcas for Biodiesel in Indonesia," 1697.

[235] Ministry of Agriculture, "Budidaya Jarak Pagar," 2013, 1, http://ppid.pertanian.go.id/doc/1/Budidaya_Jarak_Pagar.pdf.

point at 2.4–4.1 degrees C.[236] As for the other properties, they are relatively equal. Therefore, there are possible opportunities for jatropha to rise again in popularity in the years ahead, particularly as a means to provide alternative stock to the existing palm-based biofuel. Moreover, jatropha-based biofuel itself has been heavily researched and developed by many scientists and other countries. On the other hand, the economic value of jatropha commodities, especially for the producers, is still not beneficial. As proven in Indonesia during the jatropha hype, the market for jatropha is still limited compared to palm oil, which is already established and traded globally.

A large yield plantation is essential for biofuel production since fuel demand is high. A jatropha plantation could produce up to an estimated 10–12.5 tons of seed in one hectare per year, with revenue (calculated in 2007) for the farmer around IDR 5–10 million ($357–$714) per year.[237] This revenue is disappointing and not as lucrative as revenue from food crops such as coffee, cocoa, and others. Jatropha is a maintenance-free crop, however, and it can be cultivated on unproductive land. Therefore, the revenue from cultivating jatropha is projected to pay back on the investment in the fourth or fifth year.[238] Due to its naturally lower maintenance cost, jatropha may have advantages over palm oil, even though both plants need to be maintained to achieve maximum harvest. Moreover, due to the high price for palm oil at present and the dynamic of crude oil, which is at a lower price than CPO, the diversification of Indonesia's biofuel sources may lower the price of biofuels; because Pertamina, as the main biofuel producer, could switch to the cheaper non-edible vegetable oil such as jatropha, while waiting for the palm oil price to be as economically viable for biofuel. Moreover, jatropha could serve as a substitute or backup for palm oil whenever its production declines due to natural factors such as weather, disaster, or even climate change.

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[236] A.N.R. Reddy et al., "Experimental Evaluation of Fatty Acid Composition Influence on Jatropha Biodiesel Physicochemical Properties," *Journal of Renewable and Sustainable Energy* 10 (January 4, 2018): 013103, https://doi.org/10.1063/1.5018743.

[237] Julio D.J. Gome, *Petunjuk Praktis Budidaya Jarak Pagar (Jatropha curcas L.) dan Proses Pengolahan Minyak* (Malang, Indonesia: Universitas Brawijaya Press, 2016), 57.

[238] Gome, 58.

As for the relation between jatropha and military energy security, there has been no testing or development in Indonesia's military systems. Since the cloud point of jatropha's biofuel is lower than palm-based biofuel, however, it may have the necessary trait for aircraft and submarines, which are prone to fuel condensation due to fuel low-temperature operational domains, such as high-altitude flight and deep-water sailing. If jatropha's traits are suitable for such conditions, the military may help to pioneer the planting of jatropha.

The military has successfully supported the government food security program (*ketahanan pangan*) since the 1960s in the *Green Revolution* project, which significantly elevated Indonesia's food sustainability in 1984–1986 by utilizing unused land around military bases for planting food crops or by supporting government projects in irrigation and fertilizer.[239] As of 2019, Indonesia's military had successfully cultivated up to 200 thousand hectares of rice fields across Indonesia.[240] Moreover, in August 2020, the president appointed the Minister of Defense Prabowo Subianto as the leader to cultivate the national project of food estates—around 178 hectares in Central Kalimantan.[241] Therefore, the military can support Indonesia's biofuel project on the plantations based on its experience and especially to reduce the cost for production of jatropha or any other crop, which would not keep military personnel from their main tasks. Furthermore, jatropha's easier maintenance may make it suitable for support by the military; thus, the military can be the leading figure to rejuvenate the jatropha crop.

Jatropha crops in Indonesia have declined significantly over the last decade. Nevertheless, the possibility of rejuvenating interest in the crop is high if market and government incentives are profitable, especially due to jatropha's trait as a non-food commodity. Furthermore, Indonesia has already experienced jatropha hype; thus, the alarming decline of crude oil production may again revive the jatropha market (see Figure 18). As for now, the remnants of jatropha crops can only produce much smaller amounts of output (see Figure 19). As output grows, even if domestic demand for it as a fuel source

239 Muhammad Verdias Yurindra, "Militer untuk Ketahanan Pangan?," Detik, Agustus 2020, https://news.detik.com/kolom/d-5128751/militer-untuk-ketahanan-pangan.

240 Yurindra.

241 Yurindra.

is slow, Indonesia's jatropha could be exported to Japan or other countries that have already developed jatropha-based biofuel. In the interim, domestic demand may cater to pharmaceutical and cosmetic production.[242]

At present, Indonesia's military fuel demands could not be supported by the domestic production of jatropha-based biofuel alone. The estimated current production of jatropha seed is only around 385 tons, and the actual number may be even less since most plantations are only active in West Java and Nusa Tenggara, as depicted in Figure 19. Indonesia's jatropha oil product is mainly used for the pharmaceutical industry since its economic value as biofuel is limited by the low price tag on jatropha seed. So far, only one company with modern technology, the New Eco-Energy Indonesia Co. (NEEI-One), was capable of producing jatropha-based biofuel in 2021, with a capacity of 280,000 liters per day, using nanomizer (emulsification) technology.[243] The company has stated that with this technology, it could reduce the Nitrogen oxide (NOX) and methanol content that needs to be suppressed to meet the standard for emission more cheaply.[244] Furthermore, the company representatives declare that the technology helps to reduce the cost of jatropha-based biodiesel to \$0.35–\$0.42 per liter.[245] This fact may indicate that jatropha may serve as a suitable alternative, supplemental or complementary source for Indonesia's biofuel programs. Moreover, jatropha oil's current price is at par with crude palm oil, around \$1–\$1.5 per liter, slightly under CPO at \$1.1–\$1.68 per liter.[246] Therefore, the possibility for jatropha to reach a lower price than CPO in the following years is likely to happen, especially if the government incentivizes the jatropha market and industry.

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[242] Fathurrachman Fagi, "Renewable Energy in Indonesia," *Energi Baru Dan Terbarukan* (blog), March 20, 2021, http://energibarudanterbarukan.blogspot.com/2011/02/kondisi-ebt-saat-ini-di-indonesia.html.

[243] Ministry of Energy and Mineral Resources (MEMR), "Inovasi Produksi Biodiesel Berbasis Tanaman Jarak Pagar," February 17, 2021, https://ebtke.esdm.go.id/post/2021/02/18/2797/inovasi.produksi.biodiesel.berbasis.tanaman.jarak.pagar.

[244] Ministry of Energy and Mineral Resources (MEMR).

[245] Ministry of Energy and Mineral Resources (MEMR).

[246] IndiaMART, "Business Directory, India Business Directory, Companies Directory in India," August 2021, https://dir.indiamart.com/.

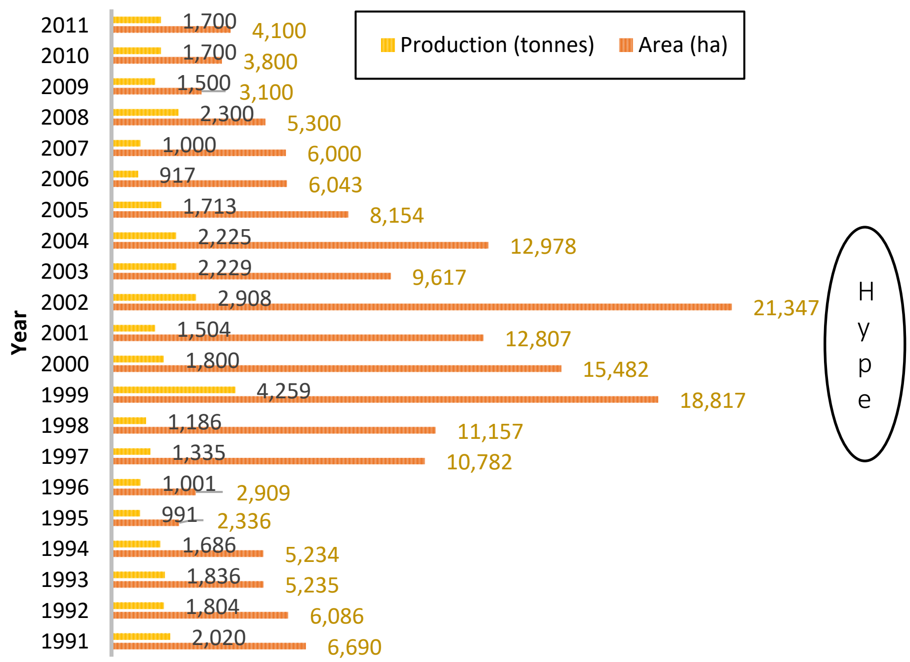

Figure 18. Indonesia's jatropha plantation capacity, 1991–2011.[247]

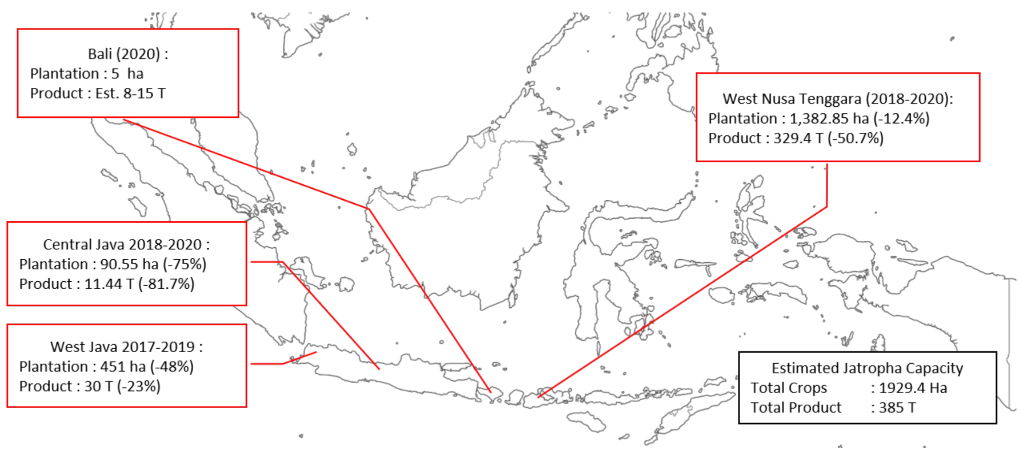

Figure 19. Indonesia's current jatropha plantation capacity.[248]

247 Adapted from Anne Casson, Y.I.K.D. Muliastra, and Krystof Obidzinski, "Large-Scale Plantations, Bioenergy Developments and Land Use Change in Indonesia," Center for International Forestry Research (CIFOR), 2014, 21, https://doi.org/10.17528/cifor/005434.

248 Adapted from BPS, "Statistik Perkebunan," 2021, https://www.bps.go.id/subject/54/perkebunan.html#subjekViewTab3.

C. MOLASSES

This section explains the potential of molasses from Indonesia's sugar cane plantation to be produced as biofuel, bioethanol (EXX). Molasses, a thick and dark refining byproduct of cane sugar or beet sugar, is a residue of syrup leftover when its sugar content cannot be economically extracted anymore.[249] Before 1948, molasses was well known to be fermented to produce ethyl alcohol (bioethanol); however, ethylene, a derivative of petroleum, has since taken over molasses' role, thus decreasing the demand for molasses.[250] Bioethanol from molasses is produced by the fermentation and dehydration process, which then can serve as the alternative to gasoline or drop-in fuel (E100) or as a gasoline blend (see Figure 20).[251]

Many countries blend their gasoline with bioethanol as well as pure ethanol. As of 2020 the United States was the largest producer of bioethanol fuel, at 13,800 million gallons, followed by Brazil with 7,930 million gallons.[252] As for Indonesia, there has been a bioethanol dilemma since the enactment of the biofuel mandate in 2013. In 2021, according to USDA, Indonesia's molasses-based bioethanol production has not been progressing with any substantial fulfillment towards the mandate.[253] Currently, there is no bioethanol for fuel production; even though many plantations produce ethanol, they only produce non-fuel grade ethanol, which is used as medical, industrial, and export commodities.[254] The dilemma in bioethanol is not only caused by lack of financial support or subsidy but also the limited feedstock from ethanol producers, although the government

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249 Britannica, "Sugar - Molasses Processing," 2021, https://www.britannica.com/science/sugar-chemical-compound.

250 Britannica.

251 Steffi Formann et al., "Beyond Sugar and Ethanol Production: Value Generation Opportunities Through Sugarcane Residues," *Frontiers in Energy Research* 0 (2020), https://doi.org/10.3389/fenrg.2020.579577.

252 "Fuel Ethanol Production in Major Countries 2020," Statista, accessed July 31, 2021, https://www.statista.com/statistics/281606/ethanol-production-in-selected-countries/.

253 Arif Rahmanulloh, "Indonesia Biofuel Annual Report 2021," Global Agriculture Information Network, June 29, 2021, 5, https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Jakarta_Indonesia_06-21-2021.pdf.

254 Rahmanulloh, 5.

mandated that Indonesia should produce the ethanol blends of E5-E10 by 2020 and E20 by 2025.[255] Moreover, in 2006–2009, Pertamina could only blend the bioethanol as E2 (2% bioethanol), on a limited scale, due to the limited government subsidy to cover the gap between the cost of fuel-grade ethanol and the lower price of gasoline.[256] From these facts, it can be inferred that both palm-based biofuel and molasses-based biofuel have encountered almost the same problem with financial support. Furthermore, the limited feedstock supported by bioethanol producers may reflect an unattractive market for bioethanol in Indonesia over the last decade.

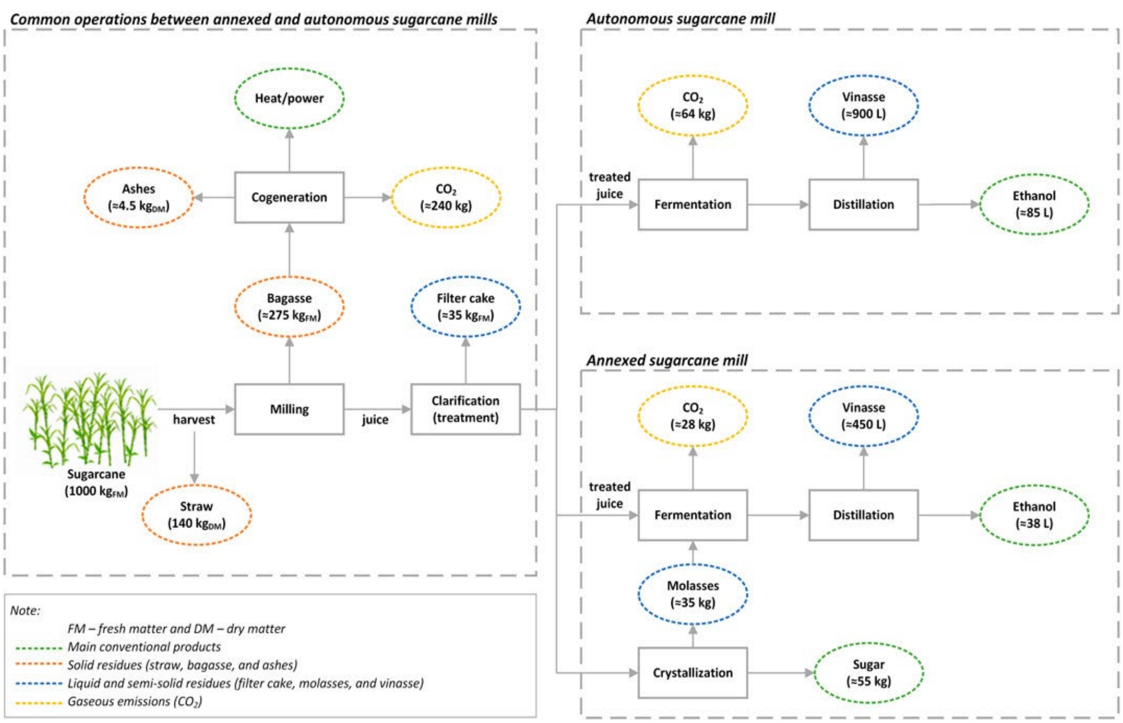

Figure 20. Molasses to bioethanol (biofuel) production.[257]

[255] Rahmanulloh, 5.

[256] Arif Rahmanulloh, "Indonesia Biofuels Annual Report 2018" (Jakarta: Global Agriculture Information Network, August 13, 2018), 10, https://apps.fas.usda.gov/newgainapi/api/report/downloadreportbyfilename?filename=Biofuels%20Annual_Jakarta_Indonesia_8-13-2018.pdf.

[257] Source: Steffi Formann et al., "Beyond Sugar and Ethanol Production: Value Generation Opportunities Through Sugarcane Residues," *Frontiers in Energy Research* 0 (2020), https://doi.org/10.3389/fenrg.2020.579577.

Indonesia certainly has the capability to implement molasses-based biofuel since the country has been producing a large amount of molasses. According to the OEC, in 2019, Indonesia was the second-largest molasses exporter globally, earning $92.3 million of revenue and supplying up to 14.7% of the entire world's export (see Figure 21).[258] Moreover, Indonesia can already produce bioethanol due to its simpler and cheaper production than biodiesel, which requires a catalyst and sophisticated technology. In contrast, bioethanol only needs yeast, which is just the technology to produce moonshine.

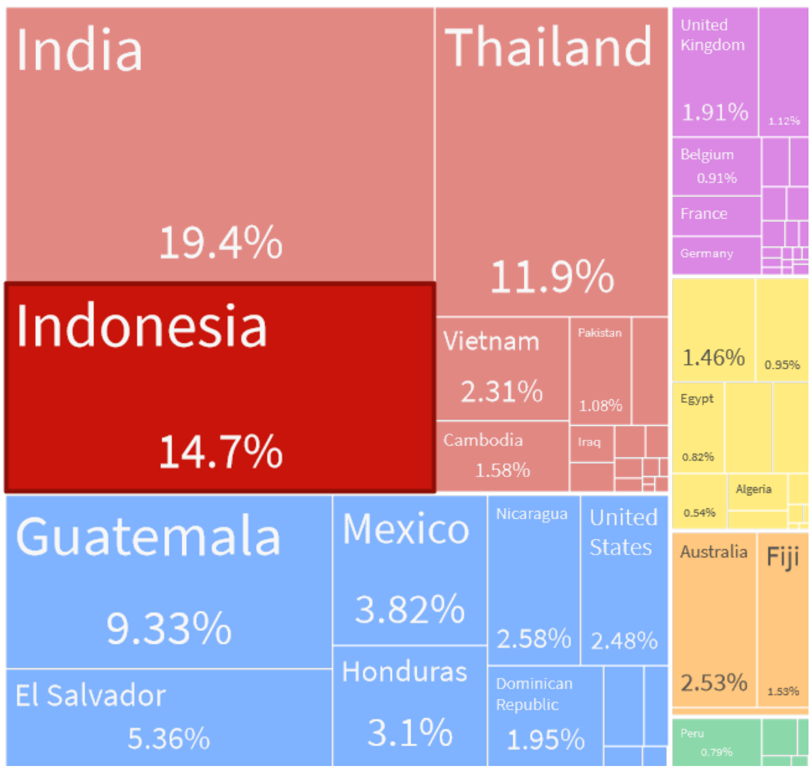

Figure 21. World's export of molasses in 2019.[259]

To connect molasses-based biofuel to military energy security, one can see from its properties that it can serve military operational purposes. Since molasses is mainly converted as an alternative to gasoline or as a fuel blend, it can be used for ground vehicles

[258] OEC, "Which Countries Export Cane Molasses? (2019)," OEC - The Observatory of Economic Complexity, 2021, https://app-bee.oec.world/en/visualize/tree_map/hs92/export/show/all/4170310/2019/.

[259] Source: OEC, "Molasses."

(see Table 8). As note earlier, however, military-grade vehicles mainly use diesel engines due to their higher torque and power output. Thus, the military will likely use bioethanol for their small vehicles equipped with gasoline engines such as VIP cars, motorcycles, UAVs, and fast rafts. According to the USDA, bioethanol has fewer calories or energy than gasoline, which will give lower power output and higher fuel consumption depending on the blend.[260] As for the U.S. bioethanol (E85), it has around 27% less energy than gasoline.[261]

Table 8. Comparison of gasoline and bioethanol.[262]

Fuel Properties	Gasoline	Bioethanol
Molecular weight [kg/kmol]	111	46
Density [kg/l] at 15°C	0.75	0.80-0.82
Oxygen content [wt-%]	0	34.8
Lower Calorific Value [MJ/kg] at 15ºC	41.3	26.4
Lower Calorific Value [MJ/l] at 15ºC	31	21.2
Octane number (RON)	97	109
Octane number (MON)	86	92
Cetane number	8	11
Stoichiometric AFR [kg air/kg fuel]	14.7	9.0
Boiling temperature [ºC]	30-190	78
Reid Vapour Pressure [kPa] at 15ºC	75	16.5

Molasses is very viable as a source of biofuel since it is supported by high yields. Yet, it has not been tested and implemented by Indonesia's military since there is a setback in Indonesia's molasses-based biofuel. In 2021, the price of molasses-based bioethanol is higher than gasoline, reaching up to IDR 12,113 ($0.83) per liter compared to Pertamax (petroleum-based fuel) at IDR 9,000 ($0.62).[263] For now, Pertamina only uses bioethanol

260 US Departement of Energy, "Alternative Fuels Data Center: Ethanol Benefits and Considerations," 2021, https://afdc.energy.gov/fuels/ethanol_benefits.html.

261 US Departement of Energy.

262 Source: Mr G. A. Kapadia and P. Patel, "Ethanol, a Promising Alternative Fuel for S. I. Engine: A Review," 2016, https://www.semanticscholar.org/paper/Ethanol_C-a-promising-alternative-fuel-for-S.-I.-A-Kapadia-Patel/6f30b87ffc03f2fefd3b9de5ae030b086ac7110a.

263 Ministry of Energy and Mineral Resources (MEMR), "Harga Indeks Pasar (HIP) Bahan Bakar Nabati (BBN) Jenis Bioethanol," July 29, 2021, https://ebtke.esdm.go.id/post/2021/07/29/2920/harga.indeks.pasar.hip.bahan.bakar.nabati.bbn.jenis.bioethanol.bulan.agustus.2021.

to improve the octane of racing-grade gasoline (Pertamax racing) with a price of IDR 44,500 ($3.08) per liter.[264] Indonesia has large reserves for molasses which grow annually. Since the demand for Indonesia's molasses comes from international trade and makes it lucrative, it is heavily exported. Moreover, because the price of molasses in the domestic market is cheaper than in the international market, domestic factories have been forced to cater to domestic demand by importing molasses from other countries. For instance, in 2019, 93% of Indonesia's molasses import was from Egypt, at over $16.9 million.[265] Over time, the demand for ethanol has also increased significantly, especially during the Covid-19 pandemic, in which ethanol is sought as an antiseptic ingredient; therefore, domestic ethanol producers must compete in fulfilling their capacity to meet the demand.

Indonesia's molasses production has shown a slight increase related to the expansion of sugarcane plantations. In 2018–2020, Indonesia's sugarcane crop area increased 6.6% to 458,432 hectares, producing around 2,416,846 tons of sugarcane, which represented an increase of 11% during that period (see Figure 22). According to Indonesian Spiritus & Ethanol Association (ASENDO), in 2020, Indonesia's ethanol production installed capacity is at 245 million liters per year, with an annual production capacity at 180 million liters and domestic consumption at 100 million liters.[266] Indonesia's current molasses-based bioethanol production is unlikely to help Indonesia's fuel demands due to its limited production and the existing high demand for non-fuel products from molasses; therefore, it may not help Indonesia's military energy security.

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[264] EBTKE, "Kebijakan Dalam Implementasi Biofuel," 8.

[265] OEC, "Molasses in Indonesia," 2019, https://app-ant.oec.world/en/profile/bilateral-product/molasses/reporter/idn.

[266] Agung Hidayat and Khomarul Hidayat, "Produsen Etanol Dapat Penuhi Kebutuhan Dalam Negeri," Kontan, March 19, 2020, https://industri.kontan.co.id/news/produsen-etanol-dapat-penuhi-kebutuhan-dalam-negeri.

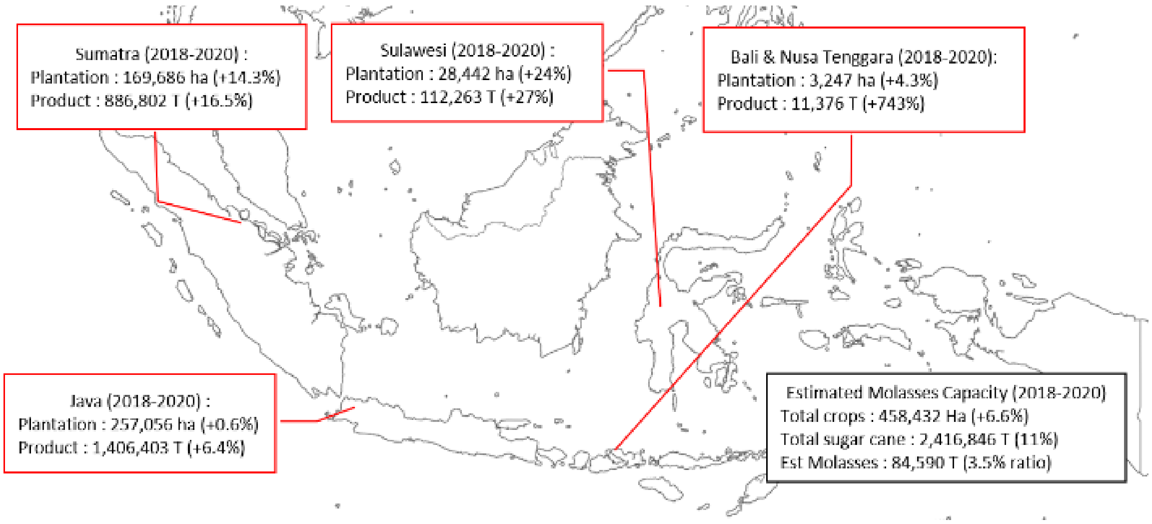

Figure 22. Indonesia's molasses production capacity 2018–2020.[267]

D. FINDINGS

The evidence related to three well-known biofuel sources in Indonesia presented in this chapter suggests that Indonesia's indigenous palm-based biofuel is the solution for Indonesia's military energy needs and is enabled by Indonesia's massive production capacity, well-established industrial setup, market support, and the projection that guaranteed the development and implementation of this alternative fuel. The publicly available evidence is listed in Table 9. Indonesia's palm oil production is more than enough to cater to the military's fuel demands, while the remaining oil supply can support other high-volume consumer sectors nationwide, including the industrial and transportation sectors.

This chapter has revealed that palm, jatropha, and molasses encounter the same obstacle: the economic price that is prone to market volatility. As warned by many scholars, biofuel sources that have conflicting demands with other production chains can be expensive due to market price volatility, even though the technology to produce biofuel is not as sophisticated or expensive compared to the petroleum production technology. This chapter also revealed that Indonesia's biofuel program has created new commodities,

[267] Adapted from Directorate General of Estates, *2018-2020 Sugarcane Statistic*, 2019, 23, http://www.ditjenbun.pertanian.go.id/.

which are profitable for export. Indonesia's biofuel and the upcoming *green fuel* may become a source of new income. When crude oil is more expensive than palm oil, biofuel can generate profit.

Table 9. Assessments on biofuel sources' viability to ensure military energy security.

No	Property	Palm	Jatropha	Molasses
1	Production capacity	High (49.12 M tons)	Poor (385 tons)	Poor (84,590 tons)
2	Industrial capacity[268]	High (32 refineries, 12,362 Mkl, capacity at 74,8%)	Poor (Estimated < 400 kl)	Poor (3 refineries, 100 Ml)
3	Biofuel yield	High 1,116 liter/ton (FAME)	High 1,077 liter/ton (FAME)	Poor 289 liter/ton (Bioethanol)
4	Products	Biodiesel (B30) *Green fuel* (under-development)	Non-fuel product (Cosmetic, medicine)	Small drop-in for racing fuel (Pertamax racing) Non-fuel product (antiseptic, food)
5	Technology maturity	Commercially proven fuel technology	Commercially proven fuel technology	Commercially proven fuel technology
6	Cost at present	$0.78/liter $0.36/liter (subsidized)	$0.45/liter	$0.85/liter
7	Development stage	- B30 is implemented - Advance to *green fuel* is underway	One company initiated nanomizer technology to enhance jatropha-based biodiesel	No available projection of industrial support for fuel-grade bioethanol
8	Capable to meet military fuel demand	Yes	Not available	Not available
9	Trade-offs related to military energy security	- Fuel availability at higher fuel cost, adjustment cost on existing facility and equipment - Lower GHG emissions but less affordable - Guarantees fuel supply to mitigate fuel debt	Not available	Not available

Introducing other cheaper sources may significantly reduce the biofuel price at the pump over time. Therefore, Indonesia's biofuel production plants with their mainstream palm oil feedstock may need to have the capability to process raw material from multiple sources, not only bio-oil but also the biomass left over from palm, jatropha, and sugarcane.

268 Arif Rahmanulloh, "Indonesia Biofuel Annual Report 2021," Global Agriculture Information Network, June 29, 2021, https://apps.fas.usda.gov/newgainapi/api/Report/DownloadReportByFileName?fileName=Biofuels%20Annual_Jakarta_Indonesia_06-21-2021.pdf.

Pertamina's projects related to palm-based *green fuel* are ongoing and promising; therefore, it can be expected that *green fuel* will replace the current biofuel blends in the years ahead. Palm oil consumption, in particular, is likely to increase since *green fuel* does not require petroleum for blending.

The evidence in this chapter suggests that palm oil's massive production is the primary comparative advantage that enables it to serve as the most favorable source to secure Indonesia's military energy security at present and in the future compared to jatropha and molasses. Indonesia's current and projected military fuel demands are minimal compared to other sectors, accounting for only around 1% of national fuel consumption. Indonesia's biofuel capacity itself may be capable of securing the entire fuel supply for the military. At the same time, Indonesia's military will be one of the few agencies still consuming petroleum fuel, whereas others are mandated to use palm-based biofuel. Thus, Indonesia's military would not need to compete with other sectors to obtain petroleum fuel. On the other hand, current economic factors related to palm oil may not meet the affordability requirement for the military because the price of palm-based biofuel does not significantly affect the military's energy budget spending. If the palm-based biofuel price increases in the upcoming years, it may in fact burden the military fuel budget, which represents on average 4% of the entire defense budget. Therefore, this alternative fuel would likely increase the standing military's fuel debts, which would in turn weigh on the government spending budget and the biofuel producers' credit income.

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IV. PALM-BASED BIOFUEL FOR MILITARY ENERGY

Indonesia is the world's largest producer of palm oil, which gives Indonesia a strong starting position to harness biofuel potential, especially for the military's energy security. This chapter further investigates the potential of Indonesia's palm-based biofuel by examining the testing of palm-based biofuel in Indonesia's military and assessing the extent to which palm-based biofuel can support military energy security in terms of the economic and environmental aspects.

A. COMPATIBILITY OF PALM-BASED BIOFUEL WITH INDONESIA'S MILITARY EQUIPMENT

In order to achieve the goals of the mandatory biofuel program, the MEMR looked into the energy needs of Indonesia's military as one of the top consumers of fuel in Indonesia. Since most of Indonesia's military equipment uses diesel and avtur, the properties of palm-based biofuel need to be compatible with the military's engine systems. Indonesia's military has many types of equipment that use diesel and jet fuel, which is being replaced by B30 and bioavtur, respectively (see Tables 10 and 11). As for bioavtur, since 2018, Indonesia's biofuel joint venture managed to produce a palm kernel-based bioavtur J-2.4, which tested successfully using CN-235 220 aircraft as the flying testbed on September 6, 2021.[269] The J-2.4 consists of 2.4% bioavtur made from palm kernel oil produced by the current *green fuel* technology at Pertamina's refinery unit in Palembang.[270] The price of J-2.4 is expected to be around \$0.85 since the current competitive market with petroleum fuel puts bioavtur at a higher price.[271] It can be inferred

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[269] Indomiliter, "PT DI Lakukan Uji Coba Penggunaan Bioavtur Pada CN-235 220 Flying Test Bed," *Indomiliter* (blog), September 6, 2021, https://www.indomiliter.com/pt-di-lakukan-uji-coba-penggunaan-bioavtur-pada-cn-235-220-flying-test-bed/.

[270] Arif Budianto, "Mantap! Indonesia Sukses Ubah Minyak Sawit Jadi Bahan Bakar Pesawat," https://www.idxchannel.com/, September 6, 2021, https://www.idxchannel.com/economics/mantap-indonesia-sukses-ubah-minyak-sawit-jadi-bahan-bakar-pesawat.

[271] Safyra Primadhyta, "Gandeng Wilmar, Pertamina Bangun Pabrik Bioavtur US\$ 480 Juta," ekonomi, accessed September 6, 2021, https://www.cnnindonesia.com/ekonomi/20150812150523-85-71662/gandeng-wilmar-pertamina-bangun-pabrik-bioavtur-us--480-juta.

that the decision to use palm kernel oil rather than another biofuel is due to its lower price; it is half the price of CPO, so it will be affordable for the airlines.

Table 10. Indonesia's military B30 usage and cost per tank of fuel.

No	Equipment[272]	Fuel capacity (liter)[273]	Size[274] (unit)	Total fuel (liter)	B30 cost ($0.78/liter)	Compatibility issue
ARMY[275]						
1	Main battle tank	1,000	103	103,000	-	Common rail
2	Armored vehicle	400	767	306,800	-	-
3	Landing craft	50,000	19	950,000	-	-
4	Self-propelled gun	300	112	33,600	-	-
TOTAL ARMY UNITS TO BE FILLED ONCE				1,393,400	1,086,852	-
(NAVAL INFANTRY) MARINES[276]						
1	Armored vehicle	400	287	114,800	-	-
2	Self-propelled gun	300	22	6,600	-	-
TOTAL MARINE UNITS TO BE FILLED ONCE				121,400	94,692	-
NAVY[277]						
1	Submarines	50,000	3	150,000	-	Low temp operation
2	Frigates	70,000	7	490,000	-	Common rail, turbine
3	Patrol	50,000	122	6,100,000	-	-
4	Landing craft	50,000	76	3,800,000	-	-
5	Support	50,000	20	1,000,000	-	-
TOTAL NAVY UNITS TO BE FILLED ONCE				11,540,000	9,001,200	
AIR FORCE[278]						
1	Airbase power	32,000	38	1,216,000	-	-
2	Radar station	32,000	20	640,000	-	-
TOTAL AIR BASES & RADARS TO BE FILLED ONCE				1,856,000	1,447,680	-
TOTAL B30 COST				**14,910,800**	**11,630,424**	**-**

Fuel capacity is estimated and adjusted to the average value; B30 cost refers to Table 9, Ch 3.
Air force airbase and radar station fuel consumption is assumed at 28 liters/hour every week

272 IISS, "The Military Balance 2021" January 1, 2021, 266, https://www.tandfonline.com/doi/full/10.1080/04597222.2021.1868795.

273 "Janes: All the World's Aircraft: In Service," accessed October 29, 2021, https://customer-janes-com.libproxy.nps.edu/JAWAInServices/Reference; "Janes: Land Warfare Platforms: Armoured Fighting Vehicles," accessed October 29, 2021, https://customer-janes-com.libproxy.nps.edu/ArmouredFightingVehicles/Reference; "Janes: Fighting Ships," accessed October 29, 2021, https://customer-janes-com.libproxy.nps.edu/FightingShips/Reference.

274 IISS, 266.

275 Kerry Plowright, "TNI Fact Sheets," ADF, 2008, https://www.vostokstation.com.au/TNI-AD.pdf.

276 Plowright.

277 Bernard Kent and Carmel Sondakh, *Laksamana Kent Menjaga Laut Indonesia* (Jakarta, Indonesia: Gramedia Pustaka Utama, 2015), 67.

278 Scramble, "Indonesian Air Force," 2021, https://www.scramble.nl/planning/orbats/indonesia/indonesian-air-force#WITB472.

Table 11. Indonesia's military avtur usage and cost per tank of fuel.

No	Equipment[279]	Fuel capacity[280] (liter)	Size (unit) [281]	Total fuel (liter)	Avtur cost[282] ($0.75/liter)	J-2.4 cost[283] ($0.85/liter)
ARMY						
1	Attack helos	1,300	8	10,400	-	-
2	Heavy helos	3,000	16	48,000	-	-
3	Medium helos	800	66	52,800	-	-
4	Light helos	500	27	13,500	-	-
5	Light transport aircraft	2,000	7	14,000	-	-
TOTAL ARMY UNITS TO BE FILLED ONCE				138,700	104,025	117,895
NAVY						
1	Medium helos	1,500	12	18,000	-	-
2	Light helos	500	16	8,000	-	-
3	Light transport aircraft	2,000	6	12,000	-	-
4	Tactical transport aircraft	5,000	5	25,000	-	-
TOTAL NAVY UNITS TO BE FILLED ONCE				63,000	47,250	53,550
AIR FORCE[284]						
1	Heavy fighter aircraft	12,000	16	192,000	-	-
2	Medium fighter aircraft	4,000	25	100,000	-	-
3	Light fighter aircraft	2,000	44	88,000	-	-
4	Heavy transport aircraft	25,000	24	600,000	-	-
5	Heavy utility aircraft	20,000	4	80,000	-	-
6	Tactical utility aircraft	5,000	17	85,000	-	-
7	Light transport aircraft	2,000	9	18,000	-	-
8	Light attack aircraft	600	15	9,000	-	-
9	Trainer aircraft	400	42	16,800	-	-
10	Medium helos	800	25	20,000	-	-
11	Light helos	500	12	6,000	-	-
TOTAL AIR FORCE UNITS TO BE FILLED ONCE				1,214,800	1,023,600	1,032,580
TOTAL AVTUR COST				**1,416,500**	**1,062,375**	**1,204,025**

279 Flight Global, "2021 World Air Forces," 2021, 20, https://www.flightglobal.com/download?ac=75345.

280 Federation of American Scientists, "Rest of World Military Aircraft," 2021, https://man.fas.org/dod-101/sys/ac/row/index.html.

281 Flight Global, "2021 World Air Forces," 20.

282 Ministry of Energy and Mineral Resources (MEMR), "Handbook of Energy and Economy Statistics of Indonesia 2020," 34.

283 Primadhyta, "Gandeng Wilmar, Pertamina Bangun Pabrik Bioavtur US$ 480 Juta."

284 Janes, "All the World's Aircraft: In Service," 2021, https://customer-janes-com.libproxy.nps.edu/JAWAInServices/Reference?

From Table 10, it is evident that Indonesia's navy is the largest diesel fuel consumer among all the services. Yet, considering Indonesia's military fuel budget for 2021, which is IDR 6,112.7 billion ($424 million), if the military decided to operate all its equipment on a full tank per day, the cost of B30 and avtur would only allow for a month of operation or around 30–33 times of replenishment (see Table 12). From this evidence, it can be inferred that the military's fuel budget seems unable to provide a complete annual fuel supply. It may also reveal two fundamental findings: the fuel budget provided covers less than the actual yearly requirements, and the military consumes more than the allocated fuel budget. Since the military generally operates for a whole year, this condition underscores why Indonesia's military keeps running up fuel debts every year. It is also evident in the statement from Djoko Siswanto, the Directorate General of Oil and Gas in 2018, that the annual diesel fuel consumption for the military amounts to 627,000 kiloliters.[285] If calculated at the current B30 price, this amount of one type of fuel only costs around $483 million, which is over the FY2021 budget for military fuel.

MoD's regulation states that the military's fuel consumption comes from routine and contingency demands.[286] Furthermore, the routine fuel index also caters to the additional requests for fuel whenever the military is required to conduct non-war and unexpected operations.[287] Therefore, it can be concluded that the military's fuel debts mainly come from the additional demands, which do not have any limitations. The previous MoD regulation No.34/2008 limited the provision for this additional demand to 30% of the routine.[288] Nevertheless, since 2012, this 30% quota has been omitted, and the current regulation does not specify any limit.[289]

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[285] CNN Indonesia, "ESDM Imbau TNI Dan Polri Pakai Pertadex Untuk BBM Alutsista," Ekonomi, September 29, 2018, https://www.cnnindonesia.com/ekonomi/20180929011804-85-334168/esdm-imbau-tni-dan-polri-pakai-pertadex-untuk-bbm-alutsista.

[286] Ministry of Defense, "MoD Regulation No.37/2018 of Fuel Standard Index," December 31, 2018, 11, https://www.kemhan.go.id/kuathan/wp-content/uploads/2020/02/Permenhan_37_2018_ttg_Standar_Indeks_BBMP.pdf.

[287] Ministry of Defense, 12.

[288] Ministry of Defense, "MoD Regulation No.34/2008" December 17, 2008, 11, https://peraturan.go.id/common/dokumen/bn/2008/bn113-2008.pdf.

[289] Ministry of Defense, "MoD Regulation No.49/2012" December 28, 2012, 17, https://peraturan.go.id/common/dokumen/bn/2013/bn159-2013.pdf.

Table 12. Fuel budget relationship to fuel type and ratio for calculated provision (in millions of dollars).[290]

	Fuel budget	Fuel budget/ month	Cost of		Calculated Provision
			B30	J-2.4	
FY2020	$389	$32.4	$11.6	$1.2	30 times/year (2.5 times/month)
FY2021	$424	$35.3			33 times/year (2.7 times/month)
The total cost of a one-time full tank			$12.8		

The calculated provision is obtained by dividing the fuel budget by the total cost of fuel.
The cost of B30 and J-2.4 is referred to in Tables 10 and 11.

According to LEMIGAS, biodiesel (B20/30) has been tested and used by the Indonesian Navy and Pelni (the national shipyard) ships since 2019.[291] They continue to use biodiesel with some exceptions, such as ships powered by engines that use the common rail injection system, turbine system, and submarines (see Table 13).[292] The testing of B30 by the Indonesian Navy and Pelni proved to be successful and acceptable. Therefore, it has continued to be used. Nevertheless, B30 usage by the navy is still limited. For example, in 2020, the 2nd Armada Command (Koarmada II) only used B30 for 13 ships (32.5%) out of 40 ships from the 65 ships in its inventory.[293] The same condition may indicate the same pattern with other armada commands since the types of ships are identical. Therefore, it can be inferred that B30 usage in the entire armada of the Indonesian Navy may be less than 50%.

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290 Adapted from Ministry of Finance, "2020 RKAKL," 13; Ministry of Finance, "2021 RKAKL," 39.

291 Faridha et al., *Biodiesel Jejak Panjang Perjuangan*, 1st ed. (Jakarta, Indonesia: Ministry of Energy and Mineral Resources (MEMR), 2021), 65, https://www.esdm.go.id/assets/media/content/content-buku-biodiesel-jejak-panjang-perjuangan-.pdf.

292 M. Nur Safrudin, "Biofuel B-20 Effect on Diesel Engine," October 1, 2020, 10, https://www.tnial.mil.id/assets/majalah/PDF-20201105-174846.pdf.

293 Heru Prasetia, Okol Sri Suharyo, and Udisubakti Cipto Mulyono, "Strategy of Accelerate the Application Biodiesel in KRI Koarmada II to Increase Alutsista Combat Readiness," *STTAL Postgraduate - International Conference* 5, no. 1 (June 10, 2021): 1, http://www.seminarpasca-sttal.ac.id/index.php/seminarpasca-sttal/article/view/90.

Table 13. Evaluation of B30 usage compared to diesel fuel in Indonesian Navy and Pelni.[294]

No	Property	Consideration	Solution	Outcome
1	Corrosive to Bronze, Copper, Lead, Tin, Zinc	Several marine fuel valves use bronze	Replace fuel system line material with stainless steel or other non-reactive metal	Added cost for replacement
2	Incompatible with several plastics and rubber (Buna-N, nitrile, natural rubber, polyethylene, polypropylene)	Soften, degrade, and permeate the material, causing damage to the system	Replace gasket, seal, and hose with compatible material (Teflon, Nylon, Chemraz, Hifluor, Perfluoroelastomer, Viton)	Added cost for replacement
3	Biodiesel is a good solvent	Increase filter plugging at initial use	Filter replacement is more frequent at initial use; clean and flush fuel system before using biofuel	Added cost for replacement
4	Biodiesel cloud point higher (~18 degC)	Biodiesel emulsifies/ gels creating stress/ clogging on lines	Fuel heater on lines and tanks; periodic circulation of fuel in system	Added cost for upgrades
5	Biodiesel oxidizes faster (~18-45 days)	Fuel tanks have air-breathers to regulate pressure, so it increases oxidation and water accumulation	Water separator/purification on the lines/tanks; biofuel additive; no storage for more than 5/6 months	Added cost for upgrades
6	Biodiesel contains more particles	Increased clogging on high-pressure fuel injector (common rail)	Use multiple filtrations recommended for biofuel (1–5 microns)	Added cost for upgrades
7	Biofuel consumption is higher	Biofuel lowers the power output 2–10%; increases fuel consumption 1–3%	Increases fuel demand	Added cost for more fuel purchases

From Table 13, it appears that the navy is more concerned about the technical aspects related to B30 usage, which is reflected in its low realization rate in the use of B30 for its entire armada. The outcomes from B30 usage in navy ships show the additional cost related to conversion compatibility and increased consumption. The cost and performance factors may become the main reason that hinders the navy from using B30 entirely. With a limited budget for fuel and the compatibility issues that biofuels pose for the navy's equipment, Indonesia's military may remain skeptical and hold back the current B30 fuel. On the other

294 Adapted from M. Nur Safrudin, "Biofuel B-20 Effect on Diesel Engine," October 1, 2020, 8–12, https://www.tnial.mil.id/assets/majalah/PDF-20201105-174846.pdf.

hand, Indonesia's military may fully support the use of biofuel if the projections for *green fuel* under Pertamina in the upcoming years is proven successful.

The military has expressed concerns over safety and the risk of damage to their expensive engine systems. According to the Directorate General of Oil and Gas, Djoko Siswanto, on August 24, 2018, the government declared a temporary relaxation from mandatory biofuel usage for three sectors: the National Electricity Company (PLN), Freeport Co., and Indonesian Armed Forces equipment.[295] Both PLN and Freeport argue that their systems are not fully prepared to use biofuel. Freeport's concern is that its plant's location in a mountain may cause condensation because the biodiesel's cloud point is higher than that of diesel. Yet, along with the relaxation in 2018, PLN started to use B20-30 biofuel for its diesel electrical power plants, which consist of 4,435 units with a total capacity of 4,077 MW, whereas the fuel consumption needed for all power plants is around 2.2 million kiloliters.[296] In addition, the Director of Logistics Supply Chain and Infrastructure of Pertamina, Gandhi Sriwidodo, stated that Pertamina could supply biodiesel for Freeport's lower altitude hub in Timika.[297] Therefore, it can be inferred that Pertamina's persistence in promoting biodiesel may be due to the need to achieve a return on investment or generate revenue as much as possible so that it can sustain its biofuel program, which requires enormous investment and subsidies to keep biofuel prices lower than petroleum at the pump.

As for the military, the armed forces are concerned about biofuel's compatibility with their equipment and the risk of possible breakdowns that could cause a significant drop in their combat readiness. In addition, all service branches rely heavily on imports for their components, which may take a long period to procure for repairs. By contrast, the navy's engineering, logistics, and maintenance efforts are supported more heavily by national and local industries, with more personnel than those supporting the air force and army.

[295] Anastasia Arvirianty, "Tiga Sektor Ini Tak Harus Ikuti Aturan Bahan Bakar Nabati B20," CNBC Indonesia, August 24, 2018, https://www.cnbcindonesia.com/news/20180824080757-4-29973/tiga-sektor-ini-tak-harus-ikuti-aturan-bahan-bakar-nabati-b20.

[296] Arvirianty, "Tiga Sektor Ini Tak Harus Ikuti Aturan Bahan Bakar Nabati B20."

[297] Liputan6, "Pertamina Tetap Pasok Biodiesel 20 Persen untuk Freeport Indonesia," September 3, 2018, https://www.liputan6.com/bisnis/read/3635625/pertamina-tetap-pasok-biodiesel-20-persen-untuk-freeport-indonesia.

Nevertheless, all the services encounter the same problems: the license, certification, or conformity from their combat system's manufacturer regarding the use of biofuel for the equipment. Therefore, the military needs to address the compatibility issues with its combat system manufacturers.

The military may have the option to choose whether to be prioritized for consuming petroleum fuel or using any available fuel. Under the current mandate, fuel is a free variable and engines are a bound variable, and engine manufacturers are not required to alter or enhance their products to fit the biofuel-grade specifications. This can be justified since the crude oil supply is more stable when compared to the oil embargo event back in the 1970s. Therefore, the MEMR is convinced that there is no technical drawback for automobiles using B30.[298] However, as shown in Table 13, B30 still poses some compatibility issues. From this situation, it can be inferred that the automotive industries and other military-related propulsion entities are reluctant or slow to adapt their system for using biofuel. Furthermore, EIA has observed that interest in flexible fuel vehicles (FFV) has declined due to the popularity of battery-powered electric vehicles.[299] Nonetheless, the military does not have any electric-powered combat system. Thus, in the foreseeable future, military combat equipment will still rely on the internal combustion engine.

Therefore, the military may need to consider having flexibility in terms of the types of fuels it can use. Indonesia's military equipment, as depicted in Table 10, has been using B30 since the government mandate in 2019. Because mandatory biofuel is effective for military and government agencies, the necessity to have flexible fuel capability for military equipment should drive both the automotive and the biofuel industries to work together to adapt Indonesia's biofuel. An FFV is the same as the normal vehicle but with a modified and

[298] Ministry of Energy and Mineral Resources (MEMR), "Tak Perlu Khawatir, B30 Aman Digunakan," ESDM, January 28, 2020, https://www.esdm.go.id/id/media-center/arsip-berita/tak-perlu-khawatir-b30-aman-digunakan.

[299] Green Car Congress, "EIA Projects Decline in Transportation Sector Energy Consumption through 2037 despite Increase in VMT, Followed by Increase," January 2019, https://www.greencarcongress.com/2019/01/20190128-eia.html.

calibrated fuel system for biodiesel blends above B20 or E85 (bioethanol 85%) for the gasoline engine.[300]

The initiative for flexible fuel has been considered since the invention of the car in the early 1900s. Henry Ford's Model T car could use gasoline, ethanol, or both.[301] The emergence of bioethanol was the impetus for FFVs that first emerged in 1980 to operate with many types of fuels (or fuel blends).[302] The multi-fuel technology is mostly used in many civilian vehicles, which gives them fuel redundancy. As for the military, the use of FFV engines may be convenient and readily adopted; as stated by Simon Dunstan, "the multi-fuel policy had prominent attractions whereby, at the flick of a switch in the driving compartment, military vehicles could refuel from various kinds of fuels.[303] Some of Indonesia's military is already equipped with a multi-fuel engine. For example, the LVTP-7A1 armored personnel carrier made by the United States can use multi-fuel.[304] Others, like the RM-70 series mobile rocket artillery made by the former Czechoslovakia, are also capable of being operated with multi-fuel.[305]

The U.S. military offers excellent examples of the relationship between FFVs and single fuel. One example is the M1A1 Abrams main battle tank; it is powered by the Honeywell AGT1500 gas turbine engine and has multi-fuel capabilities.[306] Moreover, for its aircraft, the U.S. military has been using JP-8 (jet propellant), which is Jet A-1 (kerosene-

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[300] Meisam Ahmadi Ghadikolaei et al., "Why Is the World Not yet Ready to Use Alternative Fuel Vehicles?," *Heliyon* 7, no. 7 (July 1, 2021): 17–18, https://doi.org/10.1016/j.heliyon.2021.e07527.

[301] Frank Markus, "What Is Flex Fuel and Where Does It Fit in the Automotive Future?," *Motor Trend*, April 3, 2020, https://www.motortrend.com/news/what-is-flex-fuel/.

[302] S.T. Coelho and José Goldemberg, "Alternative Transportation Fuels: Contemporary Case Studies," in *Encyclopedia of Energy* (Amsterdam, Netherlands: Elsevier, 2004), 67–80, https://doi.org/10.1016/B0-12-176480-X/00177-7.

[303] Simon Dunstan, *Chieftain Main Battle Tank 1965–2003* (London, UK: Bloomsbury Publishing, 2012).

[304] John Pike, "Assault Amphibian Vehicle Personnel Model 7A1 (AAVP7A1)," April 2000, https://fas.org/man/dod-101/sys/land/aavp7a1.htm.

[305] TankNutDave, "The Czechoslovakian RM-70 MLRS Series," *TankNutDave.Com* (blog), 2021, https://tanknutdave.com/the-czechoslovakian-rm-70-mlrs-series/.

[306] Honeywell, "AGT1500 Gas Turbine Engine," 2021, https://aerospace.honeywell.com/us/en/learn/products/engines/agt-1500.

based) fuel with military additive packages, since 1979.[307] JP-8 is a single fuel that can be used in multiple platforms, including aircraft, M1A1 Abrams, and ground vehicles with a diesel-powered engine like the Humvee.[308] The usage of single fuel has simplified the logistics with some tradeoff on engine performance and reliability in favor of modularity.[309] JP-8 has been available since 2008, when the Energy & Environmental Research Center (EERC) successfully created it from multiple biofuel feedstock (crops oil, waste greases).[310] EERC's method consists of a thermocatalytic cracking and separation process.[311] This process may be similar to Pertamina's ongoing *green fuel* project, which uses thermal and catalytic cracking with pyrolysis.[312] Therefore, it can be inferred that Indonesia may already have one unrealized solution for military energy security. Indonesia's military, however, needs to consider the FFVs in light of the upcoming completion of MEF; thus, the subsequent procurement should have the fuel flexibility feature, and Pertamina's *green fuel* development may need to explore a single fuel program like the JP-8.

To forecast whether the single fuel program is beneficial and viable for Indonesia's military, the military's fuel consumption must be calculated with the available fuel that can be used as the single fuel in Indonesia. Indonesia's refinery may produce JP-5, which is a JP-8 alternative. By having a single-fuel approach, Indonesia's military may find it cheaper to refuel (see Table 14). With the ongoing *green fuel* program, Indonesia's military could propose a single-fuel standard based on palm-based biofuel, which can then be used for other

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307 W. E. Harrison et al., "Advanced Jet Fuels — JP-4 Through JP-8 and Beyond," in *Volume 3: Coal, Biomass and Alternative Fuels; Combustion and Fuels; Oil and Gas Applications; Cycle Innovations* (ASME 1995 International Gas Turbine and Aeroengine Congress and Exposition, Houston, Texas, USA: American Society of Mechanical Engineers, 1995), 3, https://doi.org/10.1115/95-GT-223.

308 Trevor Anderson, "Diesel on The Ground - A Look at NATO Fuels and Vehicles," Diesel Army, September 25, 2015, https://www.dieselarmy.com/features/history/diesel-on-the-ground-a-look-at-nato-fuels-and-vehicles/.

309 Anderson.

310 Green Car Congress, "EERC 100% Renewable Biojet Fuel Meets Key JP-8 Standards," September 29, 2008, https://www.greencarcongress.com/2008/09/eerc-100-renewa.html.

311 Green Car Congress.

312 Isnandar Yunanto, Sri Haryati, and Muhammad Djoni Bustan, "Pyrolysis of Vacuum Residue By Thermal and Catalytic Cracking Using Active Alumina Catalyst," *IJFAC (Indonesian Journal of Fundamental and Applied Chemistry)* 4, no. 1 (February 13, 2019): 31, https://doi.org/10.24845/ijfac.v4.i1.29.

government agencies such as the PLN and commercially by companies that share similar fuel consumption patterns with the military. One potential downside, however, is that the price for a single fuel grade based on *green diesel* fuel for the military is expected to be about $1.4 per liter (IDR 20,000), which is more expensive than what the current military now consumes.[313]

Table 14. Cost comparison for single fuel program.

Current fuel Consumption	**Single Fuel**	**Next-gen *Green fuel***
B30 ($0.78/liter) 14,000 KL $12.1 million	JP-5/JP-8 ($0.5/liter)[314] $8 million -37.5%	*Green diesel* ($1.4/liter)[315]
Avtur ($0.75/liter) 1,400 KL $1.6 million		
Total $12.8 million		
30 days ops	50 days ops +60%	20 days ops

The calculation is based on the FY2021 military fuel budget divided by the total cost of fuel consumption.

The current fuel consumption values are taken from Tables 10 and 11.

B. ENVIRONMENTAL SUSTAINABILITY OF PALM-BASED BIOFUEL

Indonesia has a comparative advantage over other countries due to its abundant palm oil production. To determine whether Indonesia's palm-based biofuel can support its military, it is essential to investigate the environmental sustainability factors. Biofuel is very susceptible to climate and weather disruption since the harvest of the crops will define how much biofuel can be produced. The biofuel program is typically viewed as a supplemental energy resource to be tapped when the country's energy security is threatened due to Indonesia's heavy reliance on petroleum fuel. The search for alternative fuels will be one of the country's main agendas since any disruption to the current petroleum fuel supply will

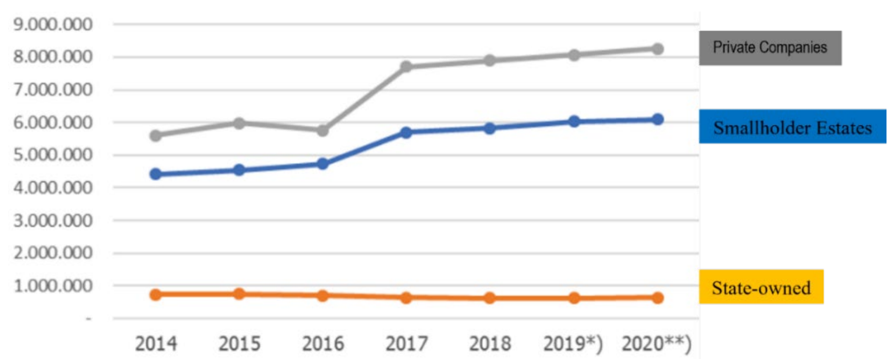
313 Anisatul Umah, "Harga Green Diesel Lebih Mahal, Bisa Rp 20 Ribu/Liter!" CNBC Indonesia, May 2021, https://www.cnbcindonesia.com/news/20210504172817-4-243148/harga-green-diesel-lebih-mahal-bisa-rp-20-ribu-liter.

314 Jet-a1-fuel, "JP 8 $82.29564 per Barrel," September 2021, https://jet-a1-fuel.com/fuel-price/jp-8.

315 Umah, "Harga Green Diesel Lebih Mahal, Bisa Rp 20 Ribu/Liter!"

reduce the country's GDP. As already mentioned, energy insecurity has economic repercussions because Indonesia's petroleum fuels are mainly supplied by state-owned corporations (such as Pertamina) and private companies in the country.

As one of the largest oil companies in Indonesia, Pertamina does not need to purchase Indonesia's crude oil since Pertamina has the privilege to extract it. Yet, Pertamina does not have its own palm plantation to provide the input of palm oil required for biofuel. In 2015, Pertamina allocated around $200 million with the state-owned palm oil company *PT Perkebunan Nusantara* (PTPN) in Sumatra and Kalimantan to develop biofuel plantation; however, as reported in 2021, this joint venture not focusing on owning palm plantation but more into building biomass electrical plant.[316] As a result, the state-owned palm plantation capacity is only a fraction of that belonging to private entities and other ownership (see Figure 23). This condition means that the government must pay more to get palm oil since the price will be subject to the market.



* temporary data, ** estimated data

Figure 23. The expansion of palm plantations in Indonesia annually in hectares.[317]

[316] MENAFN, "Biodiesel Pertamina To Work On Plantation Business," May 10, 2015, https://menafn.com/1094207822/Biodiesel-Pertamina-To-Work-On-Plantation-Business; Pertamina, "The Synergy between Pertamina and PTPN III Reduces Carbon Emissions of 70 Thousand Tons per Year from the Utilization of POME," August 21, 2021, https://www.pertamina.com/en/news-room/news-release/ www.pertamina.com.

[317] Source: PASPI, *Mitos Dan Fakta Industri Minyak Sawit Indonesia Dalam Isu Sosial, Ekonomi Dan Lingkungan Global* (Bogor, Indonesia: Palm Oil Agribusiness Strategic Policy Institute, 2016), 3, https://agroklimatologippks.files.wordpress.com/2016/02/mitosfakta.pdf.

Indonesia's palm oil is heavily exported since the demand for it is high. Therefore, crude palm oil is considered a strategic resource for Indonesia. Domestically, only a small portion of it is used for biofuel production. The ongoing mandatory biofuel program will require a greater amount of palm oil over time. The current market has provided Indonesia's palm oil producers with steady and proven beneficial trade. However, Indonesia's palm oil producers may encounter a market transformation because they will need to provide a steady supply of palm oil at a beneficial price for the government. Significantly, the government's target on biofuel is quite ambitious. In fact, biofuel has already caught up with petroleum fuels in terms of its share of national energy consumption. Therefore, in the next decade, the demand for domestic palm oil will most likely increase significantly (see Figure 24).

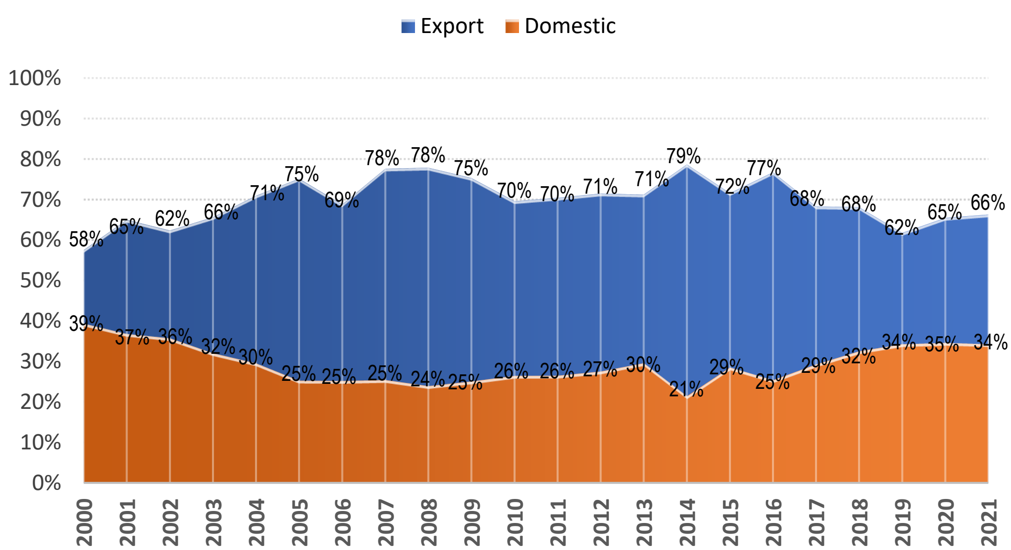


Figure 24. The use of Indonesia's palm oil for exports and domestic consumption.[318]

[318] Adapted from Indexmundi, "Indonesia Palm Oil Domestic Consumption by Year (1000 MT)," accessed November 15, 2021, https://www.indexmundi.com/agriculture/?country=id&commodity=palm-oil&graph=domestic-consumption; Indexmundi, "Indonesia Palm Oil Exports by Year (1000 MT)," accessed November 15, 2021, https://www.indexmundi.com/agriculture/?country=id&commodity=palm-oil&graph=exports.

Indonesia's government is the leading sector in the biofuel program. To support the biofuel project nationwide, the government needs to attract palm-oil producers. Currently, the government relies on the biofuel subsidy from the export tax on palm oil and its derivatives. The condition is likely to continue until palm oil and crude oil prices are comparably affordable, enabling people to purchase biofuel at the pump. Therefore, the government has postponed advancing into B40 and remained at the current mixture level of B30. The current higher price of CPO has been the main factor or the weakness that is holding back the biodiesel program to reach the higher mixture. In contrast, Pertamina is perfecting *green fuel*, which does not need to incorporate a petroleum fuel in the mixture. If this project is successfully completed, it will likely increase the demand for palm oil for biofuels. Although Indonesia has achieved a new milestone as a producer of *green fuel* and has large CPO reserves, the palm oil supply will be exhausted rapidly in the next decade if Indonesia cannot manage energy efficiency as its population continues to grow.

The eras of the two world wars and the Cold War provided numerous examples of fuel shortages that have driven many countries to biofuel. Across the globe, the most significant motivations are the existing geographical aspects of the countries themselves as well as the cost-benefit or economic factors rather than fuel shortages, existing crops, and materials in the countries.[319] The geographical factor defines a country's crops, and not all countries can grow palm. Therefore, to sustain biofuel, a country needs to be able to produce it from diverse sources. As presented in "Historical Perspective of Biofuels: Learning from the Past to Rediscover the Future," Gerhard Knothe has argued that the optimal method to achieve sustainable biofuel production is by expanding its viable sources to include animal fats and waste cooking oil.[320] This diversification factor is essential and potentially lucrative for Indonesia because it has many available sources such as jatropha, molasses, and other spent or waste oil. Indonesia needs to have the integrated capability of producing biofuel from multi-sources; consequently, the price of its biofuel product can be

[319] D. D. Songstad et al., "Historical Perspective of Biofuels: Learning from the Past to Rediscover the Future," *In Vitro Cellular & Developmental Biology. Plant* 45, no. 3 (2009): 192.

[320] Songstad et al., 192.

decreased significantly since these sources come at a much lower price than CPO and crude oil.

Indonesia's palm-based biofuel program faces one main vulnerability: the environmental issue. There have been many debates as to whether palm-oil plantations and their biofuel derivatives help reduce GHG emissions. Like other biofuel sources, palm oil, which is derived from the fruit of the palm tree, is at the center of conflicting demands for its use by food and fuel producers. Indonesia has managed to reduce the deforestation rate since 2018 to meet its contribution to the 2015 Paris Climate Agreement. The target is "to limit annual deforestation to 325,000 hectares in 2020–2030," and deforestation caused by palm oil plantations has dissipated in recent years (see Figure 25).[321] Nevertheless, deforestation is still occurring and remains a main concern, and the government needs to prevent further forest losses.

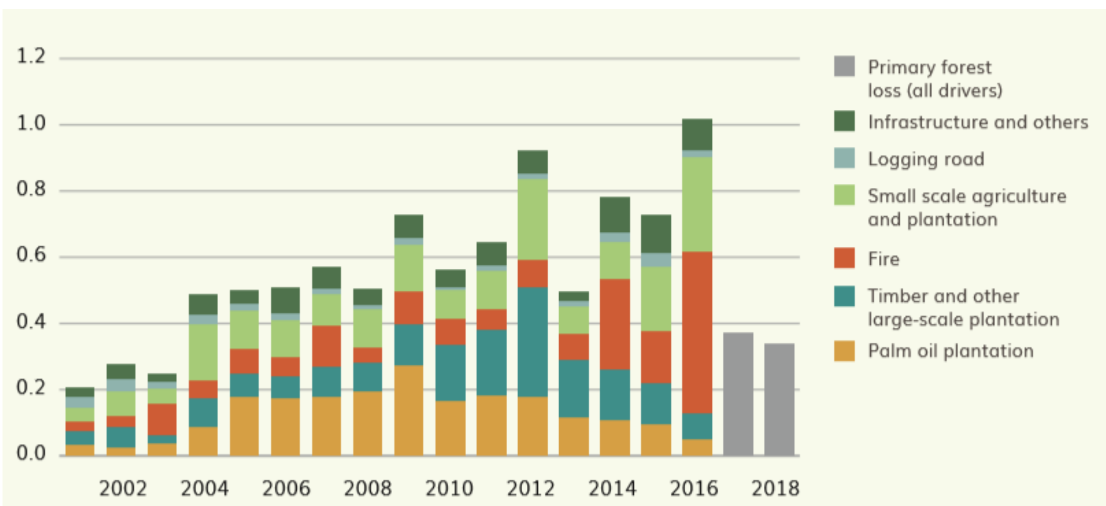


Figure 25. Indonesia's deforestation causes.[322]

[321] Arief Wijaya, Tjokorda Nirarta "Koni" Samadhi, and Reidinar Juliane, "Indonesia Is Reducing Deforestation, but Problem Areas Remain," July 24, 2019, https://www.wri.org/insights/indonesia-reducing-deforestation-problem-areas-remain.

[322] Source: NYDF, "Indonesia: A Sign of Hope for Reducing Deforestation?," September 2019, https://forestdeclaration.org/the-latest/case-study-indonesia.

Another vital factor for palm crops is the weather. The weather is directly related to harvest yield, defining crude palm oil production. For example, if a palm crop has a 200–300 mm/year water deficit, production of fresh fruit bunches (FFB) decreases by 21–32%.[323] The decrease in FFB production reaches 60% if the water deficit climbs to more than 500 mm/year.[324] In 2015, El Niño caused severe drought (dry spell) in the areas of Indonesia's most extensive palm plantations, such as di Riau, Lampung, Jambi, and South Sumatra.[325] This event reduced the FFB up to 60% in the most severe drought area in Lampung, which had a rainfall deficit of 524 mm/year.[326] Therefore, it can be inferred that the weather, affected by climate change, is indeed a factor that will likely affect Indonesia's palm oil production.

Undoubtedly, Indonesia will face alarming adverse impacts from climate change, but it will also have to contend with environmental damage caused by the methods used to expand palm plantations. Indonesia forecasts rising sea levels and droughts in the following decades. Meanwhile, palm plantations have been converting peatland to support their crops. In 2012, Indonesia had 7.8 million hectares of palm crop, of which 700–800 thousand hectares (8–10%) were peatland.[327] In 2016, the palm cultivation in peatlands had reached around 2 million hectares, an increase of 150% compared to 2012.[328] The conversion of peatland to support palm crops causes peat drainage and oxidation. In turn, the surrounding lands become prone to fires and floods and the salinity of nearby

323 Bappenas, *Indonesia Climate Change Sectoral Roadmap (ICCSR): Sektor Pertanian* (Jakarta, Indonesia: Republic of Indonesia, 2010), 21, https://www.bappenas.go.id/files/2613/5183/0762/sektor-pertanian__20110217190317__0.pdf.

324 Bappenas, 21.

325 Nuzul Hijri Darlan and Iput Pradiko, "Dampak El Niño 2015 terhadap Performa Tanaman Kelapa Sawit di Sumatera Bagian Tengah dan Selatan" [Effect of 2015 El Nino on Palm Oil Performance in Central and Southern Sumatera] *Jurnal Tanah dan Iklim* 40, no. 2 (October 10, 2016): 119.

326 Darlan and Pradiko, 117.

327 D. A. P. Sari, A.F. Falatehan, and R.Y. Ramadhonah, "The Social and Economic Impacts of Peat Land Palm Oil Plantation in Indonesia," *Journal of Physics: Conference Series* 1364 (December 2019): 1, https://doi.org/10.1088/1742-6596/1364/1/012017.

328 Wetlands, "Towards Sustainable Palm Oil," *Wetlands International* (blog), January 2016, https://www.wetlands.org/casestudy/towards-sustainable-palm-oil/.

freshwater sources increases, exacerbating the adverse impacts anticipated from climate change.[329]

By 2050, the extreme wet and dry seasons are forecasted to reduce palm oil production by 21.4% and sugar (related to molasses) by 17.1%.[330] In addition, Indonesia is also susceptible rising sea levels forecasted to inundate the area of palm crops located in the peatlands (see Figure 26). By 2100, many of Indonesia's coastal cities, including the peatlands, are forecasted to be inundated due to the rising sea level and the annual flood.[331] Therefore, Indonesia's pursuit of palm oil and other crops produced in the peatlands may likely cause environmental issues in the long term, eventually diminishing palm-based biofuel's sustainability if such impacts are not prepared for or mitigated as early as possible.

The impact of climate change on the sustainability of palm oil-based biofuels needs to be addressed as early as possible. Other renewable energies that are able to meet the needs of palm oil-based biofuels need to be worked on optimally, especially to replace the role of fuel in power plants. Therefore, it will also ensure the availability of fuel supply for the military, because the demand for palm biofuel will decrease. Consequently, the state needs to prepare Pertamina to transform from an extractive or mining company to be able to harvest renewable energy on a national scale as soon as possible. Otherwise, Indonesia will face the shock of large-scale fuel shortages as adaptation to renewable energy is incomplete.

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329 "The Challenges of Growing Oil Palm on Peatlands," RSPO - Roundtable on Sustainable Palm Oil, October 30, 2017, https://rspo.org/news-and-events/news/the-challenges-of-growing-oil-palm-on-peatlands.

330 Bappenas, *Indonesia Climate Change Sectoral Roadmap (ICCSR): Synthesis Report*, 1st ed., (Jakarta: Republic of Indonesia, 2010), 37, https://www.bappenas.go.id/files/2713/5182/6385/synthesis-roadmap__20110217190358__0.pdf.

331 Climate Central, "Land Projected to Be below Annual Flood Level in 2100," 2021, https://coastal.climatecentral.org/.

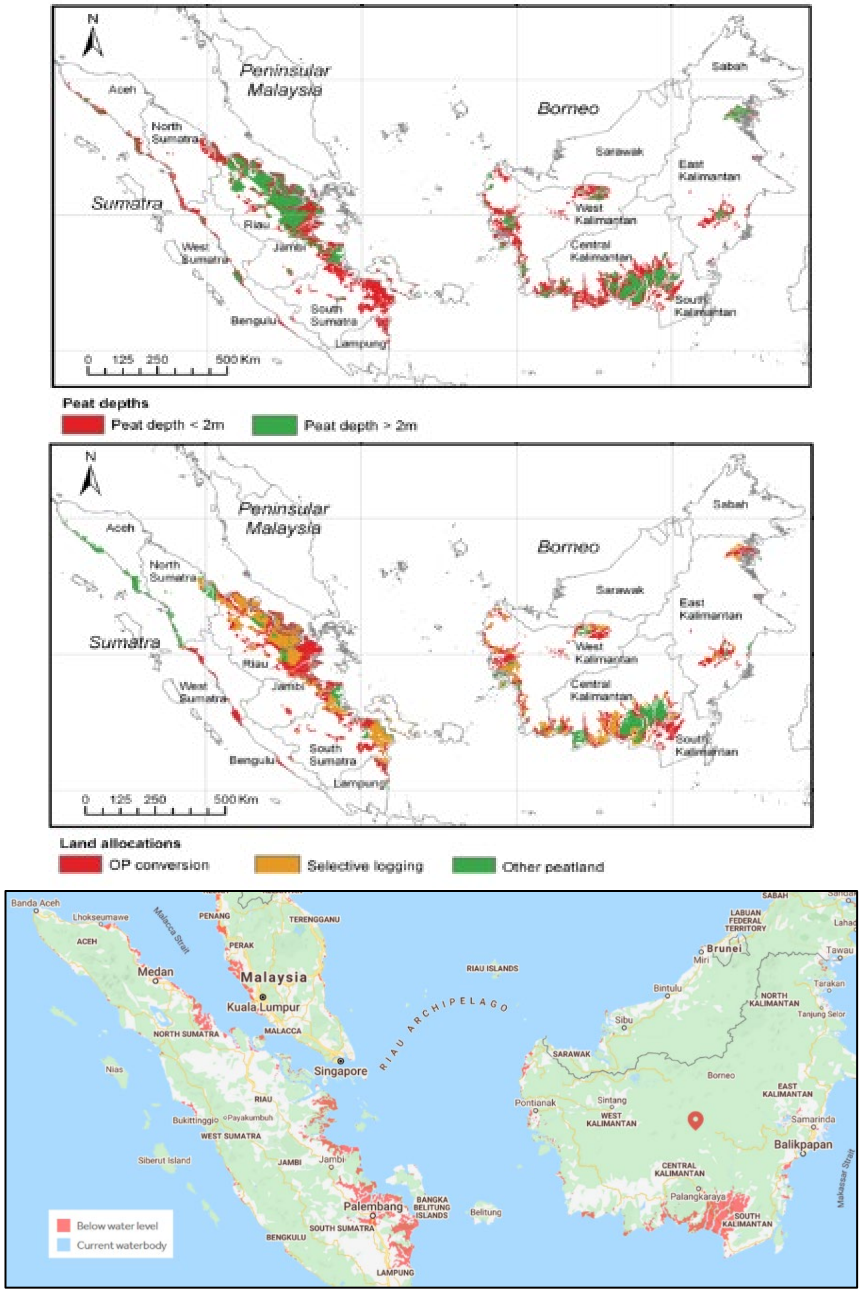

Figure 26. Indonesia's palm crops in peatlands (top)[332] and Indonesia's forecasted inundated land by 2100 (bottom).[333]

[332] Source: Jukka Miettinen et al., *Historical Analysis and Projection of Oil Palm Plantation Expansion on Peatland in Southeast Asia* (Washington, DC: International Council on Clean Transportation, 2012), 28, https://theicct.org/sites/default/files/publications/ICCT_palm-expansion_Feb2012.pdf.

[333] Source: Climate Central, "Land Projected to Be below Annual Flood Level in 2100."

Any solution for the imminent threat to peatlands must be carried out on a nationwide scale. One holistic solution to sustain palm production is offered by applying the proper soil compaction, fertilization, water management, and shorter crop stems.[334] Moreover, Elham Sumarga, Lars Hein, Aljosja Hooijer, and Ronald Vernimmen argue that the palm crops in peatlands could only be sustained for a short term and concluded that in 100 years 46% of the palm crop in the peatland of Kalimantan would be susceptible to near-permanent inundation, with only 12% remaining intact.[335] Meanwhile, the government realizes that palm crops in the peatlands are harmful to biodiversity, and the conversion has increased GHG emissions. To reduce adverse climate impacts, plantation land that interferes with the hydrology of peat structure must be retired, and the area restored to its original ecosystem function.[336]

With this in mind, in 2016, Indonesia created the Peatland Restoration Agency, or *Badan Restorasi Gambut* (BRG), to prevent the destruction of peatland. The agency has been restoring and rehabilitating the peatlands by implementing rewetting to increase the moisture content. The rewetting is accomplished by building cover canal blocks and water reservoirs over the peatlands.[337] BRG's target is to restore 1.4 million hectares of peatland; by 2020 it had restored 535,000 hectares out of the 2018–2020 target of 555,000 hectares (97% realization).[338] Eventually, Indonesia will not be able to neglect the importance of environmental sustainability and imminent climate change issues. Palm-based biofuel as renewable energy may cost Indonesia beyond its economic value if development and production are not managed equally to sustain its impact on the environment on a broader scope. Moreover, in 2020, according to the latest review of environmental sustainability of biofuel by Life Cycle Assessment (LCA), the Global Warming Potential (GWP) of palm,

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[334] Sari, Falatehan, and Ramadhonah, "The Social and Economic Impacts of Peat Land Palm Oil Plantation in Indonesia," 8.

[335] Elham Sumarga et al., "Hydrological and Economic Effects of Oil Palm Cultivation in Indonesian Peatlands," *Ecology and Society* 21, no. 2 (June 28, 2016): 10, https://doi.org/10.5751/ES-08490-210252.

[336] Belinda Morris and Gillian Lui, "Iklim dan Penggunaan Lahan Strategi Minyak Sawit Terbaru 2018–2021," The David and Lucile Packard Foundation, October 2018, 3, https://www.packard.org/wp-content/uploads/2020/01/Palm-Oil-Strategy-Revised-2018-2021-Bahasa-Revised-2020.pdf.

[337] BRG, "5 Years Report : Peatlands Restoration," 2020, 28, https://brg.go.id/publikasi/.

[338] BRG, 32.

molasses, and jatropha are at par.[339] Therefore, these sources could meet the EU renewable energy directive (RED), but only on condition of no change in land use (see Figure 27).

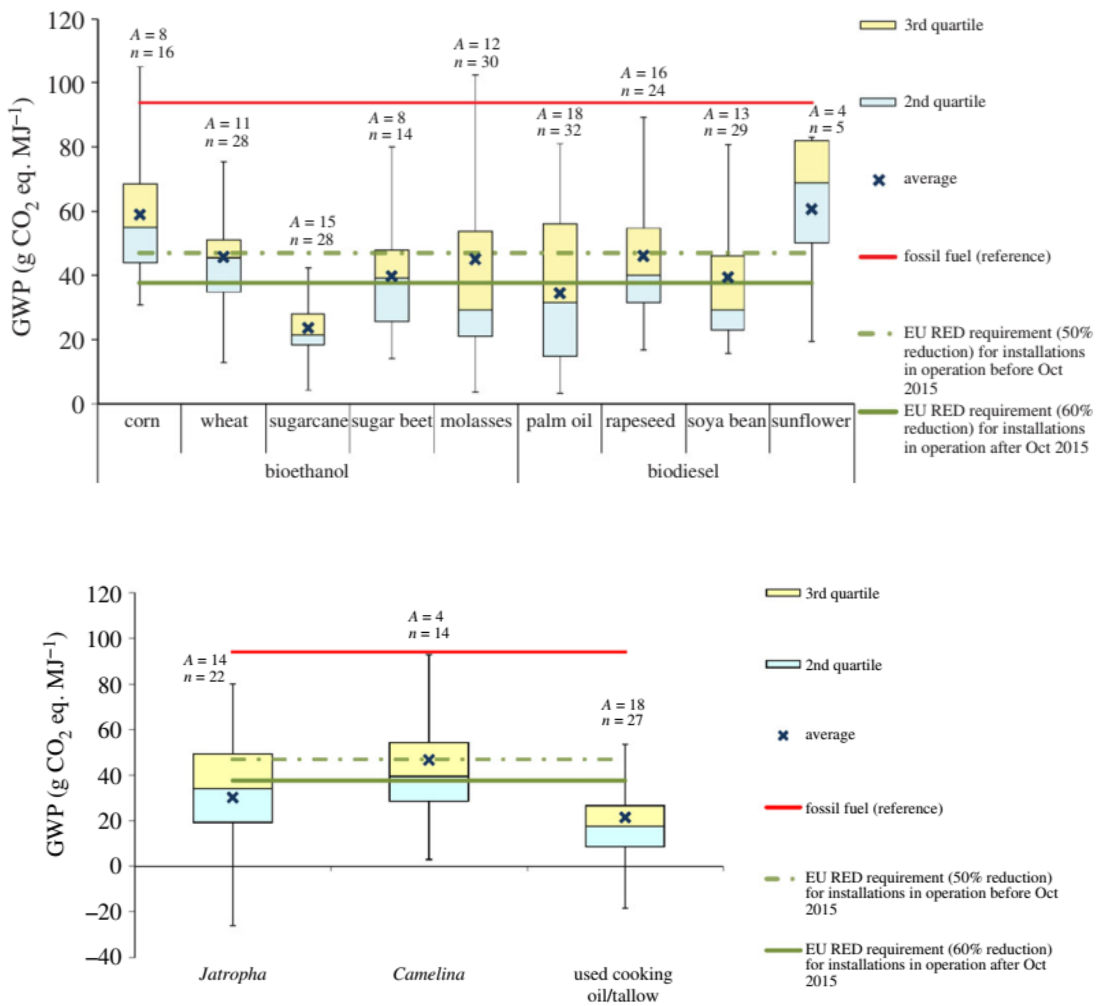

Figure 27. Global warming potential score of palm oil and molasses (top) and jatropha biofuel (bottom).[340]

From Figure 27, it appears that to maintain environmental sustainability, Indonesia must limit or stop the changing land use of forest, peatland, and other types of land for

[339] Harish K. Jeswani, Andrew Chilvers, and Adisa Azapagic, "Environmental Sustainability of Biofuels: A Review," *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 476, no. 2243 (November 2020): 8–9, https://doi.org/10.1098/rspa.2020.0351.

[340] Source: Jeswani, Chilvers, and Azapagic, 8–9.

palm, sugarcane, and jatropha cultivation, which could cause more GHG emissions. At the same time, Indonesia should identify any non-productive and arid lands, such as those located in Nusa Tenggara, to support jatropha crops. In addition, Indonesia may need to extend agricultural technology to improve palm oil production as palm-oil production will likely peak in the following decade when the forecasted climate change, rising sea level, and drought will likely contribute to decreasing palm oil yield.

C. FINDINGS

Since at least 2019, Indonesia's military has been adapting its system to indigenous palm-based biodiesel projects, due to the mandatory biodiesel program. The Indonesian Navy has become the spearhead among the other services as biodiesel is used extensively in its fleet. In contrast, the air force and the army only use biofuel for their non-combat systems, even though the extent to which it is used has yet to be disclosed. During this shift, Indonesia's military has encountered compatibility issues such as obtaining certification from manufacturers that biofuel can be used for combat systems; these manufacturers cannot guarantee that the biofuel will not damage the sophisticated and expensive propulsion systems. Indonesia's military understands some drawbacks to using the current palm-based biofuel, but recognizes it addresses the problem of energy availability. Yet, the affordability of biofuel has yet to be achieved.

This chapter affirms that Indonesia's palm oil production has one major vulnerability: environmental sustainability. On the other hand, Indonesia's military will not likely encounter a fuel shortage if Indonesia successfully converts to *green fuel* since Indonesia's military only consumes a fraction of the nation's energy compared to other sectors. Therefore, Indonesia needs to pursue energy efficiency as soon as possible rather than focusing only on providing biofuel. The chapter also revealed that jatropha is a more viable source than molasses to supplement palm-based biofuel production since jatropha has an advantage in terms of the environmental sustainability. Nevertheless, these two sources, palm oil and jatropha, cannot contribute significantly to Indonesia's biofuel target.

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V. CONCLUSIONS AND RECOMMENDATIONS

This last chapter synthesizes the findings of the research and proposes several key recommendations for Indonesia's government and the military regarding palm-based biofuel for national energy resilience and military energy security as well. As postulated in the first hypothesis, Indonesia's indigenous palm-based biofuel ensures energy supply resilience for the military. In addition, the findings presented in this thesis revealed that this biofuel gives fuel redundancy for the military; they now have two fuel supply options: petroleum and palm-based biofuel. Before the government enacted the biofuel use mandate, the military competed with other sectors for fossil fuel. Since the mandate, that competition for petroleum-based fuels has relaxed. As the military encountered compatibility issues between the current biofuel product and its combat equipment, the military has been allowed to continue using petroleum fuel for several of those systems.

On the other hand, as examined in the second hypothesis, jatropha and molasses, as the other renewable sources for biofuel, cannot viably contribute to Indonesia's biofuel production. Jatropha's unattractive market position and molasses' enormous export demands prevent them from becoming suitable candidates as a primary source for biofuel. Therefore, palm oil remains the best source to serve the Indonesian military's needs at present. Eventually, as posited in the third hypothesis, Indonesia did manage to establish a new sustainable biofuel program and has produced new commodities, which has finally positioned Indonesia as one of the world's largest biodiesel producers. The economic and environmental challenges posed by market prices and climate change are tangible and inevitable, but the solutions to these challenges are dynamic and predictable.

A. CONCLUSIONS

Indonesia's energy security is undergoing a transformation to respond to the current decline in fossil fuel production, rising energy consumption, and growing concern over environmental sustainability. In response to its changing energy security landscape, Indonesia has managed to develop palm-based biofuel to balance its energy supply and demand. Furthermore, the government enacted a biofuel usage mandate for government agencies, including the military. Indonesia's indigenous biofuel program, however, relies on biodiesel B30, whereas bioethanol has not been produced and commercialized due to lack of support from fuel producers and the market. As for bioavtur, this product is still under development and has yet to be introduced into the market. However, the palm-based bioavtur will likely to be produced in the following years.

Indonesia has all the necessary tools to achieve biofuel self-sustainability, with the ongoing *green fuel* project likely to be completed in the near future. At the same time, the challenges for Indonesia's pursuit of biofuel mainly come from market constraints that dictate weighing cost against benefit and investment potential. In addition, environmental sustainability is another challenge since Indonesia has been under pressure to reduce carbon emissions and prevent further deforestation that mainly comes from change in land use to support palm crops.

Palm oil is the winner as the primary source for biofuel today due to its distinct advantages over jatropha, molasses, and other renewables as Indonesia struggles to provide a biofuel that may serve the military's needs. In addition, the entities surrounding palm crops are more mature due to lucrative markets and supportive policies. The most important factor, though, is the commitment from the stakeholders, who drive the growth of biofuel industries nationwide.

The distinct advantage of expanded palm-based biofuel production is its self-sustainability, which comes from the large availability of palm-oil stock. This stock provides adequate funds from palm oil's export, which can support the national biofuel program. This self-investment program is the major driver of certainty that boosts the biofuel program. As for the distinct disadvantage, as forecasted and studied by many scholars, biofuel is expensive. Although palm oil is plentiful in Indonesia, the cost of its B30 biofuel is higher than that of petroleum-based fuels. Consequently, the Indonesian government needs to subsidize the cost of its biofuel to improve energy equity at the fuel pump. Yet, this challenge opens the opportunity for other crop oils and waste oil to be introduced into the feedstock for diversification in the biofuel industries, improving biofuel equity in meeting the national energy demand.

Indonesia's military encounters a trilemma derived from ensuring energy security, maintaining operational readiness, and completing the essential force (see Figure 28). The main reason for the emergence of military energy security problems is the absence of strategy within the military itself. The military has been more focused on completing the underachieved 2025 final MEF as the inherited long-term strategy since 2010. As a result, the military will face the consequences of reduced power projection. It may become a paper tiger if the strategy continues to focus on completing this wish list.

Furthermore, maintaining operational readiness as the primary objective will likely cause the military to suffer from imbalanced forces due to the incompatibility of new systems and legacy equipment and technologies that are not interoperable within the military inventory. Pursuing operational readiness also stretches the military logistically in terms of energy since the already limited fuel budget will likely need to accommodate operational freedom.

As for military energy security, transforming the infrastructures, facilities, logistics, and revising military equipment with multi-fuel capability to accept palm-based biofuel or adopting the single fuel concept are the long-term investment steps. Moreover, these steps may disrupt the national fuel supply since the military's fuel demands may be changed to meet the needs of its equipment. On the other hand, pursuing energy security may leave the military vulnerable as long as the outdated equipment remains in the military inventory.

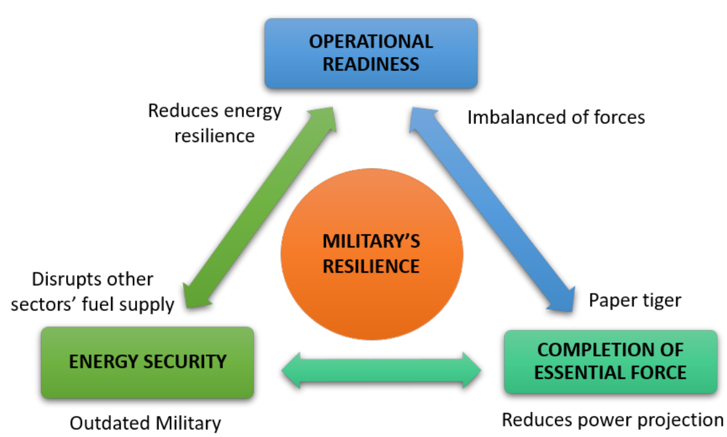

Figure 28. Indonesia's military resilience trilemma.

Indonesia's military needs to establish a holistic strategy for its future energy security. This strategy is imperative because energy security failures will affect the Indonesian military's operational, command, and supporting domains (see Figure 29). The cascading consequences show that securing energy resilience is a top-to-bottom policy. Therefore, as the primary actor in national security, the military needs to proactively adapt to biofuel since the government has already played its part, which is providing energy through palm-based biofuel.

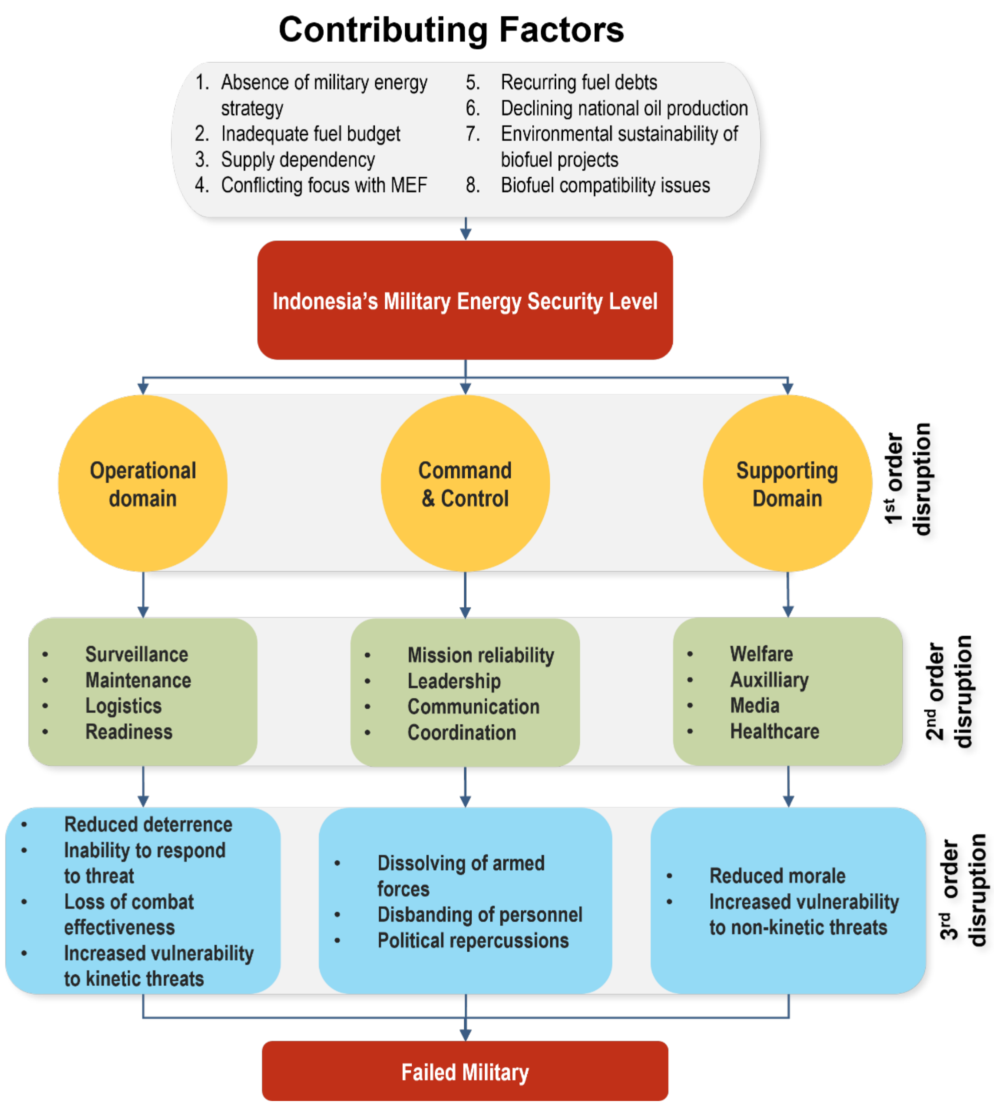

Figure 29. Cascading consequences of failure in Indonesia's military energy security.

Having indigenous palm-based biofuel has saved Indonesia from its energy concerns. Therefore, the main strengths, significant weaknesses, feasible opportunities, and possible threats related to military energy security can be explained in the following SWOT analysis (see Table 15). Indonesia's biofuel program will be predominant in the next decade; the military cannot resist the change to biofuel since the energy is produced by the state and private business.

Table 15. SWOT analysis of Indonesia's palm-based biofuel to military energy security.

Strengths	Weaknesses	Opportunities	Threats
Technical aspects			
• Does not have significant compatibility issues for the lower blend (less than 20%) • Fewer GHG emissions • Easier to produce technologically	• Compatibility issues with current military engines for the higher blend (more than 20%) • Not suitable for long-term storage (more than six months) • Less power output at maximum power setting increases fuel consumption	• Initiate multi-fuel capability from the equipment supplier • Initiate biofuel-ready requirement for future military procurement • Determine feasibility of changes to make equipment and facilities biofuel-ready	• Possible damage to unmodified combat vehicles • Biofuel being more prone to contamination • Faster fuel degradation that requires special handling
Logistical aspects			
• Secured energy supply that outlasts fossil fuel (renewable) • Easy to source due to availability in Indonesia's major islands	• Faster fuel consumption cycle due to biofuel's short lifespan • More expensive than fossil fuel under current conditions	• Initiate single fuel concept for military • Determine substitutability with another bio-feedstock • Determine feasibility of producing locally by military bases	• Competing demands with other biofuel-mandated sectors • Possible damage to unmodified fuel storage, distribution facilities
Operational aspects			
• The best alternative fuel for the current engine technology possessed by military • Use of biofuel in the military supports environmental sustainability	• Indonesia's military system is not yet to be fully compatible with biofuel • Only high-quality biofuel (green fuel) is suitable for operation in a cold climate	• Ensure future military procurement shall have the biofuel-ready capability • Ensure biofuels will have operational interoperability	• Military-grade engine suppliers' delay in providing biofuel-ready systems • Reduced military fuel provisioning due to expense of biofuel

Finally, energy security is a dynamic domain, which develops over time. The distinct advantage of biofuel lies within its intrinsic value as a renewable source that eventually outlasts fossil fuel. Currently, its distinct disadvantage is the adjustments needed to military equipment to operate reliably and effectively on biofuel. Indonesia's palm oil is only one among other renewables. Indonesia's other potential resources, such as jatropha and molasses, are the latent energy that has the capacity to support military energy security if they have the same comparative advantage with Indonesia's palm crop, which is supported by massive production and a lucrative market.

Following the United States and Brazil as biofuel producers, Indonesia is in motion to prove whether securing the national energy resilience by harnessing palm-based biofuel is beneficial. This investment cannot be undone; however, biofuel's economic dynamic and technology development will eventually dictate Indonesia's biofuel future. While investing in biofuel, Indonesia has created a new commodity: the indigenous palm-based biofuel, from a product (palm oil) that was previously used mainly as an export commodity and food source.

Indonesia's palm-based biofuel will reach its full potential as the solution for energy security when the expansion of its production capacity becomes self-sustaining. Alternatively, Indonesia can change the balance from fossil fuel as its primary energy supply to biofuel as soon as possible. Yet, one primary challenge to implementing this strategy is imminent climate change that will influence the production capacity of Indonesia's palm crop since crops will always be influenced by the weather. In the face of this uncertainty, Indonesia will still have its crude oil reserve to survive if or when the future climate can no longer serve biofuel production.

Indonesia's bet on palm-based biofuel is considered as a rational best. However, the steps toward the implementation of its sustainability needs to be carried out continuously and simultaneously with other available renewable energy. Otherwise, Indonesia energy security will be succumbed to the endless energy imports, since the transformation and adaptation of nationwide new and renewable energy is incomplete.

B. RECOMMENDATIONS

At the moment, the best solution for ensuring Indonesia's energy security is palm-based biofuel. At the same time, the factors that contributed to the military's energy security problem need to be addressed. Any solution needs to be holistic and offer a top-down approach since the cascading consequences are real (see Figure 30). First, the government needs to diversify the primary energy supply with renewables as soon as possible due to the imminent climate change that will affect Indonesia's palm crops in the future, significantly affecting biofuel production. The diversification effort should focus not only on various biofuel sources but also on wind, solar, hydro, geothermal, and other renewables, which are still underdeveloped. The first recommendation for the military is to establish a strategy of ensuring military energy security. This policy will act as the groundbreaking paradigm essential for the Indonesian military to cater to its future military expansion and modernization.

Second, at present, the proven biofuel products are biodiesel and bioavtur. The forecasted next-generation palm-based *green fuels* will be expensive since the price trend of palm oil increases annually. To survive the volatile market, the biofuel must be priced at par with petroleum-based fuel. Therefore, the government needs to have positive control over biofuel equity. Although the findings show that jatropha and molasses, as the other well-known feedstock, have not been selected as sources for biofuel, the best way to bring the cost of biofuel in line with that of petroleum fuels is to diversify the oil sources for biofuel. These additional sources should be cheap as well as non-conflicting sources (i.e., they are not sought after for other uses such as food), and they should be readily available in Indonesia.

The government needs to look carefully at its biofuel investment and intervene in biofuel economics to improve the country's energy equity. In doing so, the government must pay attention to the country's other macroeconomic and microeconomic concerns so that the palm-based biofuel does not end in a disastrous or failed program. For the military, it should enact an energy efficiency program by implementing the refuel-as-consumed scheme. Ultimately, the military must end its reliance on the limited bulk fuel budget, which is consistently exceeded, leading to the growing fuel debt. A refuel-as-consumed scheme can also improve the accuracy of fuel consumption, which will eventually keep the military within its budget for fuel expenses.

Third, the government needs to have standardized, military-grade biofuels that are compatible with the military equipment of today and for near-term procurements. From the military side, it needs to ensure its equipment and equipment that is being considered for purchase be standardized biofuel-ready or have multi-fuel capability. These steps will go a long way to ensuring the government's mandate is met and the military can uphold the mandate, ensure its energy security, maintain its operational readiness, and strengthen national security—militarily and economically.

Fourth, the government must be capable of sustaining its biofuel production. This can be done by implementing nationwide procedures such as biomass recycling. Finally, the military needs to establish a military energy plan. Under such a plan, the military may consider switching to a single fuel concept, based on either petroleum or biofuel, whichever optimizes the military's fuel budget. The most viable option is to use JP-8 fuel in both aviation and ground vehicles. With that in mind, the next MEF term must include the multi-fuel capability for military equipment.

Lastly, as revealed in this thesis, the government needs to establish operational guidelines on a nationwide scale. This includes the synergized steps required for facing the inevitable environmental and climate change threats at present and in the future. Moreover, the government needs to consider building strategic biofuel reserves to improve energy security and protection against biofuel market volatility. Meanwhile, the military needs to implement energy conservation guidelines. Furthermore, the military must look after its energy security by adapting and investing in its existing inventory as soon as possible before procuring additional combat equipment. By doing so, the other dilemmas, the operational readiness, and essential force goals will be supported firmly, thus enabling the military to be capable of projecting full and real combat power. In the end, without energy logistics, a victory is always denied.

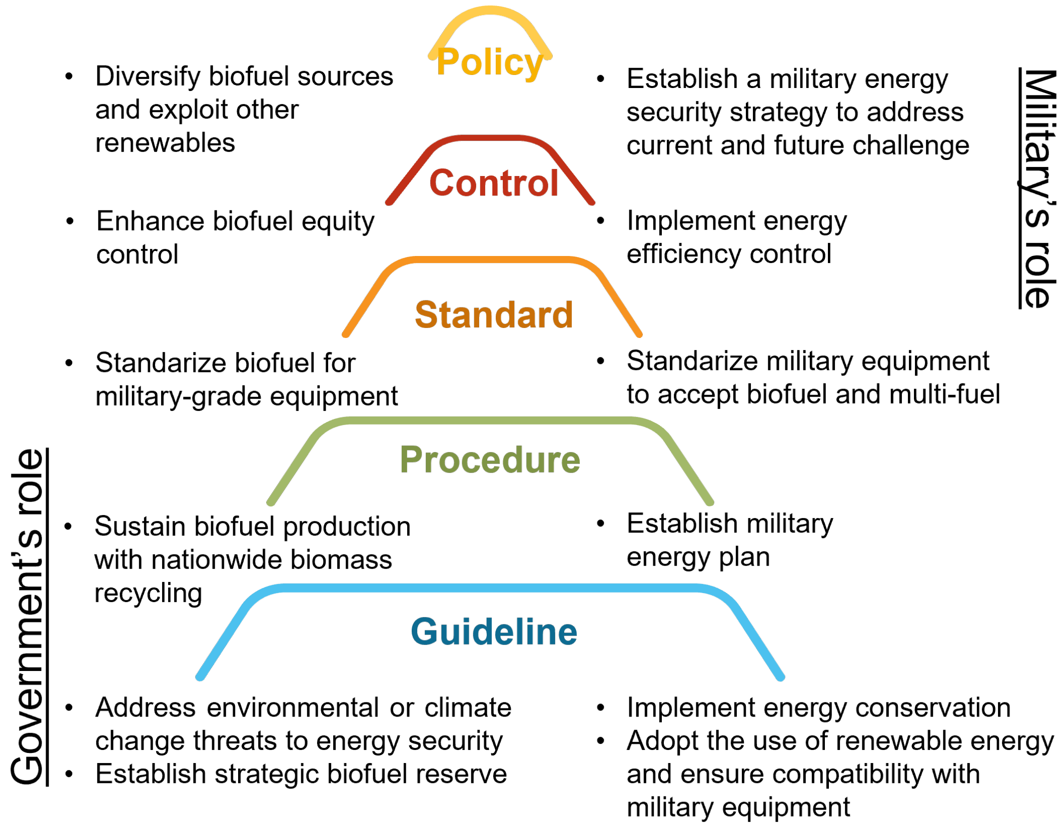

Figure 30. Top-down secure-synergize recommendations for government and military.

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