CHAPTER 2

Review of bioenergy initiatives in Indonesia for multiple benefits and sustainable development

Atiek Widayati, Ahmad Dermawan, Achmad Solikhin, Himlal Baral, Bellia Bizarani, Agus Muhamad Maulana and Ingrid Öborn

Abstract: Indonesia has committed to advancing its use of new and renewable energy (NRE) through its National Energy Policy (*Kebijakan Energi Nasional*). It has targeted NRE contributing 23% of the national energy mix by 2025, with bioenergy cited as one strategic measure for achieving this target. With Indonesia's abundant biomass resources, it is worth assessing and exploring potential bioenergy feedstocks, and identifying opportunities and challenges for development and upscaling. With sustainability being on global and national agendas, Indonesia is no exception with its focus on bioenergy. This chapter discusses bioenergy development initiatives in Indonesia over the past 15 years through a review of literature from 2005–2018, and provides a general review and updates to 2020. It discusses emerging issues pertinent to multiple-benefit potentials, competing uses and other development agendas. The study looks at Indonesia's abundant resources that could be developed for bioenergy, and discusses numerous studies dedicated to bioenergy development potential. Palm oil, *Jatropha curcas* and biogas are the most well-studied potential sources of bioenergy. Beyond these, implementation at scale remains a challenge, and feasibility studies including linkages with major offtakers are necessary. While many bioenergy initiatives have faced challenges with uptake, oil palm (*Elaeis guinensis*) biofuel is by far the most widely developed and used in Indonesia. Although opportunities exist to synergize bioenergy development with various development agendas, in some instances trade-offs might be necessary.

Keywords: Bioenergy, sustainable development, Indonesia, policy
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2.1 Introduction

Indonesia has committed to providing energy for its entire population through its National Energy Policy (*Kebijakan Energi Nasional*) as stipulated under Government Regulation No. 79/2014. The regulation specifies the importance of diversification, environmental sustainability and enhanced deployment of domestic energy resources. Diversified energy supply should include oil, coal, gas, and new and renewable energy (NRE). It mandates NRE contributing 23% of the national energy mix by 2025, where NRE can be derived from a range of sources, including geothermal, nuclear, micro-hydro, bioenergy, solar, wind, tidal and shale gas. Indonesia has also made commitments internationally to align energy provision with sustainability, as stated by the President of Indonesia at the Twenty-first Conference of Parties to the United Nations Framework Convention on Climate Change in 2015 (Ministry of Foreign Affairs 2019), and to further reduce net greenhouse gas emissions, as stipulated in its Nationally Determined Contribution (NDC) (Republic of Indonesia 2016).

Bioenergy is an important alternative renewable energy. It is defined as energy produced from plant biomass and plant-derived residues and waste (Souza et al. 2015). Traditional bioenergy mostly refers to energy from biomass burning, while modern bioenergy applies to energy produced through a wide range of technologies, including liquid biofuels, bio-refineries, biogas and wood pellet heating systems (IRENA 2020). In Indonesia, forms of bioenergy being researched and developed include biodiesel, bioethanol, bio-aviation turbine fuel (bioavtur), bio-pellets, bio-briquettes, bio-oil, biogas and syngas (Bappenas 2015; Putrasari et al. 2016). Since 2006, initiatives developed by the Government of Indonesia (GoI) to meet national bioenergy policies and mandates include biofuel or *Bahan Bakar Nabati* (BBN) development, energy self-sufficient villages or *Desa Mandiri Energi* (DME), the Indonesia Domestic Biogas Programme (IDBP) or *Biogas Rumah* (BIRU), bioenergy power plants, the Sumba Iconic Island renewables project, and bioenergy plantations or *Hutan Tanaman Energi* (HTE). In 2016, bioenergy ranked first as an NRE in Indonesian in terms of installed capacity and utilization, followed by hydro, geothermal, mini and micro-hydro power, and solar, wind and wave power (DEN 2016).

Bioenergy is highly dependent on biological feedstocks, the most prominent of which are agriculture biomass, forestry biomass, animal manures and micro-algae. Another feedstock for bioenergy is derived from municipal waste (FAO 2004). According to the Technology Assessment and Application Agency (BPPT 2017), Indonesia has biomass energy resource potential of around 32,654 megawatts (MW) and an installed capacity of 1,626 MW. Bioenergy utilization, especially biofuel, biogas and biomass, is expected to rise (Abdurrahman 2018; Ministry of Environment and Forestry 2018). For instance, biofuel utilization was projected to rise from 6.4 million kilolitres (kl) in 2018 to 52.3 million kl by 2050. In addition, bioenergy-based heat and liquid fuels are planned to provide more than half of all renewable energy used in Indonesia by 2030 (IRENA 2017).

Bioenergy research plays a major role in providing foundations before wider uptake and implementation. It is essential to align bioenergy research and development initiatives. Studies show that for successful bioenergy development it is vital to consider the integration of upstream and downstream factors, such as bioenergy feedstocks and related industries, as well as bioenergy research and development. Recent studies have assessed the sustainability of bioenergy in Indonesia (Kemper and Partzsch 2018; Papilo et al. 2018). However, studies that take stock of the development of bioenergy initiatives are very limited, and lack information on the types of bioenergy and their geographical distribution (Widodo et al. 2006; Wirawan and Tambunan 2006; Legowo et al. 2007; Silviati 2008; Widodo and Rahmarestia 2008; Dharmawan et al. 2018).

2.2 Scope of the chapter

The chapter aims to highlight progress in bioenergy research and development initiatives in Indonesia, including their geographical distribution, and to review enabling factors and challenges for wider uptake and implementation. Further, the chapter also aims to derive lessons from relations in bioenergy development and ascertain their contextual relevance, multiple-benefit potentials and alignment with development and sustainability agendas.

This chapter builds on a policy brief entitled “Exploring the potential of bioenergy in Indonesia for multiple benefits” (Widayati et al. 2017), which was based on the “International workshop on developing science- and evidence-based policy and practice of bioenergy in Indonesia within the context of sustainable development” held in 2017. The workshop aimed to increase awareness of the current state of bioenergy research and development; identify gaps, bottlenecks and challenges in developing bioenergy value chains and uptake; and provide input and recommendations for creating enabling conditions to address challenges. Adopting the four main sections in the policy brief, this chapter provides a review of the significant body of literature published from 2005–2018, and follows up with a general review and discussion of relevant updates to 2020. Ultimately, the chapter discusses emerging issues surrounding bioenergy feedstocks, especially in agriculture, forestry and bioenergy development, in relation to multiple-benefit potentials, competing uses and other development agendas.

2.3 Review of bioenergy research and development initiatives

GoI has developed several bioenergy programmes since 2006. These include biofuel (BBN) development along with a national biofuel taskforce, BIRU domestic biogas installation, biogas-based power generation, improved cook stoves, the Sumba Iconic Island renewable energy project, bioenergy plantations, candlenut biodiesel development, and bio-avtur development (Ministry of Energy and Mineral Resources 2014). Bioenergy research has been conducted to support the development of sustainable, viable and affordable bioenergy initiatives in Indonesia. Many studies have investigated prospective feedstocks for bioenergy in different regions of Indonesia, but these have yet to be applied to bioenergy initiatives involving state-owned enterprises as offtakers.

2.3.1 Bioenergy research

Numerous studies have investigated potential feedstocks for bioenergy development in Indonesia. These encompass agriculture feedstock, forestry feedstock, non-wood forest feedstock and other biomass (Annex 1). Roughly, 80 forms of feedstock were researched in Indonesia during 2005–2018. These feedstocks included biodiesel, bioethanol, bio-oil, biogas, bio-pellets, charcoal briquettes and syngas. Most research studies focused on agriculture feedstock, the highest number being on oil palm, followed by paddy, sugarcane, coconut, cassava, maize, sorghum and other agro-lignocellulose sources. The Agriculture Research and Development Agency under the Ministry of Agriculture has been conducting research into developing biodiesel from crude palm oil (CPO) since 1992 (Puslitbang Pertanian 2006). Besides its abundance, oil palm bioenergy provides greater energy potential than other feedstocks with its stable production and adequate infrastructure.

Studies on forestry feedstocks have mainly focused on lignocellulose sources and oil-containing seeds. Several studies from 2005 to 2018 looked at the bioenergy potential of non-timber forest products (NTFPs) such as nipa palm (*Nypa fruticans*), sago (*Metroxylon sagu*), black sugar palm (*Arenga pinnata*) and bamboos (Bambuseae). Other resources, mostly researched since 2007, are animal manure, microalgae, municipal solid waste (MSW) and waste cooking oil (WCO). Since the issuance of Presidential Regulation No. 5/2006 on National Energy Policy and its update under Government Regulation No. 79/2014, several government agencies have made progress towards the policies' bioenergy goals. The Ministry of Agriculture, for example, has promoted studies on the bioenergy potential of biomass from oil palm, maize, cassava, sugar, jatropha, candlenut and animal manure (Agustian 2015). In addition, the Forestry and Environmental Research, Development and Innovation Agency (FOERDIA) under the Ministry of Environment and Forestry (MoEF) developed an initiative to derive bioethanol from black sugar palm in Boalemo District in Gorontalo Province, which was incorporated into the energy self-sufficient villages (DME) programme.

Although most oil palm biomass related studies have looked at the potential of palm oil for biodiesel, some studies looked at potential for bio-pellets, bioethanol, biogas, syngas and bio-oil, with palm oil mill effluent (POME) being processed to produce biogas for electricity, and lignocellulose residues of oil palm being broken down chemically to produce bioethanol, bio-oil and bio-pellets. The Indonesian Institute of Sciences (LIPI), for instance, succeeded in converting 1,000 kg of oil palm empty fruit bunches (EFBs) into 150 litres of 99.95% fuel grade ethanol. Funding for research into using oil palm for bioenergy has increased since the creation of the CPO Fund in 2015, with the fund supporting oil palm research and development. In 2016, the CPO Fund allocated IDR 10.68 trillion for oil palm-related research, a 22-fold increase over 2015 (IDR 476 billion). After oil palm, the second most dominant agricultural biomass being assessed for bioenergy was paddy, the most common use being electric power generation through the conversion of syngas and heat into electricity from gasification, thermal incineration or microbial fuel cell (MFC) technologies. In addition, rice straw and rice husk bio-pellets have been investigated as potential sources of biomass for electricity generation.

Studies in the forestry sector have looked at lignocellulose from woody biomass for species such as calliandra (*Calliandra calothyrsus*), acacia (*Acacia sp.*) and albizia (*Paraserianthes falcataria*), mostly for manufacturing bio-pellets, generating electricity, power and heat. Meanwhile, studies on oil-bearing fruits and seeds from jatropha (*Jatropha curcas*), Alexandrian laurel or *nyamplung* (*Calophyllum inophyllum* L.), candlenut (*Reutealis trisperma*), Indian beech (*Pongamia pinnata*) and sea mango (*Cerbera odollam*) were also common. After successful studies by the Bandung Institute of Technology from 2005–2007, for instance, jatropha biodiesel has been used widely in the DME programme. In addition, NTFP biomass has also been researched. Nipa palm, black sugar palm and palmyra palm (*Borassus flabellifer*) sap have been studied for bioethanol production through fermentation processes (Effendi 2010; Fahrizal et al. 2013; Hidayat 2015; Imron et al. 2015). These plants have all been identified as having bioethanol production potential (FORDA 2013).

Other sources of biomass that have been studied extensively are municipal solid waste (MSW), waste cooking oil (WCO), animal manure and microalgae. MSW was explored for generating electricity, whereas animal manure was studied for its biogas potential. Both WCO and microalgae were reported to produce biodiesel after processing with chemical treatments (Hidayat 2008; Hadiyanto et al. 2012; Kartika and Widyaningsih 2012; Setiawati and Edwar 2012; Pradana et al. 2017). LIPI has looked at the potential of microalgae, such as *Nannochloropsis* sp., *Chlorella* sp. and *Scenedesmus* sp., expecting them to provide a ten-fold increase in total biodiesel productivity per hectare over CPO biodiesel (LIPI 2015). Major sources studied for hydrocarbon syngas were paddy, oil palm, coconut, woody biomass, rubber and municipal waste.

Looking at the geographical distribution of bioenergy feedstock research and development, most research into biodiesel has been conducted in Java, Sumatra, Kalimantan, Sulawesi, Papua, Maluku, Nusa Tenggara and Bali (Figure 1). These regions have the potential to become biodiesel producers due to their feedstock availability. They have also been locations of research into bioethanol. Riau, Lampung and Jambi provinces have been the most favoured sites for research into bio-oil derived from oil palm, paddy, woody biomass and MSW, primarily due to the availability of feedstocks in those areas.

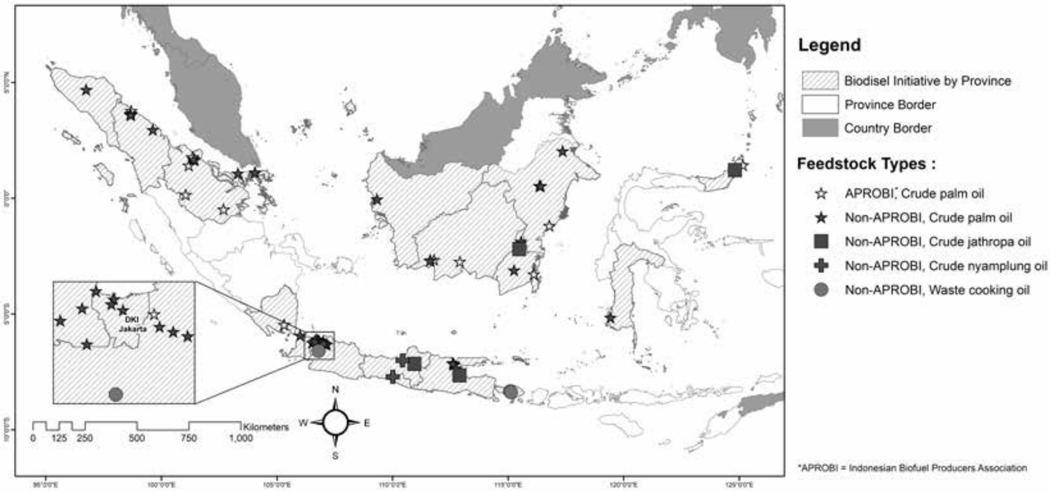

Figure 1. Geographical distribution of biodiesel initiatives in Indonesia

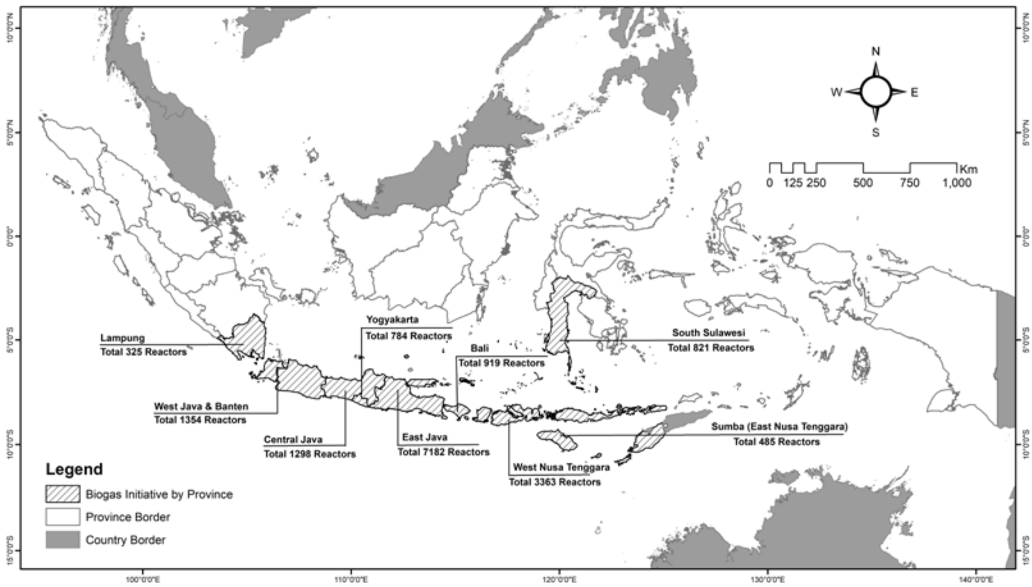

Figure 2. Geographical distribution of biogas initiatives in Indonesia

Key research locations for biogas and syngas have been Java, Sulawesi, some provinces in Sumatra and Kalimantan, Papua, Maluku, Bali and Nusa Tenggara (Figure 2). Java has been the main island for initiatives on producing biogas from animal manure. Research on bio-briquettes and bio-pellets has also been based mostly on Java, and to a lower extent Sumatra, Kalimantan and Sulawesi. As studies into bio-briquettes and bio-pellets have looked mainly at their production from oil palm residues, coconut waste, wood waste, calliandra (*Calliandra* *calothyrsus*) and acacia (*Acacia* sp.) biomass, those islands were able provide the necessary feedstocks. Studies in Papua have looked at the abundance of biomass for bioenergy feedstocks, but no studies there have focused on the region's potential for bio-briquettes, as most have looked at bio-pellets for electricity generation, bioethanol or biodiesel.

For Papua in particular, research has focused on biomass and oil-bearing fruits for more advanced bioenergy products, such as wood pellets, and on direct electricity generation, bioethanol and biodiesel. Following on from these studies, state-owned electricity company PT PLN has built biomass power plants in Papua and West Papua provinces (IESR 2019).

2.3.2 Bioenergy development initiatives

Beyond research, bioenergy development initiatives have been established in various parts of Indonesia. These initiatives are categorized here by bioenergy type, i.e., biodiesel, bioethanol, biogas, syngas, charcoal briquette or bio-pellet, with an additional category being integrated bioenergy initiatives under the energy self-sufficient villages or *Desa Mandiri Energi* (DME) programme.

Biodiesel

Biodiesel initiatives have been developed from four feedstock types: crude palm oil (CPO), crude jatropha oil (CJO), crude *nyamplung* oil (CNO) and waste cooking oil (WCO). These initiatives are predominantly situated in Java, with some in Sumatra, Kalimantan, Sulawesi and Bali (see Figure 1). CPO is the most used feedstock for biodiesel initiatives in Java, Sumatra and Kalimantan, because of its abundance. Indonesia has a large number of CPO biodiesel companies, but only 25 were members of the Indonesian Biofuel Producers Association (APROBI) in 2018. The geographical distribution of companies involved in all four biodiesel feedstock types is shown in Figure 1.

CJO biodiesel initiatives have been developed in Java, Kalimantan and Sulawesi, though these initiatives have encountered issues with feedstock viability and sustainability. Java, Kalimantan and Sulawesi are highly suitable locations for the development of CPO biodiesel initiatives because of GoI's commitment to executing the DME programme. CNO biodiesel initiatives have only been developed on Java, mainly in Central Java Province, because the feedstock (*nyamplung*) is widely cultivated and grows well in the region. WCO biodiesel initiatives have been established and supported by local governments in Bogor and Bali. In Bogor, two companies (PT Mekanika Elektrika Egra and PT Bumi Energi Equatorial) are collaborating with the Bogor Municipal Government to use WCO biodiesel for its 'Trans Pakuan' city buses. A similar collaboration is ongoing in Bali, where the company PT Bali Hijau Biodiesel and the Bali Provincial Government are collaborating to develop 'Ucodiesel' from used cooking oil to fuel four Bali Green School buses. However, both initiatives risk being discontinued due to various issues including material supply continuity and profit-oriented goals (Fujita et al. 2015; Syahdan et al. 2017).

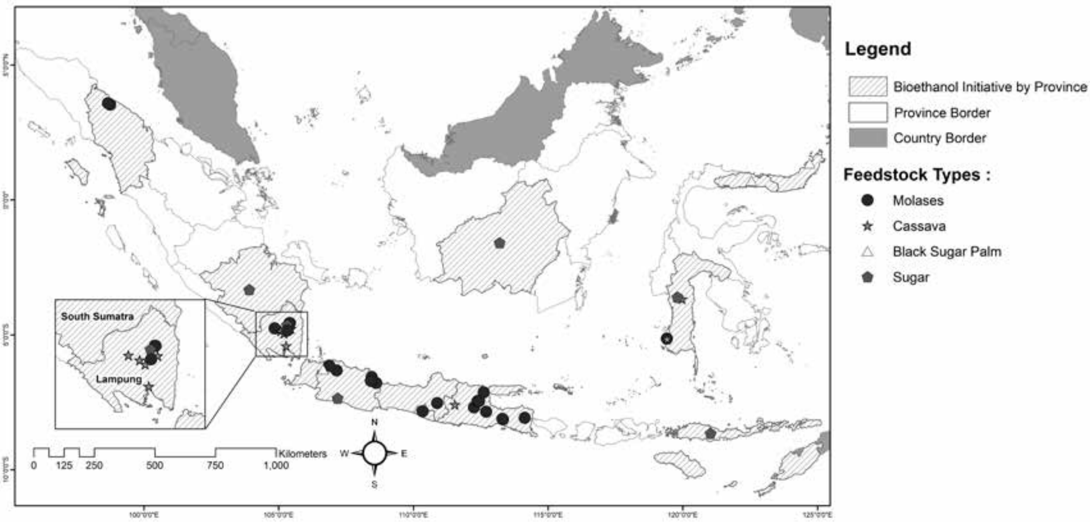

Figure 3. Geographical distribution of bioethanol development initiatives in Indonesia

Bioethanol

Bioethanol is the second most important biofuel after biodiesel in supporting the BBN biofuel programme. Four feedstocks are used for bioethanol initiatives: cassava, molasses, sugar and black sugar palm (Figure 3). Of the 40 bioethanol production initiatives realized to date, 32 use molasses and sugar, seven use cassava, and one utilizes black sugar palm. Only one initiative, which uses molasses as its feedstock, is registered with APROBI. Most companies produce bioethanol for cosmetics, pharmaceuticals, cigarettes, ink and paint. Most of these initiatives are centred in Lampung and East Java, as these provinces are the main feedstock producers, though black sugar palm has been utilized for ethanol production outside these provinces in Gorontalo, Tangerang and Minahasa. The sugar palm-based bioenergy initiative in Gorontalo involves MoEF, while the one in Tangerang involved the Technology Assessment and Application Agency (BPPT) before it was forced to stop due to unprofitable implementation and negative perceptions associated with ethanol production and alcohol. Bioethanol is also being produced from similar feedstock using traditional methods in South Minahasa, though the resulting bioethanol concentration is low at only 24% (Wenur and Waromi 2017). Consequently, the process necessitates re-distillation and improved processing.

Biogas

Biogas initiatives were implemented in Indonesia in 2007 to support the DME programme, while the Indonesia Domestic Biogas Programme (IDBP) or *Biogas Rumah* (BIRU) spearheaded by the Rumah Energi Foundation has been ongoing since 2012. This programme, with more than 25,000 biogas units in 14 provinces, has benefited more than 100,000 people (Rumah

Energi 2021), with biogas commonly used for cooking and electricity generation. The BIRU programme is widely distributed throughout Java, but is only being implemented in a few areas in Sumatra, Kalimantan and Sulawesi (Figure 2). Papua has abundant feedstock for biogas, including animal manure and Sago, the residues of which can be digested anaerobically to produce biogas (Muthukumar and Sangeetha 2014). However, biogas initiatives have been absent in the region.

Bio-pellets and bio-briquettes

As Indonesian bio-pellet initiatives generally utilize wood as their raw material, the resulting bio-pellets are often referred to as wood pellets. Such initiatives are mostly situated in Java, and to a lesser extent in Kalimantan and Sumatra (Figure 4). Wood pellet initiatives have been boosted through government support with the establishment of 31 'HTE' biomass plantations (Ministry of Environment and Forestry 2018). State-owned forestry company Perhutani is collaborating with the Korea Forest Service (KFS) and Korea Green Promotion Agency (KGPA) to accelerate biomass plantation and wood pellet development. Around 3,300 trees have been cultivated in the Bogor Forest Management Unit (FMU), with cultivation extended to the planting of a 500-ha *gamal* (*Gliricedia sepium*) forest in the Semarang FMU. Other fast-growing trees, such as calliandra (*Calliandra calothyrsus*), albizia (*Paraserianthes falcataria*) and acacia (*Acacia* sp.), are also being cultivated. A community forest-based wood pellet project, called 'Hutan Rakyat untuk Green Madura', was established in Bangkalan District, Madura, with the tagline *"Kaliandra Bersemi, Pelet Kayu Berseri"*, implying that growing calliandra will ensure successful wood pellet production. This co-enterprise aims to support a low-carbon economy and climate change mitigation.

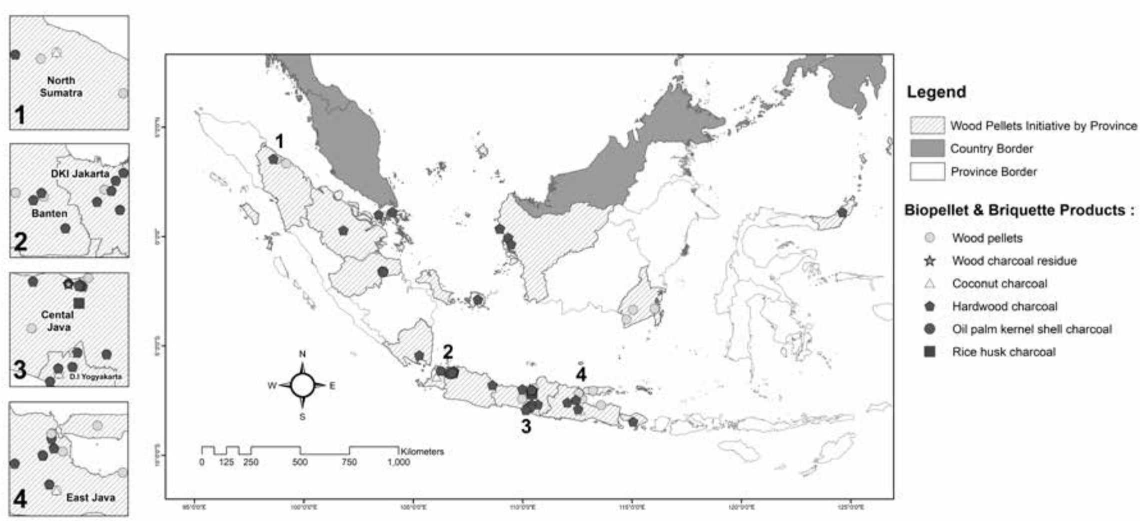

Figure 4. Distribution of bio-pellet and charcoal briquette development initiatives in Indonesia

In addition to wood pellets, charcoal briquette bioenergy initiatives have also been developed with different types of feedstock, including coconut, hardwoods, oil palm kernel shells, rice husks and wood residues. Most charcoal briquette initiatives are based in Java where woody biomass is widely available. Indonesian charcoal briquettes have international markets, particularly Taiwan, and compete well with briquettes produced in Malaysia, Thailand and Vietnam.

Bioenergy power plants

Biogas, bio-pellets and syngas have all been used to produce energy, heat or electricity. Figure 5 shows bioenergy power plants that have been in operation in Indonesia since 2001. Feedstocks for bioenergy power plants include oil palm residues, POME, MSW, wood residues, maize cobs and bamboo. These initiatives fall under two types of contracts: excess power and independent power producers. The first bioenergy power plant, built in Riau Province in 2001, runs on oil palm residue and POME feedstocks. Oil palm residues are thermally incinerated to produce synthetic hydrocarbon gases or heat for electricity generation (Pradana and Budiman 2015). POME is converted to electricity by means of biogas (Firdaus et al. 2017). Oil palm residues and POME are utilized in bioenergy power plants developed in Riau, North Sumatra, Bangka Belitung and Jambi provinces where oil palm residues are ubiquitous.

An MSW-based power plant has been built in Surabaya, while plans to build similar plants in Semarang, Bekasi and cities in South Sumatra and Bali provinces are awaiting approval. MSW-based power plant development plans are ongoing in Makassar, Surakarta, Bandung,

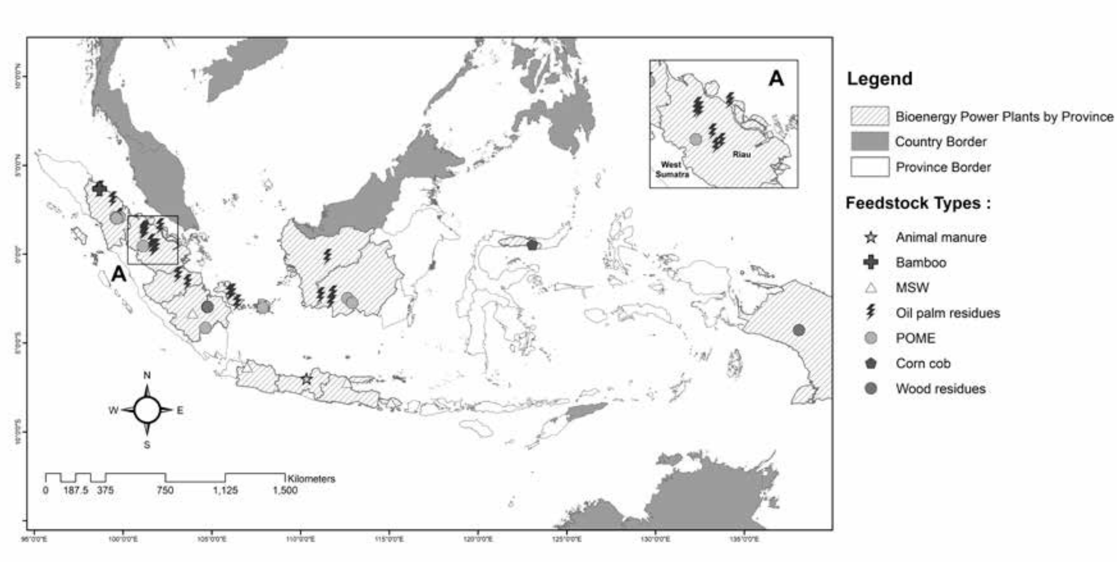

Figure 5. Bioenergy initiatives for biomass-based electricity generation in Indonesia

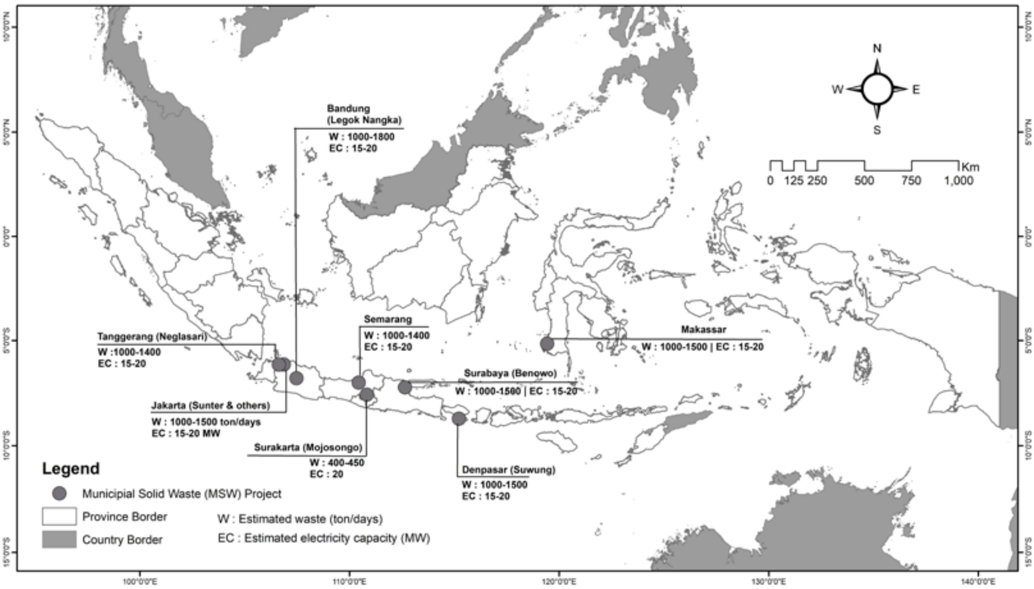

Figure 6. Operational and planned MSW-based power plants in Indonesia

Tangerang and Jakarta (Figure 6), with projections of 400–800 tons of waste per day being converted to electricity, and power capacities ranging from 9.96 to 20 MW. Surakarta is one of the cities pioneering the realization of waste-based power plants in Indonesia (Ishaan 2018). Other feedstocks being harnessed for power generation are animal manure, maize cobs, wood and bamboo, and these are the feedstocks for power plants in Semarang, Gorontalo, South Sumatra and Papua, and Mentawai Islands, respectively.

The energy self-sufficient villages or Desa Mandiri Energi (DME) programme

DME is a GoI bioenergy initiative aimed at addressing increasing fossil fuel prices and energy crises. The purposes of the programme are village energy self-sufficiency, and to create jobs, reduce poverty and encourage targeted villages to plan productive enterprises (Taufiq and Purwoko 2013). According to Widodo et al. (2008), five key commodities in the DME programme are jatropha, palm oil, coconut, cassava and sugarcane. In addition, bioenergy from maize, sorghum and black sugar palm can also be developed through DME. The programme is managed directly by the Ministry of Development of Disadvantaged Regions, Ministry of Agriculture, Ministry of Home Affairs, Ministry of Manpower and Transmigration, Ministry of Marine and Fisheries and state-owned agroindustry company PT RNI. Figure 7 shows 27 provinces implementing DME. There are two types of DME: non-fuel DME (micro and macro hydropower, biogas and solar) and biofuel DME (jatropha, *nyamplung* and palm oil). Unfortunately, despite being a nationwide initiative, the programme has encountered several issues during implementation, particularly for jatropha where there have been problems with securing jatropha seedlings, encouraging farmers to grow jatropha, cultivating it and making it profitable.

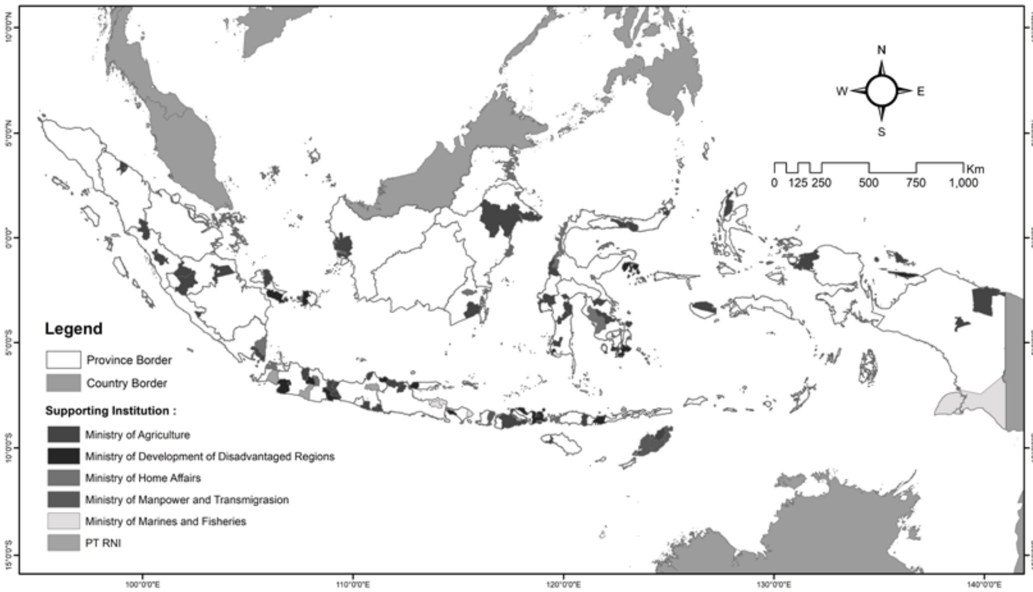

Figure 7. Energy self-sufficient villages (DME) programme sites in Indonesia

2.4 Enabling conditions and challenges for bioenergy initiatives

2.4.1 Enabling policies

Bioenergy development in Indonesia has been enabled by a range of national policies and regulations (See details in Annex 2). Under Law No. 30/2007 on Energy, GoI emphasizes regional and central government roles in enhancing the nation's NRE stock and its utilization. In addition, this law mandated the development of a National Energy Policy (*Kebijakan Energi Nasional*), which was finally formulated and stipulated under Government Regulation No. 79/2014. An important element of the National Energy Policy is the promotion of NRE. Under the regulation, GoI is committed to providing facilities and incentives to stakeholders who conserve energy and develop alternative energy sources, such as geothermal, biofuel, hydro, solar, wind, biomass, biogas, wave power, and ocean thermal energy conversion. The regulation was elaborated on with Presidential Regulation No. 22/2017 on the National Energy Plan, which mandates NRE contributing 23% of the national energy mix by 2025 and 31% by 2050. In pursuing these policies, the Ministry of Energy and Mineral Resources issued Ministerial Regulation No. 10/2012 on the realization of NRE in different sectors, including transportation and electricity generation. Electricity generation is mainly managed by the Ministry of Energy and Mineral Resources and operated by state-owned electricity provider PT PLN. Through Minister of Energy and Mineral Resources Regulation No. 50/2017, GoI obliges PLN to purchase electricity from new and renewable energy sources. However, as mandatory purchases are subject to the National Energy Policy and General Plan for Electricity (RUKN), this regulation is not always enforceable.

2.4.2 Incentives for bioenergy development

Beyond policies, other enabling conditions are required for bioenergy application. One such enabler is 'incentives', which broadly cover government provision of subsidies, infrastructure and tax breaks. Another aspect of incentives is the provision of mutual benefits to the various parties interacting in the production, provision and use of bioenergy. Mutual benefits, such as rewards for ecosystem services or through public-people-private partnerships and other interactions between government, the private sector and communities, can serve as indirect incentives. Such incentives are addressed in Ministry of Finance Regulation No. 21/2010 and Government Regulation No. 9/2016 amending Government Regulation No. 18/2015. In addition, it is clear that Presidential Regulation No. 5/ 2006 on the National Energy Policy, which promotes the use of new renewable energy, provides facilities and incentives to stakeholders who conserve energy and develop alternative energy sources, such as biomass and biogas. Furthermore, Law No. 30/2007 on Energy also stipulates that GoI may offer facilities and/or capital, tax, or fiscal incentives for renewable energy development until renewables become economically viable. The government also plays an important role in guaranteeing feedstock supply.

2.4.3 Major challenges to bioenergy development

Two major challenges commonly associated with bioenergy development have been identified. First is the high initial investment costs for production chains. These high costs are mostly associated with biomass delivery (transportation) and establishing processing facilities. The latter is of greater concern due to issues relating to land acquisition and social conflicts. Potential investors are confronted with poor incentives provided by existing regulations, political situations, lack of familiarity with energy efficiency projects, high financial and technical risks, and poor financial returns. In addition, upfront transaction costs for energy audits and feasibility studies have discouraged investors, who are also concerned that costs might increase due to a lack of experience among engineering service companies. Taking these concerns on board, GoI has established a more attractive investment mechanism for renewable energy power plants under Minister of Energy and Mineral Resources Regulation No. 4/2020, which amends regulations No. 50/2017 and No. 53/2018.

Second, despite some progress being made with B30 biodiesel (a 30:70 blend of biodiesel and petroleum diesel by volume), major hurdles to overcome for effective B30 implementation include biodiesel quality, stakeholder support, pricing policy, trade barriers and protectionism. Furthermore, adoption of the B40 blend, originally projected for June

2021, has been delayed due to the high price of crude palm oil. Other sources of biodiesel have never got beyond the pilot stage for similar reasons. The failure of jatropha (*Jatropha curcas*) biodiesel in 2005–2007 was mainly due to the absence of supporting factors for implementation. WCO biodiesel initiatives established with local government support in Bogor and Bali to fuel buses have failed due to raw material supply issues and their profit-oriented goals. Concomitant with the above, a specific challenge for small-scale producers is a general lack of access to biodiesel production chains.

2.4.4 Obstacles for upscaling/wider application

Many studies have been undertaken at downstream and upstream levels to support bioenergy implementation. Despite providing sufficient evidence to support implementation, these studies have yet to be fully utilized. Meanwhile, progress with large-scale use of bioenergy for fuel and power generation has been varied. With pilot projects across Indonesia, issues surrounding off-take by state-owned enterprises have been cited as major challenges. For instance, state-owned oil and gas company Pertamina has committed to applying second generation biofuels through an integrated project approach in partnership with plantation and processing licensors. This commitment is reflected in its mission to 'carry out integrated core business in oil, gas, new and renewable energy based on strong commercial principles' (https://pertamina.com/en/vision-mision-and-the-6c-excellent-values). Pertamina has also conducted first-stage field trials for co-processing with Refinery Unit (RU) II Dumai to produce green diesel and with RU III Plaju to produce green gasoline. In addition, Pertamina and the Bandung Institute of Technology have developed a catalyst for green processing (PIDO 130) to process refined bleached deodorized palm oil. However, issues identified for biofuel development (Trikoranto 2018) in Pertamina included: 1) limited supply of fatty acid methyl esters (FAME) for blending B20 (a 20:80 blend of biodiesel and petroleum diesel) in Pertamina fuel terminals; 2) technical issues related to B20 usage in cars; 3) infrastructure readiness for blending non-PSO B20; and 4) difficulties accelerating B30 and B40 implementation. Indonesia has been making strides with B30 implementation and is planning to move towards B40 in 2022.

Other challenges to scaling up bioenergy initiatives in Indonesia are distances and provision of infrastructure between sites of power generation and the main electricity grid, as well as prices for bioenergy electricity, which typically need to be higher than prices paid by state-owned electricity company PLN. Uncertain feedstock availability and unattractive prices are also factors hampering the use of biomass for larger-scale electricity production.

2.5 Contextual relevance in bioenergy initiatives

Other pertinent aspects beyond the core areas of bioenergy development are relevant issues to learn from. Contextual relevance and locality factors are important considerations. These include connections between the supply side, such as feedstock availability, and the demand side, such as the population's energy needs. Though in many instances, bioenergy initiatives in Indonesia have considered these aspects, their successes and continuity have varied.

2.5.1 Geographic and local contexts

Priority areas for bioenergy development should be based on local needs, while also taking resource or feedstock availability into account. A common reference for local need is the electrification ratio. PLN has faced major challenges in areas where no main energy grid systems exist. However, this should not stop electricity generation with PLN as the main offtaker, considering that energy provision can be harmonized with bioenergy through different strategies. For example, priority could be given to areas where PLN is using diesel generators. Similarly, in areas where energy supply from Pertamina is limited, strategies could be developed for integration with biodiesel and bioethanol, which may benefit from the contextual relevance of feedstock availability.

Competitiveness with fuel and power generated from fossil fuels is another consideration in developing alternative energy sources, including bioenergy. In areas where electricity is very expensive and fossil fuel prices very high, which is typically the case with the outer islands in Indonesia, bioenergy production is locally relevant and economically viable. Conversely, where fossil fuel prices are low, bioenergy may not be able to compete under normal market conditions.

2.5.2 Successes and challenges based on contextual factors

Various bioenergy initiatives have been developed with strong locality or geographical contexts, especially relating to feedstock availability. While locality factors determine cost efficiency for things such as transport, they also relate to other factors such as land suitability and climate for specific crops. In some areas, feedstocks such as nipa palm (*Nypa fruticans*) and sago (*Metroxylon sago*) grow wild along coastal riverbanks, while in other areas feedstocks are cultivated as an integral part of initiatives to ensure supply for energy production. As discussed earlier, various initiatives, such as the case of crude jatropha oil, have faced challenges despite efforts to ensure local feedstock provision. The case of black sugar palm-based bioethanol also demonstrated feedstock availability issues, although cultural issues were present as well. Such issues resulted in these initiatives either failing or being discontinued.

With Indonesia's extensive oil palm plantation development, palm oil-based biofuel can flourish and is being mainstreamed under incremental biofuel blending targets. Palm oil-based biofuel has been Indonesia's main consideration in responding to its falling fossil fuel production and in efforts to reduce fossil fuel imports (Dharmawan et al. 2018). It also benefits from the massive development of industrial oil palm plantations for CPO production in many parts of Indonesia. Low fossil fuel prices and established infrastructure for fossil fuel-based energy provision are competing factors, as mentioned earlier. However, CPO-based biofuel is flourishing, even in regions like Java with good fossil fuel supply, due to strong supporting policies and other enabling factors such as developing vehicle infrastructure favouring biofuel uptake.

2.6 Multiple uses and alignment with development agendas

Other environmental and development agendas can provide foundations for synergies with bioenergy development so that bioenergy can provide added value as a bi-product or co-benefit. Bioenergy crops can be planted for multiple purposes in addition to energy production. Selecting species that can be harvested sustainably and are suitable as bioenergy feedstock for the restoration of degraded or marginal lands could provide income, fuel and energy for local communities. Feedstock from crop waste, such as rice husks and rice straw, can also have multiple uses as bioenergy sources.

2.6.1 Restoration of degraded land

Through Minister of Environment and Forestry Decree No. 306/2018, GoI identified 14 million ha of degraded lands requiring restoration and rehabilitation. Indonesia also has large areas of degraded peatlands. In 2016, GoI targeted 2 million ha for peatland restoration and established the Peatland Restoration Agency (BRG) to manage the process. Minister of Environment Decree No. 163/2009 and the Peatland Restoration Agency's national strategy document (BRG 2016) recommend bioenergy crop species, which are listed in the Ministry of Environment and Forestry's technical guidance for restoration and rehabilitation. Jaung et al. (2018) identified 3.5 million ha of degraded lands in Indonesia with high potential for bioenergy crop cultivation. However, due to their spatial distribution, economic viability remains the biggest challenge.

Various initiatives have proposed and conducted trials on potential bioenergy crops for degraded land rehabilitation. One plant with potential for biomass-based power generation is bamboo, which is also beneficial for rehabilitation and stabilization of steep gradients and riverbanks. Bamboo is considered promising due to its abundance, energy potential and environmental and livelihood benefits. Nevertheless, various challenges, including economic viability, have been identified and require further study (Sharma et al. 2018).

Nyamplung (*Calophyllum inophyllum)* is a widely recognized bioenergy crop, the seeds of which produce oil with potential for biofuel. The species is listed in various documents, including from MoEF and the Peatland and Mangrove Restoration Agency (BRGM), as a potential species for degraded land restoration. Trials in different degraded land settings have demonstrated that *nyamplung* can survive harsh conditions in severely degraded peatlands as well as on mineral soils (Maimunah et al. 2018; Leksono et al. 2021). In addition to degraded peatland restoration, *nyamplung* has also been named as a potential species for mining area reclamation, with an initiative in Central Kalimantan (Maimunah, pers.com.).

2.6.2 Social and community forestry

The integration of community management rights in the forestry sector in Indonesia has led to social forestry schemes, such as *Hutan Kemasyarakatan* (community forest) or *Hutan Tanaman Rakyat* (community plantation forest). The community-based practices under these schemes have the potential to become sources of biomass for bioenergy feedstock. In addition, the agroforestry systems integrating trees and various crops common in many social forestry schemes in Indonesia may offer options for combining feedstocks and other commodities within a single system. Wood extracted from forests can be used to produce wood pellets or bio-briquettes, while lignocellulose/polysaccharide-based forest biomass and seed oils can be used for producing bioethanol, biodiesel, bio-oil and syngas. Smallholder farmers could play pivotal roles as feedstock providers, and beyond feedstock provision, they could be empowered to establish farmer organizations or platforms to become actively involved in bioenergy value chains. Any efforts to make this happen should include the development of business models for small and medium enterprises (SMEs) and other forms of local capacity building. Through such synergies, social or community forestry could become viable schemes for smallholders to connect with buyers and achieve economies of scale.

2.6.3 Multiple benefits or competing uses?

The integration of bioenergy crops with other tree species under agroforestry practices has the potential to provide multiple benefits for local livelihoods and food security. Honey production in *nyamplung* agroforestry systems can provide livelihood benefits that help local food security (Rahman et al. 2019). 'Agrosilvofishery' systems combining *nyamplung* cultivation with fish farming are a viable option for peatland environments, and have potential to provide livelihood sources while restoring degraded peatlands (Samsudin et al. 2020). Such integrated systems also reduce pressure on arable land and natural forests.

Nyamplung oil has been shown to have other economic benefits, such as in the production of therapeutic oils (Léguillier et al. 2015). As the crop already has market value in Indonesia due its popularity in essential oil products, it has further potential to provide benefits when incorporated with degraded land restoration initiatives. Such multiple benefits could pose a problem with competition if bioenergy production were also on the agenda. However, even in such cases, bioenergy could still be produced from residues and processed for bioethanol.

As described earlier, rice straw has significant potential for use as a feedstock for biogas. No additional investment or additional land would be required to produce this feedstock, there would be no competition with food crops, and the utilization of such waste could provide multi-functionality within a landscape. However, there is a competing use for rice straw or rice husks as fertilizer for agriculture. These competing uses may prove beneficial for local livelihoods and/or local economies, but may also pose a supply continuity risk if bioenergy production is to be developed. This demonstrates a trade-off between bioenergy production and soil fertility management with rice straw being an organic nutrient source.

2.6.4 Sustainability of palm oil biofuel programmes

Oil palm-based biofuel has been the most widely developed bioenergy in Indonesia. Its development was initiated with the aim of reducing dependence on fossil fuel imports, and as part of the renewable energy mandate under Indonesia's National Energy Policy. Progressive development is shown in the form of an incremental increase in biofuel blends, currently at B30. Challenges to achieving targets remain for various reasons. These include falling global oil prices and the recent economic recession due to the pandemic (da Conceição et al. 2021). Questions remain over whether oil palm biofuel truly represents an environmentally and climate friendly energy source, with concerns that oil palm plantation expansion risks further forest loss (da Conceição et al. 2021; Halimatussaidah et al. 2021). This concern is exacerbated by the current rate of oil palm productivity (da Conceição et al. 2021), as biofuel production may be dependent on incentives (Halimatussaidah et al. 2021). The social aspects of oil palm biofuel are still problematic, considering the opportunity gaps between large-scale companies and smallholders when participating in biofuel programmes. With such challenges, further implementation will require strong policies and regulations to ensure alignment with environmental and social safeguards and compliance with green and no-deforestation principles. Efforts to strengthen smallholder involvement can be developed by ensuring their participation in bioenergy value chains. For instance, smallholder farmers could engage in the provision of biomass-based feedstocks, and participate with simple and affordable technologies in the production of certain forms of bioenergy such as wood pellets, carbon charcoal and bio-briquettes.

2.7 Summary of successes, gaps and challenges

Bioenergy initiatives in Indonesia have shown some achievements and successes over the course of the past ten to fifteen years. The Government of Indonesia has established clear policies targeting renewable energy as part of the national energy mix. The government's support for NRE has shown goodwill towards more sustainable energy sources, including bioenergy. To date, bioenergy research and development in Indonesia has been achieved with a collaborative nature across research and development agencies/organizations.

Oil palm-based biodiesel is being used at the national level, with some being exported to Europe. The B30 blend has one of the highest biofuel contents in the world, and as such can be considered quite an achievement for GoI. Abundant feedstock and established infrastructure are important factors in this success. The use of biogas at small-scale and household levels in rural areas has also been promising, and is especially beneficial for optimizing waste for biomass.

Nevertheless, gaps, bottlenecks and challenges remain for bioenergy to play a bigger role in Indonesia in contributing to NRE implementation and application at scale beyond the pilot stage.

Reviews and discussions in this chapter are summarized below:

- Bioenergy research has made significant advances in recent decades, but implementation and wider uptake remain major challenges, with the exception of some progress in palm oil biofuel and biogas programmes.
- Bioenergy production costs are high, particularly in the initial or investment stages; and economic viability is a challenge. Government financial support and incentives are necessary for implementation at scale.
- There is criticism with CPO-based biofuel, that small-scale producers lack access to participate in biodiesel production. This will require policy and regulatory improvements and interventions, as well as capacity strengthening on business enterprises.
- Despite the current abundance of feedstocks, the quality, quantity and continuity of different tree-crop species might pose risks for large-scale bioenergy production. Competition may emerge over the use of feedstocks due to other more profitable or preferable utilizations. Land use-related aspects of feedstocks may also be problematic, with risks of land conversion for more profitable commodities and tenurial issues in many parts of the country.

2.8 Conclusions and ways forward

Bioenergy has huge potential for development in Indonesia. It is linked to forestry, agriculture and urban waste management. In order to realize existing potential, enabling conditions (policies and regulations governing incentives, price guarantees and subsidies) need to be created together with associated governance structures at different levels of administration. Research findings should be applied to pilots and wider implementation. Research and development organizations need to engage with the private sector, state-based offtakers and other practitioners to develop innovations and business models at appropriate scales and in the most suitable contexts. For example, the latter may refer to particular geographical areas that are economically and socially attractive for bioenergy development and in need of land rehabilitation. Importantly, future research should consider PLN and Pertamina’s power and fuel requirements in research areas in order to improve viability. Finally, bioenergy development should be planned in the context of sustainability, green-growth planning, climate-change mitigation and adaptation, degraded land restoration and achievement of Sustainable Development Goals. Strategic mapping is required to synergize existing efforts, on restoration or REDD+ for instance, and to ensure synergy with programmes and schemes on the ground. Bioenergy development in Indonesia has the potential to contribute to the Bonn Challenge, a global effort to restore 350 million hectares of degraded and deforested lands by 2030, and to the nation's Nationally Determined Contribution and greenhouse gas emissions reduction commitments under the United Nations Framework Convention on Climate Change.

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Annexes

Annex 1. Bioenergy feedstocks and numbers of studies on their potential in Indonesia

	Bioenergy Feedstock	Period of research/study							
		≤ 2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
	Agriculture feedstock								
1	Oil palm (*Elaeis guinensis*)		3	7	10	15	13	34	37
2	Coconut (*Cocos nucifera*)		2	3	2	4	8	8	10
3	Sugarcane (*Saccharum officinarum*)		1	7	3	3	6	8	13
4	Cassava (*Manihot esculenta*)		1	7	4	5	8	7	2
5	Paddy (*Oryza sativa*)			4	3	7	12	9	14
6	Maize (*Zea mays*)		5	3		2	4	4	7
7	Sorghum (*Sorghum bicolor*)			2	2	5	1	1	4
8	Rapeseed (*Brassica napus*)						1		
9	Cacao (*Theobroma cacao*)							2	2
10	Tobacco (*Nicotiana* sp.)								1
11	Banana (*Musa* sp.)								1
12	Pineapple (*Ananas comosus*)				1	1	2		1
13	Peanut (*Arachis hypogaea*)						1	1	
14	Soybean (*Glycine max*)		1				1	1	1
15	Sunflower (*Helianthus annuus*)						1		
16	Sweet potato (*Ipomoea batatas*)		1	2	1	1		1	2
17	Taro (*Colocasia esculenta*)				1	2	1	3	
18	Ganyong (*Canna edulis*)			1	1	1	2		
19	Agricultural biomass (lignocellulose)	1	1	1		2	5	1	7

	Bioenergy Feedstock	Period of research/study							
		≤ 2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
	Forestry feedstock								
20	Wood biomass (lignocellulose)	3		3	1	4	13	5	18
21	Calliandra (*Calliandra calothyrsus*)		2			1	2	1	4
22	Acacia (*Acacia* sp.)				1	1	2	2	7
23	Eucalyptus (*Eucalyptus* sp.)							1	1
24	Lead (*Leucaena leucocephala*)					1		1	1
25	Albizia (*Paraserianthes falcataria*)				1	1	2	3	1
26	Bishop wood (*Bischofia javanica*)							1	
27	Tarap (*Artocarpus odoratissimus*)						1		
28	Corkwood (*Sesbania grandiflora*)						1		
29	Gmelina (*Gmelina arborea*)					1		1	1
30	Durian (*Durio zibethinus*)								1
31	Gamal (*Gliricedia sepium*)						1		2
32	Jatropha (*Jatropha curcas*)		9	4	4	3	6	4	3
33	Mahang (*Macaranga gigantea*)							1	
34	Mara (*Macaranga tanarius*)							1	
35	Candlenut (*Aleurites trisperma*)				1	4		4	3
36	Alexandrian laurel (*Calophyllum inophyllum*)				2	3	11	4	12
37	Indian beech (*Pongamia pinnata*)					1	2	1	4
38	Rubber (*Hevea brasiliensis*)	1		1		2	4	2	4
39	Cashew (*Anacardium occidentale*)							1	
40	Mangrove cannonball (*Xylocarpus moluccensis*)						1		
41	Pine (*Pinus merkusii*)					1			1

	Bioenergy Feedstock	Period of research/study							
		≤ 2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
42	Jabon (*Anthocephalus cadamba*)								2
43	Trembesi (*Samanea saman*)								1
44	Kapok (*Ceiba pentandra*)				1		1	1	2
45	Pulai (*Alstonia scholaris*)							1	
46	Pride of India (*Lagerstroemia speciose*)							1	
47	Wild mango (*Spodias pinnata*)						1		
48	Iron (*Eusideroxylon zwageri*)								2
49	Cloves (*Syzygium aromaticum*)								1
50	Mahogany (*Swietenia* sp.)						1		1
51	Teak (*Tectona grandis*)			1		1		2	1
52	Meranti (*Shorea uliginosa*)						1		
53	Red meranti (*Shorea leprosula*)							2	
54	Breadfruit (*Artocarpus altilis*)						1	1	
55	Bendo (*Artocarpus elasticus*)							1	
56	Cinnamon (*Cinnamomun zeylanicum*)							1	
57	Coffee (*Coffea* sp.)							1	1
58	Evergreen magnolia (*Michelia velutina*)						1		
59	Cananga (*Cananga odorata*)							1	
60	Laban (*Vitex* sp.)							1	1
61	Jackfruit (*Artocarpus heterophyllus*)								1
62	Loba (*Symplocos fasciculata*)								1
63	Cajeput (*Melaleuca* sp.)								3
64	Amboyna pine (*Agathis alba*)						1		
65	Sea mango (*Cerbera manghas*)					2	1	1	1

	Bioenergy Feedstock	Period of research/study							
		≤ 2004	2005–2006	2007–2008	2009–2010	2011–2012	2013–2014	2015–2016	2017–2018
66	Africa leaf (*Vernonia amygdalina)*								1
67	Spiked pepper (*Piper aduncum*)								1
68	Butterfly (*Bauhinia purpurea*)								1
69	Indian rhododendron (*Melastoma malabthricum*)								1
	Non-Wood Forest Feedstock								
70	Nipa palm (*Nypa fruticans*)				1	3	6	8	3
71	Black sugar palm (*Arenga pinnata*)			1	1	3	2	5	4
72	Sago (*Metroxylon sago*)		1	2	4	3	3	4	3
73	Palmyra palm (*Borassus flabellifer*)					1		2	
74	Bamboo (*Dendrocalamus* sp.)							1	4
75	Hyacinth (*Eichhornia crassipes*)						1	3	1
76	Elephant grass (*Pennisetum purpureum*)								1
	Other biomass								
77	Municipal waste			1	1		4	3	5
78	Waste cooking oil			1	2	3	1	3	4
79	Animal manure			1	5	7	10	12	6
80	Microalgae			2	2	5	3	1	3
81	Human excreta							1	

Source: from various sources analysed by the authors

Annex 2. Policies, regulations, national plans and other strategic documents associated with bioenergy development in Indonesia

No.	Type and Institution	Subject	Objectives and details	Feedstock	Bioenergy type
1	Government Regulation No. 3/2005	Supply of Electricity	Regulates partnerships between independent power producers (IPPs) and state electricity company PLN to develop electricity projects. An exception is given to companies that generate power for their own use or those using renewable energy; this way they can set up plants independently without having to partner with PLN	Various	Various
2	Ministry of Energy and Mineral Resources Blueprint for the National Energy Implementation Program 2005–2025 issued	National Energy Implementation Programme	Provides development road maps for various sectors, covering renewable and non-renewable energy sectors	Various	Various
3	Presidential Regulation No. 5/2006	National Energy Policy	Promotes the use of renewable energy by providing facilities and energy conservation incentives to operators and developers of certain alternative energy sources like geothermal, biofuel, river flow, solar, wind, biomass, biogas, sea waves, and ocean thermal energy	Various	Various
4	Presidential Instruction No. 1/2006	Biofuel Supply and Utilization	Mandates 13 ministries and governmental agencies to take action in advancing biofuel development from feedstock supplies	Agriculture	Biofuel
5	Presidential Decree No. 10/2006	The establishment of a National Biofuel Development Taskforce	The taskforce was formed to formulate a roadmap for biofuel development in Indonesia, and ended in 2008	Not specified	Biofuel
6	Law No. 30/2007	Energy	Emphasize the contributions of local and national governments in order to enhance the nation’s stock of new and renewable energy and its utilization	Various	Various
7	Government Regulation No. 6/2007	Forest arrangement, forest management plan, and forest utilization	Utilization of non-timber forest products in unproductive production forests based on sustainable principles	Forest	Biomass

No.	Type and Institution	Subject	Objectives and details	Feedstock	Bioenergy type
8	Law No. 18/2008	Waste management	Aimed at improving public health and environmental quality, and utilizing waste as a resource.	Municipal waste	Biomass
9	Government Regulation No. 3/2008	Forest governance, management and utilization	Ensuring the term "*utilization of non-timber forest products in unproductive production forest*" includes the development of biofuel feedstock commodities	Forest	Biomass
10	Minister of Energy and Mineral Resources Regulation No. 32/2008	Biofuel utilization	Stipulates minimum biodiesel and bioethanol quantities to be utilized in public and non-public transport, commercial and industry sectors, and for electricity generation with a progressive scale to 2025	Not specified	Biodiesel and bioethanol
11	Minister of Finance Regulation No. 156/2009	GoI bears biofuel VAT for 2009 budget	Reduce climate change impacts; ensure renewables make up 23% of national energy mix by 2025 and 31% by 2050	Not specified	Biodiesel and Bioethanol
12	Law No. 30/2010	Electricity Law	Gives higher priority for renewable energy and clean technology in electricity generation and encourages small-scale distributed power generation from renewable sources such as biomass	Forest and agriculture	Biomass-based power generation
13	Minister of Energy and Mineral Resources Regulation No. 39/2017	Approaches for implementing new and renewable energy	Provides guidance for new and renewable energy implementation and power saving	Various	Biomass, biogas, municipal waste, biofuel
14	Minister of Energy and Mineral Resources Regulation No. 19/2013	Purchasing of electricity by PLN from municipal waste power plants	Stipulates permits, prices and technical requirements for implementation. In its general provisions, the regulation recognizes municipal waste power plants for generating power using solid waste through sanitary landfill or zero-waste technologies	Municipal waste	Biomass
15	Minister of Energy and Mineral Resources Regulation No. 25/2013	Biofuel utilization	Revises some articles on sanctions for business units failing to meet biodiesel allocation targets, and includes intra-sectoral responsibilities (oil and gas, electricity, renewable resources) in achieving targets	Not specified	Biodiesel and bioethanol
16	Minister of Energy and Mineral Resources Regulation No. 4/2012	Feed-in tariffs for biomass-based electricity	Sets feed-in tariffs for electricity generated from biomass	Forest and agriculture	Biomass-based electricity

No.	Type and Institution	Subject	Objectives and details	Feedstock	Bioenergy type
17	Government Regulation No. 79/2014	National Energy Policy (KEN)	Independent energy management; energy availability; equal energy access; jobs; environment	Various	Various
18	National Medium-Term Development Plan (RPJMN) 2015–2019	The National Medium Term Development Plan for 2015–2019	Declared the need to improve the contribution of solid waste-based electricity. The plan stipulates that local governments should ensure the provision of locations and embed this vision into municipal planning.	Various	Various
19	Minister of Energy and Mineral Resources Regulation No. 27/2014	PLN to buy electricity from biogas and biomass electricity generators with capacities up to 10 MW	FiTs or feed-in tariffs are formulated as follows: base tariff X regional factor. Base tariffs range from IDR 1,050 to IDR 1,500 per kWh when connected to low voltage supplies	Not specified	Biogas and biomass
20	Ministry of Energy and Mineral Resources Strategic Plan 2015-2019	Five-year strategic planning	Established three mechanisms for biogas development: non-commercial biogas programmes through the state budget (public investment); semi-commercial biogas programmes through Indonesia-Netherlands cooperation; and commercial biogas programmes through private investment in biogas power plants. Stipulates that in order to support national energy diversification, dedicated land should be prepared for biofuel crops	Various	Various
21	Ministry of Agriculture Strategic Plan 2015–2016	Five-year strategic planning	Encouraged the provision of energy feedstock to help achieve the target of 23% renewable energy (including biofuel) in the national energy mix by 2025	Agriculture	Not specified
22	Minister of Energy and Mineral Resources Regulation No. 20/2014	Biofuel supply, utilization and trading system	Obliges all sectors to use 30% biofuel blend by 2025. Set a 5% higher target to achieve by April 2015	Not specified	Biodiesel and Bioethanol
23	Government Regulation No. 24/2015	Oil Palm Plantation Fund	Plantation development, human resources capacity building, downstream improvements for plantations, optimization of utilization for industry, bioenergy and exports, price stability, increased welfare	Palm oil	Biofuel

No.	Type and Institution	Subject	Objectives and details	Feedstock	Bioenergy type
24	Presidential Regulation No. 61/2015	CPO Fund	To ensure sustainable oil palm plantation development by using the fund for human resources development in the palm oil sector, research and development, palm oil promotion, and oil palm plantation revitalization, including biodiesel utilization (as an add-on)	Palm oil	Biofuel
25	Minister of Energy and Mineral Resources Decree No. 3239/2015	Biofuel Market Price Index	Reduce fossil fuel imports; generate foreign exchange	Not specified	Biofuel
26	Minister of Energy and Mineral Resources Regulation No. 26/2015	Biodiesel utilization through CPO Fund	Expedite biodiesel blending mandate targets; ensure a well distributed biodiesel fund	Palm oil	Biofuel
27	Minister of Energy and Mineral Resources Regulation No. 44/2015	Purchase of electricity by PLN from municipal waste power plants	Refines definition of municipal waste power plants, stating that they work by a) methane gas collection in sanitary landfills or anaerobic digestion, and b) thermally from thermochemical technology. The pricing policy in the new regulation differs from the previous one	Municipal waste	Biomass
28	Minister of Environment and Forestry Regulation No. 12/2015, as amended by Minister of Environment and Forestry Regulation No. 17/2017	Plantation forest (HTI) establishment	Defines types of woody forest plants, cultivated annual crops, and other types of plants that support forest product industries, and supply raw materials for wood biomass- and biofuel-based bioenergy	Forest	Biomass
29	Government Regulation No. 105/2015	Utilization of forest estate	Non-forestry uses of forest estate are allowed for strategic objectives, such as certain forms of agriculture for food and energy security	Forest	Not specified
31	Minister of Energy and Mineral Resources Regulation No. 12/2015	Provision, utilization and trading administration for alternative biofuels	To achieve the 30% renewables targets by 2025 for sectors including transportation, electricity generation, industry and commercial activities		
32	Minister of Industry Regulation No. 31/2015	Ministry of Industry Strategic Plan 2010–2014		Not specified	Not specified

No.	Type and Institution	Subject	Objectives and details	Feedstock	Bioenergy type
33	Presidential Regulation No. 18/2016	Acceleration of the development of municipal waste power plants in seven cities in Indonesia	Infrastructure funded through state and regional government budgets. Article 7 of the regulation states that PLN is obliged to purchase power generated from plants in Jakarta, Tangerang, Bandung, Semarang, Surakarta, Surabaya and Makassar	Municipal waste	Biomass
34	Minister of Energy and Mineral Resources Regulation No. 21/2016	PLN to buy electricity from biogas and biomass electricity generators with capacities up to 10 MW	Promotes higher rates than the previous regulation. USD cents are used as the currency reference	Not specified	Biogas and biomass
35	Presidential Regulation No. 24/2016	Collection and utilization of (oil palm) Plantation Fund	Oil Palm Plantation Fund Management Agency (BPDPKS) is responsible for collecting, managing and distributing CPO funds	Palm oil	Biofuel
36	Minister of Finance Regulation No. 30/2016	Service fees for public service agencies for Palm Oil Plantation Fund management at the Ministry of Finance	Revenues collected through levies, which are different to palm oil export tax, charged on exports of crude palm oil and derivatives, and vary from USD 20 to 50 USD per MT	Not specified	Not specified
37	Minister of Finance Regulation No. 140/2016	Determination of export goods subject to export duties and tariffs for export duties	Export tax ranges from 0 USD per MT when the international CPO price is below USD 750, to USD 262 per MT when the international CPO price is USD 1,250	Palm oil	Not specified
38	Presidential Regulation No. 22/2017	RUEN (National Energy Plan)	Renewable energy to make up 23% of the national energy mix by 2025 and 31% by 2050 as long as economic needs are met	Various	Various
39	Minister of Energy and Mineral Resources Decree No. 1415/2017	(RUPTL) National Electricity Generation Plan	Meeting energy demand with required standards and lowest cost. Reducing fossil fuel use and increasing use of renewable energy, especially hydro and geothermal	Various	Various
40	Minister of Energy and Mineral Resources Regulation No. 12/2017	Utilization of renewable energy resources for electricity	National energy security, CO_2 emissions reductions	Various	Various
41	Minister of Energy and Mineral Resources Regulation No. 50/2017	Amended with Minister of Energy and Mineral Resources Regulations No. 53/2018 and 4/2020	The government obliges PLN to purchase power from plants with renewable energy sources. PLN is compelled to operate renewables-based power plants with 10 MW must run capacity	Various	Various

No.	Type and Institution	Subject	Objectives and details	Feedstock	Bioenergy type
42	Minister of Energy and Mineral Resources Regulation No. 12/2017	Utilization of renewable energy resources for electricity	Promotes national energy security and decreases CO_2 emissions through the utilization of solar power, wind, water, biomass, biogas, solid waste, and geothermal power plants	Various	Various
43	Minister of Energy and Mineral Resources Regulation No. 53/2018	Amended with Minister of Energy and Mineral Resources Regulation No. 4/2020	No changes to renewables prices and build, own, operate and transfer (BOOT) scheme. Biofuel is added as renewable energy to generate electricity	Various	Various
44	Minister of Energy and Mineral Resources Regulation No. 4/2020	Utilization of renewable energy sources for electricity supply	(i) The renewed possibility for PLN to use the direct appointment mechanism, (ii) the removal of the requirement that projects be developed exclusively under the BOOT scheme, and (iii) the fact that PLN must prioritize the purchase of electricity from renewables IPPs (based on the must-run regime) without any restrictions on generation capacity	Various	Various
45	Minister of Energy and Mineral Resources Regulation No. 16/2020	Ministry of Energy and Mineral Resources Strategic Plan for 2020–2024	Updated plan for bioenergy development in Indonesia	Various	Various