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Prospects for wood-based electricity for the Indonesian National Energy Policy

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List of acronyms

BAPPENAS	Badan Perencanaan Pembangunan Nasional. National Development Planning Agency
BAPPEDA	Badan Perencanaan Pembangunan Daerah. Regional Development Planning Agency
BLU	*Badan Layanan Umum*
CHP	combined heat and power
FiT	feed-in-tariff
FMU	Forest Management Unit
GoI	Government of Indonesia
HTE	*Hutan Tanaman Energi*, industrial energy plantation
HTI	*Hutan Tanaman Industri*, industrial tree plantation
HTR	*Hutan Tanaman Rakyat*, smallholder tree plantation
IPP	Independent power plant
KPC	Kaltim Prima Coal
MoEF	Ministry of Environment and Forestry
MoEMR	Ministry of Energy and Mineral Resources
MORRE	mine reclamation for rural renewable energy
MoU	Memorandum of Understanding
NRE	New and renewable energy
NTT	Nusa Tenggara Timur
PLN	Perusahaan Listrik Nasional, state-owned electricity company
POME	palm oil methane effluent
RENSTRA	Strategic Plan of the Ministry of Environment and Forestry
RPJMN	National Medium-Term Development Plan
RUEN	*Rencana Umum Energi Nasional*
SPV	special purpose vehicle
UTL	PT. Usaha Tani Lestari

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Summary

To achieve the target of 23% renewable energy by 2020, Indonesia has been actively exploring options to loosen its dependence on fossil fuels. While biofuels have been developing fast and remain a priority for the government, wood-based energy also holds great theoretical potential. Yet, it remains under-studied. This report is a first attempt to assess its state of development, feasibility and potential.

Wood-based energy could be based on the high-profile large-scale industrial tree plantation program in Indonesia. This is one of the largest in the world with millions of hectares planted but it has partially failed to achieve public objectives. The government envisions its revival, with bioenergy as an alternative to the mature pulp and paper market. To do so, a feed-in tariff policy has been put in place as an incentive to build power plants for using biomass (or biogas material).

There is a rationale for the promotion of wood-based energy in Indonesia, as technologies are available and large tracts of degraded land are found across the archipelago. It may also contribute to diversification and clean energy supplies to remote places, in the context of a need to augment the electrification rate in rural areas and reduce expensive fossil fuels imports.

Based on literature research, active interactions with stakeholders at national and provincial levels, and three case studies, we identified major challenges for the development at scale of wood-based energy in Indonesia. Albeit large-scale plantations dedicated to supplying independent power plants might make economic sense in perfect conditions, major uncertainties related to land tenure, unstable policies and the contradictory interests of the state-owned electricity company have sent the wrong signals to investors so far.

Besides improving these aspects with a much friendlier investment environment, and much increased efforts toward a proof of concept, it is also worth exploring in more details the feasibility of low-scale projects run by villages where technical assistance will be an absolute requirement for both plantation management and plant maintenance.

1 Introduction

Energy security represents a great challenge in Indonesia as supplies need to catch up with rocketing demand (predicted to three times higher by 2035) due to economic growth and changing living standards (OECD/IEA 2015). Moreover, the country extends over thousands of islands and local contexts differ greatly in terms of infrastructure, incomes and access to local sources of energy. The government has committed to significant reductions of greenhouse gas emissions (between 26 and 41% against business-as-usual by 2020, depending whether external support is made available to help the country achieve targets), but still relies heavily on fossil fuels with 95% of the national primary energy supply made up of crude oil, coal and natural gas, and less than 5% from new and renewable energy (NRE) sources,[1] such as hydropower and geothermal (OECD/IEA 2015; MoEMR 2016). The role of biomass-based energy has been limited to the use of firewood and charcoal for households. There is a need to stimulate energy production based on renewable and sustainable sources and processes in order to reach energy security and to reduce greenhouse gas emissions (Bappenas 2015).

The Government of Indonesia (GoI) issued Regulation 79 of 2014 that aims to achieve 23% of energy production from NRE by 2025. Under the new energy policy, the GoI issued the National General Energy Plan (*Rencana Umum Energi Nasional* – RUEN) in March 2017. RUEN provides a detailed national plan up to 2050. Under RUEN, the GoI prioritizes several NRE sources: geothermal, water, micro, bioenergy, solar and wind. RUEN projects that the role of bioenergy will be prominent with a contribution to 37% of the NRE supply by 2025, and 39% by 2050. It also projects that the bioenergy will supply 5.5 GW by 2025 and 26 GW by 2050.

As the country has huge natural resources, vast forested areas and degraded lands, and suitable conditions for the development of oil palm, the idea of relying on bioenergy to achieve energy targets took root in the government. Bioenergy refers to energy production based on biomass and can take many forms from liquid biofuels, such as biodiesel produced with palm oil and bioethanol with sugarcane, to solid biofuels, such as pellets or chips produced with wood, and others. Biomass can serve the purposes of electricity generation, transportation fuels or heat production, although there are limitations to the application of bioenergy at scale and its economic feasibility without government subsidies (Bappenas 2015).

The potential for bioenergy development is assumed to be significant, as millions of hectares of degraded land could theoretically be used for the production of various kinds of biomass, either as residues (e.g. from agriculture, forestry or municipal waste), alternative products (e.g. biofuels vs. other palm-oil-derived products), or dedicated tree plantations (established and managed specifically to supply the mill). Moreover, the government plans to stimulate the restoration of degraded lands and to support access to electricity in remote rural areas, in a context of declining production of fossil fuels and increased reliance on imports (Hidayat 2016) that are expected to play in favor of bioenergy (Bappenas 2015).

This paper looks specifically at wood-based electricity production, with biomass power plants being supplied by woody biomass from dedicated tree plantations, which is a scheme promoted by the government, but still in its infancy. A number of investors have shown interest in on-grid wood-based electricity projects, including power plants and associated tree plantations to supply fuel, either

1 In the National Energy Policy (Government Regulation 79 of 2014), new energy refers to the energy that comes from new sources. New energy sources refer to energy sources that are produced both from renewable and nonrenewable sources. Renewable energy refers to energy that comes from renewable energy sources, which are energy sources that can be sustainable under good management.

large-scale plantations (*Hutan Tanaman Industri – HTI*) or outgrower schemes. Alternative options of interest to investors include using woody biomass for co-firing with other energy sources (e.g. coal or palm kernel shells) or making economic use of residues from wood processing (e.g. sawn wood or plywood). At the same time, through the issuance of the National General Energy Plan (*Rencana Umum Energi Nasional – RUEN*), the Indonesian government is promoting the development of renewable energies in order to meet its energy mix target and to satisfy the country's rapidly rising energy consumption, which will reduce its dependence on fossil fuel imports.

However, preliminary discussions with a number of stakeholders raised numerous challenges: an insecure regulatory and institutional environment, overly extensive and opaque bureaucratic processes for licenses, land-use conflicts with local communities, feed-in tariffs that fail to ensure the economic feasibility of wood-based electricity generation, or the state-owned electricity company (*Perusahaan Listrik Negara - PLN*) not being fully collaborative and potentially a bottleneck (Pirard et al. 2016b).

The objective of this research is thus to assess the level of development of wood-based electricity production based on existing and planned projects, and to assess its potential to contribute to the new energy policy as announced by the Ministries of Environment and Forestry (MoEF) and of Energy and Mineral Resources (MoEMR). We leave aside production and export of pellets that are reported to have dropped after the brief surge of exports to South Korea (Argus 2016; personal communication, Korindo, September 2016).

The report is structured as follows: the methodology is presented; available technologies in Indonesia for wood-based electricity are identified and briefly described; the policies and legal framework for the revival of the HTI program with tree plantations dedicated to bioenergy are discussed; case studies are presented; results and discussion unfold and a number of recommendations are provided.

2 Methods

The potential of the sector is linked to economic, policy and institutional aspects that we address in our analysis. Data collection was based on multiple interactions and interviews with the main stakeholders in this field. We also reviewed a collection of secondary data on regulations and databases of projects and operational units (see Annex 1). We participated in a series of meetings organized by the MoEF and the MoEMR over the period 2015/2016, which discussed the state of development of tree plantations, refinement of incentive schemes and enhanced communication between the business community, government and other stakeholders. We co-organized a national stakeholder workshop in May 2016 with the Ministry of National Development Planning Agency. This gave us the opportunity to discuss critical issues and produce knowledge that further guided our approach.

We also investigated in greater depth three case studies in Riau, Nusa Tenggara Timur and East Kalimantan provinces, where investors and the government are in the early stages of developing wood-based electricity production. This allowed us to derive lessons to inform policies in this emerging field, particularly regarding the Indonesian government's recent attempts to revive the underperforming HTI program with the new diversification of products and markets.

Data collected at national level concerned the range and scope of national policies and were mostly qualitative. At the case study level, they included quantitative information that helped us determine the level of development, rationality and feasibility of projects on the ground:

- Economic feasibility for investors, standard cost calculations
- Ease of conducting business, including licensing process
- Energy-related Infrastructures and market
  - Level of integration with electricity production and other processing needs
  - Off-grid or on-grid connectivity, the need to finance additional infrastructure, such as transmission lines
  - Availability/accessibility of technologies
  - Local electricity demand and supply situation, availability of previous assessment to ensure soundness of investment
- Use of degraded/forested land
- Product diversification/forest management at plot and at plantation levels
- Technologies used for power generation

3 Role of technology

Biomass energy is solar energy that has been converted into organic matter through photosynthesis. Humans created techniques to convert this energy into heat, power, fuel, etc., which allowed human development. While the earliest and most primitive techniques for this conversion process may have been around for more than one million years (Gowlett and Wrangham 2013), technological innovation continues, allowing the ever more efficient use of biomass energy for human purposes.

Solid and liquid biomass can be converted into electricity by drawing on processes such as combustion, gasification, biological digestion or fermentation in a first step and subsequently making use of the heat or gases produced in the respective process to move turbines or to fuel generators that produce electricity. In the present chapter, we focus on steam combustion and gasification with solid biomass as a feedstock because these have been identified as the most relevant technologies in the Indonesian context when it comes to producing electricity from biomass.

3.1 Biomass gasification – chemical process and technological options

The thermochemical gasification process draws on a solid material containing carbon (e.g. coal or biomass), which is converted into gases, such as hydrogen, carbon monoxide and methane, by thermal cracking and partial oxidation.

Figure 1 illustrates the operating principles behind two of the most relevant types of gasifier for biomass gasification. In an updraft gasifier, depicted on the left, the feedstock is fed from above and subsequently enters the drying zone. After drying, the volatile components of the feedstock are vaporized under heat; a process known as pyrolysis. Depending on the feedstock, the volatile vapors are composed of hydrogen, carbon monoxide, carbon dioxide, methane, hydrocarbon gases, tar and water vapor (E4tech 2009). The products of the first two zones move upwards and are directly released from the gasifier, which is why the syngas (synthetic gas) produced in an updraft gasifier is characterized by relatively high tar contents (Obernberger and Thek 2008), making a costly gas cleaning process necessary before, for instance, using the syngas in internal combustion engines (e.g. a gas generator). The biomass subsequently enters the reduction zone and the oxidation zone where a fumigator (usually air, oxygen-enriched air or steam) enters the gasifier and where the biomass is almost completely oxidized. The oxidized ash is collected at the bottom of the gasifier, from where it can be removed for other uses.

Downdraft gasification follows the same thermochemical processes described above. However, the biomass and product gases flow in the same direction. This means that the gases produced in the drying and pyrolysis zones have to pass through the throat of the gasifier where the tars undergo secondary decomposition reactions (Figure 1, right). Thus, the syngas resulting from the downdraft gasification process is considerably lower, which reduces the subsequent costs of gas cleaning and tar removal (Obernberger and Thek 2008).

While updraft and downdraft gasifiers are the most common types of fixed-bed gasifiers, there are several other types, most importantly, the double fired gasifiers, which combine the advantages of the two systems described above.

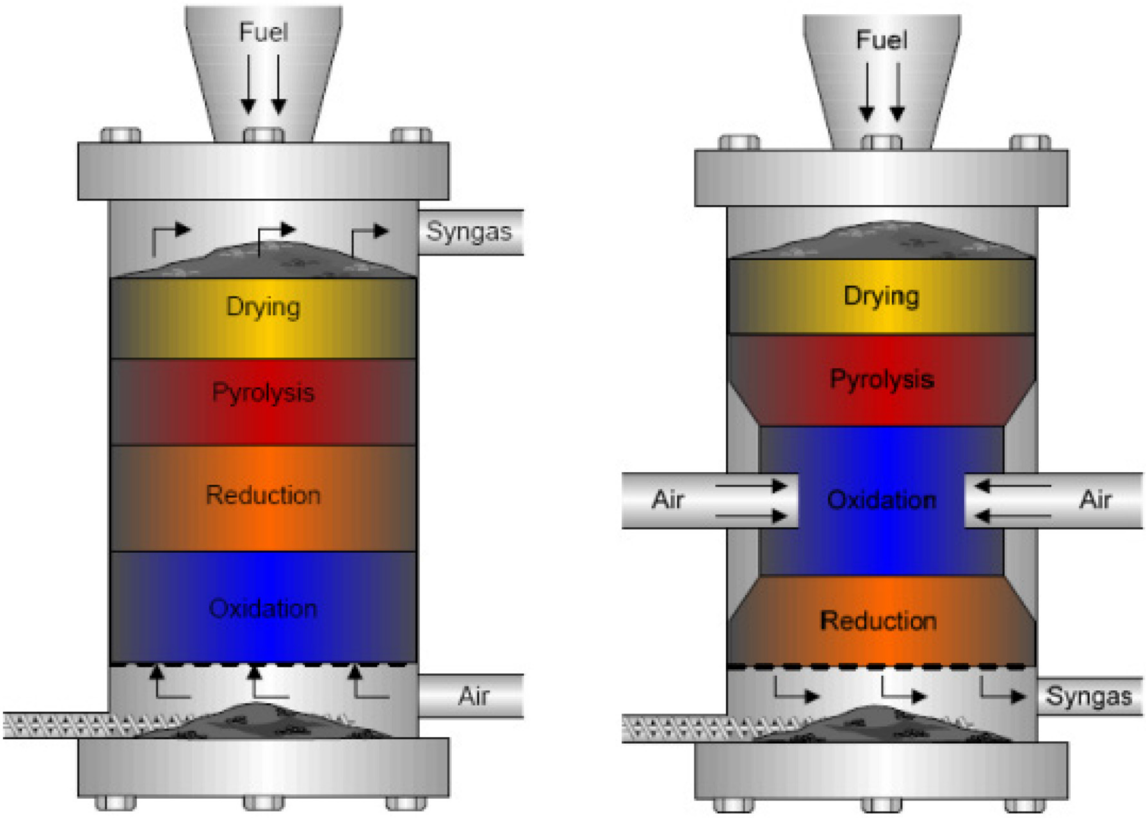

Figure 1. Schematic illustration of updraft (left) and downdraft fixed-bed gasification (right)
Source: Olofsson et al. 2005

The other group of gasifier types relevant in the context of biomass-based electricity generation is fluidized-bed gasifiers. While in a fixed-bed gasifier the feedstock is not moved by the gas flow and only slowly moves through the different zones from top to bottom, the fluidized-bed gasifier is operated under much higher gas flow velocities. As the feedstock is mixed with a gasification medium (e.g. sand), there are no distinguishable reaction zones as in the fixed-bed gasifier, but the biomass is agitated and moves within the gasifier. The resulting syngas therefore has a high dust concentration and also needs to be cleaned of tars before put into further use. Several different types of fluidized-bed gasifiers exist and are discussed in E4tech (2009).

The suitability of the different gasifier types for specific biomass-to-power projects has to be evaluated against a set of criteria, ranging from investment costs to suitable feedstock. Table 1 provides an overview of some of the most important criteria.

Other types of gasifier, such as entrained-flow and plasma gasifiers are technologically considerably more advanced and have not reached commercialization yet. These technologies are particularly relevant for the conversion of biomass into liquid fuels and so will not be discussed in the present paper. E4tech (2009) provides an in-depth discussion of these technologies.

Table 1. Comparative features for gasifier types

	Fixed bed, updraft	Fixed bed, downdraft	Fluidized bed
Investment cost	Medium	Medium	High
Scale of operations	Small to medium scale (100 kW to 20 MW)	Small to medium scale (20 kW to 5 MW)	Large scale
Suitable for wood chips as feedstock	Yes	Yes	Yes
Feedstock particle size	Relatively insensitive (5–100 mm)	Requires larger particles (20–100 mm)	Depending on type of fluidized-bed gasifier, but generally more sensitive than fixed-bed gasifiers
Feedstock moisture content	Up to 55%	<20%	Depending on type of fluidized-bed gasifier,
Syngas quality	Can contain up to 10–20% tars	Relatively clean with low content of tars (due to secondary decomposition)	High calorific value. Might have higher tar and dust content than downdraft fixed-bed gasifier
Complexity of operations	Medium complexity of operation	Medium complexity of operation	High complexity of operation

Source: Authors' work based on Obernberger and Thek (2008); E4tech (2009); Worley and Yale (2012).

3.2 Steam combustion

Biomass can also be converted into electricity by steam combustion. While there are different steam combustion technologies, the basic principle is straightforward. The feedstock is burnt in order to generate high temperature and high pressure water steam in the boiler of the plant. This steam subsequently enters a steam turbine where the thermal energy of the steam is converted into mechanical energy and ultimately electricity. The low-pressure steam exiting the steam turbine is condensed and the water is fed back into the boiler where it is reused in the same process.[2]

Compared to biomass gasification, steam combustion has been technologically and commercially viable for decades. While fixed-bed gasifiers are applicable at small to medium scales, conventional steam combustion plants can only be profitable at larger scales, typically ranging from 2 to 25 MW. With electric annual use efficiencies (= annual electricity production/annual fuel input, based on its net caloric value) typically ranging between 18 and 30%, steam combustion plants are consequently slightly less efficient in converting biomass into electricity than plants drawing on the gasification process, which can reach annual use efficiencies of 30 to 35% when the syngas is used in internal combustion engines and even higher efficiencies when electricity is generated from modern gas generators (IEA 2007). The efficiency for both technologies increases when combined heat and power (CHP) cycles or even trigeneration of heat, power and cooling energy come into play (see following section).

Although the larger-scale investments and lower efficiencies of steam combustion make it sound less attractive than gasification, there are strong advantages that could convince investors to adopt this mode of biomass-based electricity production. As the technology is well-known and quite simple to handle, it may be of interest for risk-adverse investors. Moreover, access to finance might also be made easier with these lower levels of risk.

2 http://www.bios-bioenergy.at/en/electricity-from-biomass/steam-turbine.html

3.3 Combined heat and power (CHP) generation and trigeneration

Assuming the above-mentioned annual use efficiencies of 30%, we can state that in a simple gasification or biomass combustion plant around 70% of the energy stored in the feedstock is released into the atmosphere without having been put into use. Most of this is in the form of waste heat, with some stored in the tars and ashes produced in the combustion or oxidation processes. However, both sources of energy can be put into further energetic uses in secondary processes. Figure 2 illustrates some of the options for secondary energy production within the gasification and steam combustion processes.

Large amounts of energy are released in the form of excess heat that can be recovered with a number of technological options. Usually, the steam that has to be separated from light tars and heavy tars, as well as from other solid material, can be cooled in a heat exchanger, where a great part of its heat is captured and can subsequently be transferred to a hot water circuit and heating systems. In some of the most modern plants, the heavy tars that have been separated from the steam are in turn used for household heating. Making use of the excess heat and the energy stored in waste tars, modern plants can reach thermal efficiencies of around 65% and, as described above, electric efficiencies of 30% or more. This means that overall plant efficiencies of more than 90% are achievable (Obernberger and Thek 2008).

CHP technologies based on biomass combustion have proven commercial maturity for plants with a capacity of 2 MW or more, as have medium-scale plants based on the Organic Rankine Cycle and Stirling engine-based small-scale operations (Obernberger and Thek 2008). CHP technologies based on biomass gasification have rapidly moved toward commercialization in the past decade; however, it seems that few are economically and technically viable at present.

Combined cooling, heat and power production, so-called trigeneration, is a further enhancement of existing CHP technologies. Waste heat from a biomass-based power plant or CHP plant can be used for cold production through thermodynamic cycles in absorption or adsorption chillers. The thermodynamic cycle of an absorption chiller is based on a refrigerant and a solvent, where the first

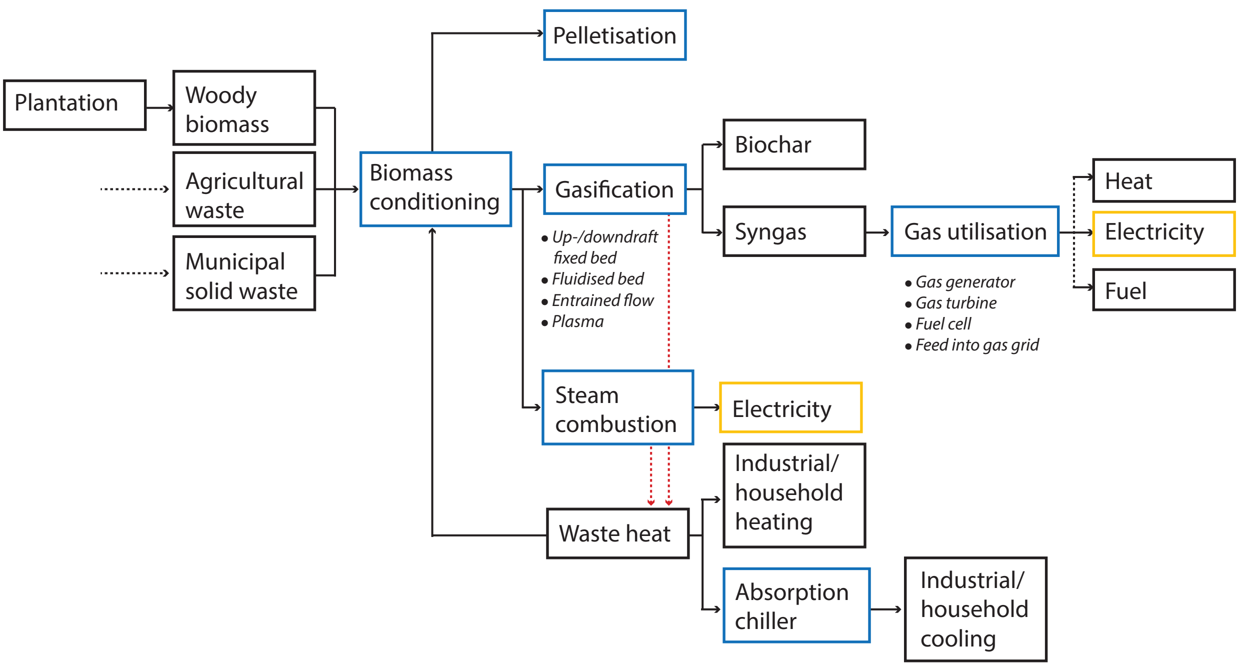

Figure 2. Some of the technological options for biomass-to-power conversion
Source: Author's illustration

must be totally soluble in the latter. Many commercial absorption chillers draw on lithium bromide and water as refrigerant and solvent and are thus able to achieve cold temperatures of 3°C, while the temperature of the input heat must be at least 80°C. Even lower temperatures can be achieved if ammonia is used as a refrigerant and higher input heat temperatures can be supplied.

While CHP plants are rather complex to operate, the complexity of operation further increases with trigeneration plants as the systems for cooling, heating and power production have to be combined and continuously adjusted to each other.

3.4 Choice of biomass

The choice of biomass for biomass-based power generation depends primarily on the requirements of the installed technology, the desired syngas (synthesis gas resulting from gasification) quality and the availability of suitable feedstock. While the first two factors are of technological nature, feedstock availability may be determined by an interplay of economic, policy and social factors at global, national and local levels that can usually not be directly influenced by the plant manager.

The range of technological options for biomass gasification results in considerable variation in terms of required feedstock properties. Table 2 depicts the most critical feedstock properties and how they affect the gasification process. First, there are technological and processual restrictions to the physical properties of the biomass feedstock depending on the applied gasification technologies. As already outlined in Table 1, variations in particle size and shape, moisture content, porosity and density of the feedstock can generally be handled better by fixed-bed gasifiers than by fluidized-bed gasifiers, and updraft fixed-bed gasifiers are the most insensitive technological option of the three. Plasma gasification, which is technologically much more complex than the gasification technologies described above, can accept nearly all biomass feedstocks with minimal pre-treatment and is frequently fed by municipal solid waste or organic waste.

Second, the thermochemical properties of the feedstock directly affect the quality of the syngas and hence the options for further uses of the gas. While the content of hydrogen, oxygen and carbon of the feedstock mainly determines the heating value, the nitrogen and sulfur content of the biomass are directly reflected in the chemical properties of the syngas and thus adjustments of the integrated gas cleaning system are required, which might limit the options for further uses of the syngas. For example, fuels cells demand high-quality and relatively constant composition of the syngas to run efficiently, which means that the plant must be operated and monitored precisely and continuously without allowing frequent changes in feedstock composition (Karellas and Karl 2007). Having a reliable supply of homogenous feedstock from an affiliated tree plantation could meet these requirements for high-quality syngas and hence some edge for wood-based electricity.

The type of biomass used as feedstock is not only critical for the chemical composition of the resulting syngas but its ash content and the properties of the ash also affect the gasification process. Lower ash content is generally favorable for the gasification process, as ash reduces the heating value and hence the energy density of the feedstock and requires adjustments in the grates, heat exchangers and the gas cleaning equipment. Moreover, the ash melting point sets limits to the operating temperature of the boiler.

Woody biomass is generally characterized by higher energy densities and a lower ash content, as well as by ash melting points above 1000°C. which makes it easier to handle and applicable to a wider range of gasifier types. Herbaceous biomass, such as rice husk or straw, might be available at cheaper prices, although it has less favorable thermochemical and physical properties.

The quality and composition of the syngas is thus determined by technological factors, such as the type of gasifier installed, processual factors, such as the operating temperature in the boiler, as well as

Table 2. Biomass properties and impacts on the gasification process

	Biomass properties	Impact on gasification system
Physical	High moisture content (hygroscopic)	• Decrease in heating value of fuel. • Storage durability. • Fuel transportation costs. • Lower process temperature. • Reduction in producer gas quality, gasification efficiency and fuel conversion. • Optimal moisture content for gasification: 10-15% wt.
	Low apparent density	• Energy density (→ transportation, storage and handling costs). • Feeding system.
	Shape and distribution of particle size	• Transport and feeding system. • Gasification technology. • Reactivity of fuel.
	Low friability	• Fuel pre-treatment and feeding (entrained-flow gasifiers).
	Porosity / specific surface area / distribution of pore size	• Reactivity of fuel.
Thermochemical	Cellulose, hemicellulose and lignin content	• Reactivity of fuel.
	Ultimate analysis	
	– C, H, O content	• Heating value of fuel.
	– N content	• Fate of fuel-bound N during gasification: mainly transformed into NH_3 and HCN → design of gas cleaning section. • Emissions.
	– S content	• Fate of fuel-bound S during gasification: mainly transformed into H_2S and COS. → design of gas cleaning section. • Interaction with alkali metals: emissions, deposits, corrosion. • Deactivation of downstream catalysts.
	– Cl content	• Decrease of softening temperature of ash. • Enhancement mobility of K (→deposition and agglomeration). • Emissions, corrosion and ash sintering.
	High volatile content, low fixed carbon content	• Reactivity of fuel.
	Ash content	• Decrease of fuel heating value. • Energy density: transportation costs. • Emissions. • Ash disposal costs. • Design of equipment (grates, heat exchangers, gas cleaning).
	Ash composition	• Ash-melting behaviour (softening and melting temperatures) → deposition, agglomeration, fouling.
	– Na and K content	• Involved in ash deposition and formation of deposits. • Lowering of ash melting temperatures. Formation of eutectics. • Reaction with Si and S: deposition, agglomeration, fouling, corrosion. • Ash valorisation.
	– Mg, P, Ca content	• Increase of ash melting temperature. • Ash disposal applications.
	– Heavy metals	• Emissions. • Ash disposal costs, ash applications.

Source: International Energy Agency, http://www.ieatask33.org/download.php?file=files/file/publications/Fact_sheets/IEA_Biomass_as_feedstock.pdf by the physical and thermochemical properties of the feedstock. The interplay of these factors makes the operation of a biomass gasification plant and the continued production of a high-quality syngas extremely challenging, especially when continuous supply with a relatively homogeneous feedstock cannot be guaranteed. This might be one of the main advantages that well-managed integrated projects – particularly with power plants being fed by nearby dedicated tree plantations – might have over power plants that are dependent on sourcing their feedstock on the market.

3.5 Potential for biomass-based power generation in Indonesia

Based on the above discussion, we can state that power generation based on the biomass combustion process is a proven and widely applicable technology. Biomass gasification technologies have moved rapidly toward commercialization and some of the less complex gasifier types (e.g. fixed-bed gasifiers) can today be operated reliably and economically. Biomass combustion appears to be preferable for large-scale (>2MW) plants, while gasification has more potential at the medium and possibly at the small scale (Obernberger and Thek, 2008). However, the complexity of operation of biomass gasification plants – particularly when it comes to maintaining constant gas quality and treatment of potentially toxic waste – reduces the potential of broad application of the technology, especially as locally operated units supplying electricity to remote villages. This is because operation of a biomass gasification plant requires well-trained personnel that might not be available in remote areas of the country. To produce high-quality gas and run the plant economically requires feedstock with constant thermochemical properties (this is at least true for the gasifier types fully commercial today). However, feedstock supply remains a huge challenge and either requires a well-managed (integrated) plantation, outgrower scheme or reliable supply of feedstock over national or international markets. Market prices of biomass, be it palm kernel shells, wood chips or municipal waste, usually display certain degrees of volatility, which might threaten gasification plants' economic viability. This is where operations with dedicated tree plantations might have an advantage over operations that depend on market supply providing a constant supply of homogenous feedstock at, depending on the context, relatively low opportunity costs.

While the operation of single-purpose biomass gasification plants (i.e. solely producing power) is complex, complexity increases sharply when secondary processes, such as heat or cold production, are included, even though this holds huge potential for increasing overall plant efficiencies and thus the potential economic and environmental desirability of this technology (Obernberger and Thek 2008). Both, combined heat and power generation still require proof of concept in the Indonesian context. There are, however, promising pilot plants in Europe that demonstrate where the technology might be going over the coming decade (Obernberger and Thek 2008).

4 Policy and governance framework

This report deals with two complementary components, i.e. plantations and power plants. There are basically two plantation schemes that can produce the feedstock required: one is within the HTI program for large-scale activities and the other is with outgrower schemes, where power plants outsource their fiber supplies. The latter can be further divided into smallholder tree plantation (*Hutan Tanaman Rakyat – HTR*) programs, whereby farmers get use rights to public land to establish plantations, and individual plots established on private land by villagers. We will discuss policies on HTI and HTR in following sections.

Power plants can be either part of the grids that are built and maintained by the National Electricity Company (*Perusahaan Listrik Negara* – PLN) or off-grid, where the private sector is in charge of building the plants. When there is a sufficiently large power supply from separate private sector grids, PLN could make the appropriate connections to expand the system. A number of options are available with respect to technology, integration with feedstock production, connection to the grid and other aspects, which we will discuss in relation to existing policies.

4.1 Industrial Tree Plantations (HTI) as a platform to promote Industrial Energy Plantations (HTE)

The global context is clearly one of increased planted forests areas across the world (Warman 2014), and an additional 5 million hectares was estimated to have been planted annually in the decade to 2010 (Payn et al. 2015). Depending on the scenarios used, planted forests are predicted to cover anywhere from 303 to 345 million hectares by 2030, with most of the absolute increase taking place in Asia and under company management (Carle and Holmgren 2008). Plantations established for industrial roundwood production are likely to dominate, although a small but increasing number of plantations are established for other commercial purposes. For example, an estimated 403,000 ha of plantations were established for commercial carbon sequestration worldwide by September 2011 (Diaz et al. 2011), and a growing area of plantations are being established for bioenergy production, even though it remains a marginal proportion of the global plantation estate (Hedenus and Azar 2009).

In Indonesia, as of 2015, 280 licenses have been issued for industrial tree plantations (HTI) covering 10.7 million hectares (Ministry of Forestry 2016), which represents a spectacular increase from nine concessions in 1995. Over the period 2010–2014, the planted area within these concessions has increased from 0.9 million hectares to 2.25 million hectares, although sources from the same ministry state this may even be as high as 5 million hectares (unpublished statistics from Ministry of the Environment and Forestry).

This expansion is mostly due to the pulp and paper sector that has established about 1.5 million hectares of acacia and eucalyptus estates to supply mills in Sumatra and, marginally, in Kalimantan. However, there is also diversification, not only because the state-owned company manages about 2.4 million hectares of teak and pine estates outside of the HTI concessions, but also because the HTI program is increasingly being used for alternative products, of which rubber and bioenergy are the most aggressively sought (unpublished MoEF documents and outputs from meetings in 2016).

The programs under RUEN include developing biogas-based electricity through the use of palm oil methane effluent (POME), increasing biomass-based electricity generation and promoting the development of non-food bioenergy crops. Some companies have used POME and other palm oil waste for their own electricity needs, and some even export their excess power to PLN, although the amount of electricity exported to PLN was quite low at 101 MW in 2015 (Hasanudin et al. 2015; MoEMR 2016; Nur et al. 2017). Wood-based electricity is, however, dominated by pulp and paper companies in Sumatra, where they have the capacity to produce 955 MW of electricity. The MoEMR reported only one biomass gasification plant in Sumba with a capacity of 1 MW (MoEMR 2016).

To promote electricity generation from woody biomass, the GoI has popularized the concept of Tree Plantations for Energy (*Hutan Tanaman Energi – HTE*). HTE is currently included under MoEF Regulation P.12/Menlhk-II/2015 on Industrial Tree Plantations. HTE does not refer to specific rules applied to plantations, as they still operate within the usual HTI framework. However, it provides room for bioenergy-oriented investments to unfold and, hopefully, thrive as the scope is expanded and other species are permitted. Indeed the Ministry regulation embraces three main groups of species: woody forest trees, woody estate crops, and other crops that are allowed as part of HTI. Woody forest trees and other crops for HTI should be recommended by the Ministry's Research and Development Agency, and woody estate crops should follow another ministerial regulation on non-timber forest products.

The Tree Plantations for Energy are handled by a Memorandum of Understanding (MoU) between MoEF and the Ministry of Energy and Mineral Resources (MoEMR) that was signed in 2014. This MoU was also viewed as a way to trigger investments in power plants with adequate support provided by MoEMR. On paper, this MoU had the following objectives: planning the development of wood-based energy; implementing and evaluating outcomes; pushing for the support in terms of fiscal policies by the Ministry of Finance; supporting involvement of regional stakeholders for energy security; and facilitating the availability of proper funding. Two major follow-ups came from the MoU: the proposed subsidy for NRE in the state budget, and the "Dana Ketahanan Energi" discussed in section 4.3. However, progress is still limited.

The history of the HTI program in Indonesia does not bring much optimism for the development of wood stocks for energy, as it has basically only been fully implemented for the two main pulp and paper groups that control the bulk of the productive planted estate. Indeed, operations are difficult on the ground because of insecure land tenure and local claims (e.g. Dhiaulhaq et al. 2014) or general negative perceptions by local populations toward industrial tree plantations (Pirard et al. 2016a). In the case of wood energy, there is fierce competition with other traditional sources of energy (a similar situation happened in the past when the pulp and paper industry had extensive access to natural forests so that plantations were underdeveloped). As a consequence, it appears that investors remain prudent.

Things might change, however, as plans were reported for using the Revolving Fund managed by the MoEF in order to support HTE. The Revolving Fund is managed under the public service agency (*Badan Layanan Umum* – BLU), and the BLU uses the Revolving Fund to support forestry development, including tree plantations (Obidzinski and Dermawan 2010 ; Nugroho et al. 2013). The experience of the agency in financing smallholder tree plantations (*Hutan Tanaman Rakyat* – HTR, see section 4.2) provides lessons about the challenges of accessing the funding from BLU, where the short payback period, inflexible financing schemes and the commercial rates that are applicable to large-scale plantations have resulted in few applications for financing (Widyantoro 2012; Nugroho et al. 2013). At the end of 2015, a ministerial regulation was issued to expand the business model of BLU, allowing it to provide financing schemes through loan, profit-sharing or sharia systems. It also expands the scope of forestry business schemes, from HTI and HTR to include village forests, private forests (*Hutan rakyat* – HR), agroforestry, ecosystem restoration and non-timber forest products.

Discussions are reportedly ongoing at the MoEF and MoEMR in order to create a specific HTE license for energy tree plantations (based on a new joint regulation by the two ministries). While it is not clear yet what the specific rules provided by this upcoming regulation will be, one innovative feature is said, by one of our informants from the private sector, to be the possibility of building the power plant inside the concession without having to obtain a separate license from the Ministry of Industry.

Currently, some energy tree plantations are developed on agricultural land (*Area untuk Penggunaan Lain – APL*) and, therefore, are outside of HTI concessions under MoEF responsibility.

4.2 Smallholders' HTR program

In 2007, the GoI established the HTR program for smallholder tree plantations (Obidzinski and Dermawan 2010). The program targeted 5.4 million hectares within the state forest that would be allocated to communities by 2010, and fully planted by 2016. The aims of the program are twofold: providing additional supplies of timber in a context of overcapacity at the processing level in the country and associated illegal logging; and improving the livelihoods of people living in and around degraded production forest areas. Once mature, these new plantations are expected to produce enough raw material to fill the current supply–demand gap and also to spur growth in the timber industry sector to support the rural economy, including contributing to rural electrification based on local feedstock in plantations.

Beyond the allocation of land-use rights on the state forest domain, the program provides incentives, such as loans at subsidized interest rates, allocated through the public service agency Forest Development Funding Center (*Pusat Pembiayaan Pembangunan Hutan* – PPPH also known as BLU). These loans range from USD 700 to 1000 per hectare, and include an 8-year grace period to account for the time lag between the investment and the first harvest. In addition to this financial incentive, the program proposes three different models in order to match local conditions and expectations. Indeed, beyond the classical model, where communities or cooperatives implement the scheme at their own cost (*pola mandiri*), the "partnership model" (*pola kemitraan*) involves a joint venture agreement with plantation companies. Further, the "developer model" (*pola developer*) allows companies to lead the application process and the establishment of plantations before these are distributed in part to participating communities.

In terms of overall support, the application procedure for HTR has been simplified compared to the standard procedure for large-scale industrial tree plantations HTI. The MoEF's technical agencies at the provincial level are responsible for the assessment of the applications. Permits are then issued by the head of the district on behalf of the MoEF. The MoEF also commits to providing technical assistance during the first 3 years of planting for each license holder, and helping in the marketing of the production, which might translate into the development of local processing capacities, such as small-scale power plants, but this remains to be clarified.

Despite this range of incentives and support, the implementation of HTR has fallen short of expectations. According to unpublished data, by September 2016 the MoEF had allocated 760,000 ha to HTR, of which 199,000 ha are covered by 7,700 HTR permits. No data on the actual planting and production of timber in HTR is available.

4.3 Power plants and feed-in-tariff policy

The main policy that was issued in order to support investments in new power plants was the feed-in-tariff (FiT) regulation. This regulation provides different sale prices for electricity depending on the type of renewable material and the regions of production. The table below summarizes the regulatory sale prices and regional adjustment factors for biomass and biogas based on the latest regulation (i.e. MoEMR Regulation No.21/2016).

The current FiT rate is higher than the one issued in 2014, and is set with US dollars as the reference currency, which reduces foreign exchange volatility risk. However, PLN is reluctant to purchase at the regulated price, as it is much higher than its sale price or its production cost. It is possible for PLN to follow the regulation if the government provides a subsidy to close the gap (more explanation

Table 3. Regulatory sale prices for electricity and regional adjustment factors according to feed-in-tariff regulation

	Capacity up to 20 MW		**20 MW < capacity 20 MW ≤ 50 MW**	**Capacity > 50 MW**
	Low voltage	**Medium and low voltage**	**High voltage**	**High voltage**
Reference price for Biomass-based (USD cent / kWh)	16.00	13.50	11.48	10.80
Reference price for Biogas-based (USD cent / kWh)	13.14	10.64	9.05	8.51
	Regional adjustment factor (reference price is multiplied by the regional adjustment factor)			
Java	1			
Sumatra	1.15			
Sulawesi	1.25			
Kalimantan	1.3			
Bali, Bangka Belitung, Lombok	1.5			
Riau archipelago, Nusa Tenggara, other islands	1.6			
Maluku and Papua	1.7			

Source: Permen ESDM No.21/2016

on this matter is given in section 6.3). Recently, there have been discussions between the Ministry of Energy and parliament on allocating budget to subsidize renewable energy production. Despite its acknowledgment on the importance of renewable energy development, parliament hesitates to provide support in the form of “subsidy”. The budget office has rejected the government proposal to subsidize NRE.

Another scheme is under discussion with the “Dana Ketahanan Energi” (energy security fund). The idea was raised in mid-2015 but the regulation had not been drafted by the end of 2016. Originally, the idea was that the fund would be financed by incorporating it into the consumer prices of gasoline or solar diesel (Istoto 2016). The fund would be collected and managed by a public service agency under the MoEMR or the Ministry of Finance. However, there has been opposition to the idea of collecting funds from consumers. By mid-2016, the GoI had decided to allocate a budget for the energy fund in the revised state budget of 2016. It is currently managed by the Ministry of Finance as part of the state budget management (Republic of Indonesia 2016, 2017). Its potential uses are to support the development of renewable energies especially in remote areas with low rates of electrification. This support could lead to the establishment of a new intermediary institution between independent power plants based on biomass and PLN in order to ensure that electricity can be sold to PLN according to the FiT regulation. Indeed, this would prevent PLN losing money whenever the alternatives to bioenergy are available and cheaper.

4.4 Others

Here we outline some other policies that may have an impact on the development of wood-based electricity. First, ongoing Indonesian forest sector reform has to be taken into consideration, especially as the development of Forest Management Units (FMU) as permanent local forest management entities has become a national priority, stipulated in the National Medium-Term Development Plan (RPJMN) and the Strategic Plan of the MoEF (RENSTRA). FMUs are expected to improve local forest governance and management in cooperation with local stakeholders from government, communities and the private sector. By the end of 2014, 120 FMUs had been legally established across Indonesia, however, only 20 FMUs had reached were operating. The Indonesian government aims to establish 100 FMUs per year until 2019 to reach the final number of 600 FMUs covering the entire 120 million hectares of state forest of Indonesia.

The role of FMUs could be critical for the development of bioenergy because they could address some major problems encountered by plantation managers and investors. This could prove essential in the case of bioenergy through the removal of a number of barriers. Land tenure as a major inhibitor of plantation development should be addressed, e.g. by providing clean and clear licenses and accelerating the licensing process. FMUs are clearly in a perfect position to translate the vision of the government on wood-based energy on the ground, but their effectiveness will only just start to be visible when they become operational.

The central government is also promoting bioenergy with the so-called “Bioenergi Lestari” program, based on collaborations with selected regional governments and with a focus on wood-based power generation. The rationale is to have concrete and pragmatic activities on the ground involving regional authorities and universities in order to pave the way for larger-scale investments and implementation. So far, little evidence exists to demonstrate its achievements. Central Kalimantan is an example where two districts are involved, Pulang Pisau and Katingan, through a number of MoUs signed with the MoEMR in 2015.

These MoUs provide the basis for the establishment of special teams, the elaboration of a program of work, socialization activities at field level, fundraising efforts, feasibility studies, experimental plots and other tasks. The areas earmarked for energy plantations are respectively 12,000 ha and 43,505 ha, but they had not been realized by mid-2016 (Pemerintah Kabupaten Pulang Pisau 2016). Also of interest is the importance of social forestry, very much in line with the MoEF priorities, as 6514 ha and 11,710 ha respectively, were to be planted through social forestry schemes and made available to energy supply chains (*Hutan desa* or *Hutan rakyat*) (Bioenergi Lestari workshop in Palangkaraya, 2 June 2016). Last, local universities are involved in plot experiments and the results might be useful once investors participate.

Another public means to promote wood-based electricity production is through efforts and investments by the state-owned company, Inhutani III. This company has several HTI concessions and has earmarked 4500 ha for energy plantations based on a short rotation coppice system. A MoU was signed mid-2016 for a feasibility study involving Inhutani III, PLN (as off-taker) and Pertamina (as power plant developer) before moving forward with the project. Its materialization would serve as proof of concept for other investors to follow.

5 State of development: Tree plantations and (integrated?) power plants

5.1 Supply side: An embryonic revival of tree plantations

The development of wood-based electricity production in Indonesia is currently gaining pace. A total of 32 HTI concessionaires have either already revised (with approval from the MoEF) their management plans to include energy production, or are in the process of submitting revised management plans (see Figure 3). Overall, about 1.1 million hectares of concession land is currently designated for plantations for energy use.

5.2 Processing side: (Integrated?) Power plants

However, business development on these concessions is still at a very early stage and – while there are a number of independent power plants (IPPs) drawing on agricultural residues and municipal waste as feedstock – no integrated wood-based electricity production project is running yet. Only forest-based industries have so far developed operational power plants running on their own residues from forestry operations; for instance, the case of PT Korintiga Hutani in Central Kalimantan that sells excess power to the grid.

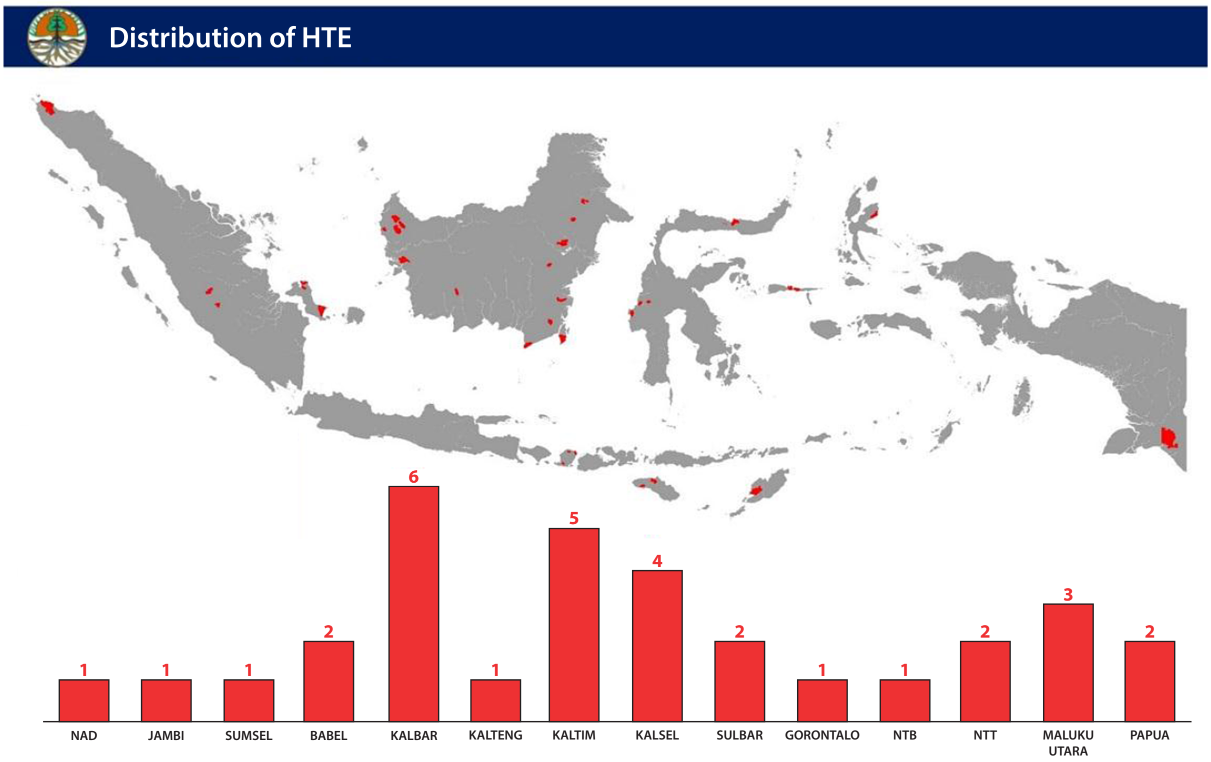

Figure 3. Distribution of HTE
Source: Communicated by the MoEF

It was not possible to obtain clear and reliable lists of projects from the MoEMR. The information provided in a systematic way does not distinguish per type of biomass. The files list 14 accepted power plant projects with a biomass component and capacity between 1 and 20 MW per project and a total of 120 MW. Another 11 projects are currently being evaluated or revised. They are either IPPs or integrated with other industries and sell excess power. Our informant from the ministry confirmed four projects fully dedicated to supplies from tree plantations with *Calliandra calothyrsus*, *Acacia mangium* or *Eucalyptus*-based supplies, yet without disclosing the respective capacities.

Despite small-scale biomass gasifiers being available and well suited to small-scale, off-grid operation, the prospects for this model remain uncertain. Practical experience from countries such as India and Sri Lanka shows that the operation and maintenance of small-scale gasifiers is challenging and that the model has difficulties competing with other sources of energy such as locally operated diesel generators, solar panels and mini-hydropower, as both its investment and operational cost are generally higher than those of competing small-scale technologies.

6 Case studies

For the present analysis, three case studies were chosen that reflect – to a certain degree – the different possible business models, socioeconomic and natural environments, and regional disparities among the projects that are being developed.

All three projects are currently at an early stage of development, however, of the few biomass electricity currently being developed, they are among the most advanced:

- Kundur Island, Riau Islands (Kepulauan Riau): Outgrower schemes are being promoted for *Calliandra* tree plantations to supply the 1 MW gasification plant on an island with proper electrification, but heavy reliance on expensive fossil fuel imports. The revised FiT tariff might be a game changer for a power plant that diversified its sources of supply with wood, coconut shells and palm kernel shells.
- Sumba, NTT (Nusa Tenggara Timur): High electricity needs with plans to develop fisheries and tourism, commitment by the government to provide full supply through renewable energy with (among others) construction of a biomass power plant as part of the fiscal transfer program and emerging HTI investments. High FiT might help, but is constrained by local climatic conditions.
- GIZ MORRE, East Kalimantan: Degraded mining sites are being rehabilitated.

The case studies were prepared from a long questionnaire completed by company representatives and followed-up by a field visit for verification and additional data collection.

6.1 Kundur Island: Reliance on outgrowers with back up access to other biomass sources

The company PT Prima Gazifikasi Indonesia is part of the larger group PT Energi Baru, with operations in various kinds of energy both conventional and renewable, as well as oil palm assets. Its objective is to develop bioenergy in the Province of Kepulauan Riau with ongoing activities in Kundur Island and plans to expand on the nearby Moro Island.

The company was involved in the take-over of a failed coal gasification project on Kundur Island that never produced, but was intended to supply the PLN power plant located next door. Indeed, PLN has two diesel power plants that were established on the island in the 1990s. This made development attractive, with lots of migrants and a rising population of about 50,000 people. PLN has tried to diversify for some time with coal and solar, because the costs of diesel is very high in this area, but without success (plant stability and pollution being among the main contributors to its failure). The government sought investors to revive these projects, which included a coal gasifier (2.5 MW) and use of standing assets (the electricity generation part of the system) with biomass supplies and a new gasification system (fluidized-bed gasifier technology). PT Prima Gazifikasi reached a power supply agreement with PLN in this context.

The situation on the island is as follows: The electricity consumption is in the range of 2–7 MW, depending on the time of the day, with peaks around 18:00–21:00, and biomass power plants could provide the baseload. Production capacity with two diesel power plants is 7 MW. PT Prima Gazifikasi started to build the new gasification system with 1 MW capacity in 2012, but complications arose over the type of contract that would be used with PLN. The previous one between PLN and the company running the coal gasifier was of the "pass-through" type, i.e. PLN would take care of the fuel supplies and buy the electricity. However, with biomass instead of coal, it appeared that PLN would not agree to the same approach, so PT Prima Gazifikasi has to buy the feedstock. This makes the company an

IPP with high costs of electricity production that the first FiT regulation in 2013 would not be able to cover adequately.

The new FiT regulation issued in 2016 provided for the special case of the islands (taking into account the much higher costs in terms of equipment and maintenance) that succeeded in making the project economically feasible. Production began using palm kernel shells. However, the price of kernel shells increased significantly with competition from export markets, so production was stopped until new sources of biomass could make up for this loss. As it stood at the time of our visit in September 2016, production is erratic and supplies are made of a mix of rubber trees, palm kernels shells and coconut shells. This seems to be a transition period and the company aims to invest in (or secure) *Calliandra* plantations in order to make the supply sustainable. An alternative is coconut shells that are produced in sufficient quantities on the island (about 100 tons/day with current 1 MW production requiring 30 t/day) but the price of approximately IDR 750,000/ton is too high, even taking into account their high calorific content.

It should be noted that (i) electricity production from biomass is available at a cheaper price to PLN than from diesel on Kundur Island, and (ii) the project is constantly evolving and adapts to the changing context in terms of electricity tariffs, but also availability and cost of supplies. The priority is to develop sufficient *Calliandra* plantation estates to exclusively supply the biomass to run the plant, with short rotation coppice every 6 months after the first year and processing into chips at the power plant site (full production requires 40 ton/day owing to low moisture content below 20%). To do this, the initial plan was to buy 26 ha of land for the establishment of an experimental plot that would provide a proof of concept to the neighboring populations with resulting uptake (benefiting from seedlings from the company).

The director is confident that *Calliandra* is a very productive, and easy to maintain at low cost, tree species that also provides nectar for honey and food for livestock. So far this plan has not been realized, even if contacts are maintained with five village heads who might be willing to move forward with it. Targeted lands are planted with rubber, which has dramatically dropped in price, so that landowners are open to the idea of replacing the trees with *Calliandra* (but this could change if rubber prices go up again). This would also have the advantage of providing early revenues with purchases of rubber wood to feed the power plant.

So far, these plans have not materialized, but at the time of our visit, negotiations were underway with the owner of 60 ha of rubber and gambir plantations to invest into *Calliandra* plantations. These 60 ha, located 40 km away from the plant, would represent about 10% of the total fuel needs for the 1 MW power plant and maybe decisive in convincing other land owners to join the project. If a virtuous cycle of enrollment and investments unfolds, the company is ready to invest in another 2 MW at the same site.

One purportedly decisive argument for the company to enroll farmers is the production and distribution of biochar as a side product of electricity generation. Biochar captures about half of the carbon content of the feedstock and can be used as a soil conditioner. This is deemed especially strategic and important in this context because the quality of the soils is poor and biochar has been tested and proven, in this context and others, to restore the quality and productivity of the soils. Therefore, the company would provide free biochar to farmers in exchange for investments in *Calliandra* plantations and priority sales to the power plant. Note, that with a power plant of 5 MW or more, the production of biochar would exceed the threshold required to make it a commercially attractive commodity outside of the island.

The company pays IDR 250,000/ton for fuelwood by-products, e.g. resulting from land-clearing operations, but would pay up to IDR 400,000/m^3 for *Calliandra* wood from plantations with a high calorific value. For land purchases to develop these plantations, the value is very low and land can be bought for around IDR 20 million/hectare.

The company is aware of the existing legal framework and actively participates in discussions about new incentive schemes. For instance, it was involved in lobbying for the latest and the previous FiT regulations, and made its decisions in direct relation with these outcomes.

The company is also actively prospecting for another power plant and *Calliandra* plantations on Moro Island based on a similar concept. A capacity of 2 MW is sought as well as partnerships with outgrowers and experimental plots. In additions, there are ongoing plans in Central Kalimantan based on large-scale tree plantations under a different model. Finally, PLN has plans to connect Kundur Island with Ungar Island, which would expand the market for more biomass investments.

6.2 The NTT Sumba project: Can public investment in power plants be the way forward?

The Sumba Iconic Island program was launched in 2010, backed by the Energy Ministry and PLN, and supported by major donors such as the Asian Development Bank and Norway. The island of Sumba is aiming to supply 100% of its electricity consumption from renewable sources by 2025. The study district of Sumba Barat is currently satisfying between 70 and 80% of its energy consumption from fossil energy sources while 98% of households on Sumba Island use open fire stoves for cooking and rely on collecting firewood from natural areas or small-scale plantations (HIVOS 2013).

In order to contribute to the ambitious goal of 100% renewable energy supply by 2025 for the entire island, the government of the Sumba Barat district signed an agreement with the state-owned PT Len Industri (Persero) to build up solar power infrastructure in the district. According to BAPPEDA, the district development planning agency, an additional 10 MW in solar power capacity could be installed. This would include road lights powered by solar cells (as already installed in district capital, Waikabubak), small decentralized solar units within the 25 villages and 18 traditional villages of the district (4–5 per village, 500 already installed at household level) as well as small on-grid solar plants.

To attract industry and supply Waikabubak with renewable energy, a biomass gasification plant with a power capacity of 1 MW (investment costs of approximately IDR 30 billion = USD 2–2.5 million) was built by the Indonesian government and handed over to the district government as part of the Indonesian fiscal transfer program. A 20-year power purchase agreement has been signed with PLN, which built an estimated 2–3 km of transmission to connect the power plant to the existing Waikabubak grid. For BAPPEDA, the 1 MW biomass power plant is a crucial step toward energy security and the 100% electrification target. The great capacity of the power plant (relatively to total energy consumption of the district) and its ability to produce electricity regardless of weather and time of the day (given feedstock security) make the biomass power plant an important asset in the district's energy infrastructure.

The ownership of the power plant lies with the local government of Sumba Barat, which will form a special purpose vehicle (SPV) with the company running an on-site HTI *Calliandra* plantation, PT. Usaha Tani Lestari and a company operating the power plant. The respective shares and the profit-sharing mechanism have yet to be determined, but HTI will fully supply the plant.

PT. Usaha Tani Lestari (UTL) holds a 4700 ha concession in the southwest of Waikabubak, on which the gasification plant was installed and where UTL is in the process of setting up a plantation to supply the required biomass. The plantation project is a good example of the complexity of the bureaucratic framework in which bioenergy projects operate in Indonesia. In total, the process of receiving the concession and license for the energy plantation (HTE) took approximately 7 years from prospecting until operation. While prospecting started in 2007, it was only in late 2015 that the first 20 ha were planted on the concession land. However, it was not only bureaucratic and extensive concession and licensing processes that delayed the uptake of operations for almost a decade, but several other factors that have prevented the full operation of the plantation to date.

When receiving the concession in Sumba Barat, PT. Usaha Tani Lestari expected more than 4000 ha to be usable for *Calliandra* and potentially teak plantations. However, it quickly became clear after setting up operations on the site, that there were land claims by local communities (most notably Bodoshula village) on large amounts of the concession area. Locals use the concession land for agricultural purposes (rice, vegetables, fruit), grazing their buffalo (herds are sizable) and for ceremonial purposes. In fact, an interview with the local village chief revealed that – while locals seem generally convinced by the potential benefits the nearby power plant – their biggest concern was that their sacred land on one of the hilltops on the concession should be excluded from utilization. The village chief was therefore hoping for a MoU between the informal and formal authorities and UTL to formalize these restrictions.

PT. Usaha Tani Lestari expects that about 2000 ha (instead of 4000 ha as originally planned) can be used for the plantation once agreement with the local communities is reached. A realistic approach would aim to expand the *Calliandra* plantation up to the point at which it can continuously supply the power plant (about 785 ha, according to PT. Usaha Tani Lestari's planning) and plant teak for roundwood production on the remaining land.

However, these issues have restricted development of the plantation so far and less than 100 ha of energy plantation had been planted at the time of the field visit. As the power plant is ready to operate, how to get the required 30 t of feedstock per day will be problematic during at least the first 2 years of operation. Plant operators might have to rely on feedstock sourced from local communities until the plantation can continuously feed the power plant. Local people plant *Calliandra* around their rice fields and go to the forests to collect firewood, which has led to concerns over forest degradation in Sumba.

Applying a short rotation coppice system, the first harvest is expected to take place a year after planting with 2–2.5 kg of biomass per plant. Further harvests will take place every 6 months for about 10 years before the second rotation begins. Assuming an average 30 t per day (10950 t p.a.) of biomass is needed in order to continuously supply the power plant, a production of 2–2.5 kg per tree per year and a population of 6600 trees/ha, around 2–3 ha would need to be harvested daily.

The company chose to rely on *Calliandra* for several reasons: First, *Calliandra* is suitable for cultivation on sharply sloping terrain as found on the concession. Second, the species is suitable for the dry conditions found on the concession in Sumba Barat. There are also claims that *Calliandra* can rehabilitate soil water-holding capacity. Third, *Calliandra* wood displays a relatively high heating value of 19 MJ/kg and a relatively low moisture content of 9–12%, which means that no drying process is required before the biomass enters the boiler.

If the co-benefits of *Calliandra* (see previous case study) materialize and could be accessed by local people, they would be an important way of integrating the latter into the operation of the plantation. PT. Usaha Tani Lestari plans to integrate surrounding local communities at various levels as seasonal labor in operating the plantation, as co-users of the concession land and possible co-benefits, as well as end-users of the electricity produced. However, there is no detailed scheme of how to integrate local communities more systematically and there are still many issues (e.g. preservation of sacred land, agricultural use by local people, etc.) to be resolved in order to secure long-term support of local communities for the operation.

The power plant, the nursery and the PT. Usaha Tani Lestari facilities are next to each other. However, the assessment of the concession land showed that there is no single, large plot of land on which *Calliandra* can be grown. There are several individual plots – varying in size (four plots of approximately 2 ha, 8 ha, 11 ha and 70 ha have been cleared and planted) and location – that are suitable for planting *Calliandra*. As the terrain in quite rugged with alternating areas of relatively dense secondary forest (most of which should or must be conserved), thicket and grassland, transportation is an issue, even though the absolute distance to the power plant is not large. Dirt roads have been cleared into the terrain and secondary forest in order to access the different plots of the plantation, however, these have steep inclinations, are very rugged and are already being heavily eroded. It is unlikely that small trucks will be able to pass along them to collect the harvest.

6.3 The MORRE ex-mining site rehabilitation project in East Kalimantan

Mine reclamation for rural renewable energy (MORRE) is an initiative developed by the East Kalimantan Province Government with technical support from GE-LAMA-I, a development cooperation project implemented by GIZ and ICRAF and funded by the German IKI-BMUB for the period of 2013–2017. It contributes to the implementation of the 2010–2020 local climate change mitigation action plan (RAD-GRK) and serves other local development objectives, such as rehabilitation of 200,000 ha of degraded land, reclamation of 40% of ex-mining lands, increasing the electrification ratio to 80% and raising the share of renewables in the energy mix to 3%. The initiative is backed by two local regulations (*Peraturan Daerah – Perda*) i.e. Perda 8/2013 about reclamation, whereby mine void[3] should not be more than 10% of the total disturbed land, and Perda 6/2016 about degraded land rehabilitation, which states that bioenergy crop development is one of the purposes of degraded land rehabilitation.

The MORRE project is part of domestic efforts to intensify mine reclamation. The province government (through the Mining and Energy Agency) has promoted the concept since 2015. Mining companies were asked to identify potential ex-mining land for bioenergy crop development and PT. Kaltim Prima Coal (KPC) has been responsive. This company delivers about 11% of total national coal production, making it one of the largest coal mine companies in Indonesia. It operates in East Kutai district and manages a mining area of 90,938 ha. According to its mine closure plan, there will be 25,140 ha of ex-mine land to be reclaimed by the end of the permit in 2021, of which 7082 ha had already been reclaimed by the end of 2015. Based on the local ecosystem characteristics, the company divides ex-mine land into five zones: protection, buffer zone, conservation, tourism and utilization. A few models have been developed for the utilization zone, such as integrated cattle and fish farms. In its letter to the Mining and Energy Agency dated 5 November 2015, the company mentions that the potential area for bioenergy crop is 2873 ha and they plan to develop a 100 ha demonstration plot in the utilization zone.

At the time of writing (November 2016), about 20 ha of the demonstration plot have been planted with two species, *Calliandra calothyrsus* and *Leucaena* sp., at 3 m by 3 m spacing. The species were chosen because they are commonly planted on ex-mine land as they can survive on relatively acid and the dry soils characteristic of ex-mine soils. They also produce high-nutrition green fodder, which can be used to support the integrated cattle farm project developed by KPC. In addition, the plants produce high calorific wood – more than 4600 kcal/kg – for fuel.

While KPC is self-sufficient in power from internal coal and diesel power plants, there is a power shortage in towns surrounding KPC areas. Most of the power supply for non-mining activities comes from diesel generators, managed by PLN. Diesel generators are also used to supply villages[4]. KPC areas are spread across three township areas, namely greater Sengatta (covering North and South Sengatta sub-districts), Bengalon and Rantau Pulung sub-districts. The total power demand from households in the three areas, not include demand from government offices and other economic activities, is estimated to be 7 MW higher than the total capacity of PLN's diesel power plants in the areas (see Table 4).

3 An area of excavation that remains after all rehabilitation of a mine is complete.

4 District government provided villages with diesel generator engines, while the village government manages the operation of the off-grid power generation and distribution service to households. This arrangement is unreliable, as it depends on the capacity of the local community organization to sustain the service. Moreover, the off-grid power service cannot access electricity subsidies for poor households, creating financial risk to the off-grid facility if they are forced to supply electricity all households, including the poor who cannot pay for it.

Table 4. Power supply and demand in townships surrounding KPC area

Township surrounding KPC areas	Demand/supply (MW)		Surplus/shortage
	Demand from households*	Supply from PLN**	
Greater Sengatta	18	15	-3
Bengalon	5	1.5	-3
Rantau Pulung	1	0	-3
Total	**24**	**17**	**-7**

Note:

*Author's calculation with assumption each household consume 3.6 MWh per annum on average. Supply to government offices and services, as well as home industries, is not included.

**As of 2013; data from PLN local office

Table 5. Key assumptions in MORRE financial model

Key assumptions		
Biomass gasification power plant gross capacity	1,200	kW
Dry wood to electricity conversion	1.2	kg/kWh
Dry wood needed	18,228	ton/year
Dry-to-wet ratio for wood	50	%
Wet wood yield	15	ton/ha/year
Dry leaves yield	2	ton/ha/year
Dry leave price	150,000	Rp/ton
Land needed	1216	ha
Basic FiT	0.135	USD/kWh
Incentive (koefisien area)	1.3	
Exchange rate	13,079	Rp/USD
Expected return on equity	8	%
Loan interest rate	10.9	%
Loan cost (provision, adm., legal, etc.)	1.5	%
Inflation rate	6	%
Corporate income tax	25	%
Total investment cost	41,155	million Rp
• Equity (30%)	12,347	million Rp
• Debt (70%)	28,809	million Rp

According to the draft of business concept prepared by GE-LAMA-I, the idea is to set-up a SPV, which will act as an IPP to manage bioenergy crop plantations and power generation activities in integrated way. The SPV can be a local government-owned enterprise, cooperative or a private firman linked to the mining company.[5] In addition to the set of assumptions (see Table 5), it is also expected that coal mine company cover 80% of the development and maintenance costs of bioenergy crop plantation for the first 10 years.[6] The development and maintenance costs of power generation, in contrast, are assumed to be fully borne by the SPV. Based on those assumptions, the financial model shows that MORRE has the potential to be financially viable at the current FiT rate of USD 0.135 with 1.3 incentive factor per kWh (see Table 6).

5 For safety reasons, the link to the mining company is essential during the time where the mining company is still active.

6 This idea has not been discussed in detail with PT.KPC.

Table 6. Estimation of financial performance of MORRE concept

Production cost	2,229	IDR/kWh (average cost for a 20 years cycle)
NPV	7,959	Million IDR
Project IRR	14.7%	%
Net C/B ratio	1.3	
Payback period	6.4	Year

Table 7. Summary of PLN's financial performance

	2013	2014	2015
Average production cost (IDR/kWh)	1321	1420	1300
Average sell price (IDR/kWh)	818	939	1034
Earning before subsidy (IDR trillion)	-73.8	-71.9	-28.9
Subsidy (IDR trillion)	101.2	99.3	56.5
Earning before foreign exchange margin and tax (IDR trillion)	16.6	15.5	13.2
Net earnings (IDR trillion)	-8.4	14	15.6

Source: 2015 PLN's annual report

The situation of PLN has to be considered carefully because it has limited financial capacity to purchase electricity from IPPs at FiT rate. The company is expected to face losses due to the large gap between its retail prices (IDR 1034/kWh) or its average production cost (IDR 1300/kWh) and FiT rate (for biomass ranging from IDR1400 to 3500/kWh).[7] As seen in Table 7, PLN's financial performance depends heavily on government subsidy, which is ultimately beneficial to households and businesses as electricity users. In this situation, it is hard for PLN to purchase electricity at FiT rate, unless the government provides another subsidy to renewable energy producers. Considering limited government financial capacity (where total government expenditure is only around 16% of GDP), the only possible way to do this is to shift the electricity subsidy from users to renewable energy producers. The removal or reduction of subsidy to users will increase PLN's retail price, while at the same time narrowing the gap between the retail price and biomass-to-electricity production cost, which will lower the need for subsidies for renewable energy producers. Moreover, the removal or reduction of subsidy to electricity users will create an incentive for households and business to use electricity efficiently.

Another policy needed to support full implementation of MORRE is the allocation of ex-mining land to bioenergy crop development, with better guidance on reclamation activities to provide a legal basis for wood harvest on reclamation land. Legal certainty is also needed for at least a 20-year power purchase agreement cycle, which means that it is crucial for the SPV to ensure its control over the land even after the end of the mining permit validity.

7 According to MoEMR Regulation 21/2016, the lowest and the highest rate for biomass is USD 0.108 and USD 0.272 (USD 0.016 with 1.7 incentive factor), respectively.

7 Conclusion

As Indonesia aims to achieve ambitious targets for renewables of 23% of total energy consumption by 2025, bioenergy is an important area, due to the country's large resources of biomass. Although the development of biofuels is engaged with the biodiesel mandate that requires liquid fuels to contain at least 20% of biofuels and the great potential provided by the vast oil palm plantation estates, we focused on power generation based on wood supplies.

The government has tried to revive industrial tree plantations (HTI) with plantations dedicated fully or in part to energy. It has put in place a FiT policy that rewards power plants running on wood material with higher prices when electricity is sold to the state-owned company, PLN. Existing efforts to promote wood-based electricity production are justified by the need to diversify sources of energy in a country that has become one of the greatest importers of fossil fuels in the world, and by the availability of degraded land in remote areas where villages still depend on very costly power plants running on fossil fuels transported over long distances.

Technologies exist and are available in Indonesia with gasification as the primary choice. This technology underlines the usefulness of having a constant and homogeneous source of biomass, which makes tree plantations an attractive option, as they are relatively unaffected by weather fluctuations, can produce throughout the year and produce good quality gas due to the homogeneity of the material produced. A limitation is the relative difficulty of managing these plants at small scale in remote areas, where villagers may not be able to operate and maintain them over the years.

Our case studies show the diversity of situations and the challenge of generalizing lessons and needs. They are located on three different islands and on three different kinds of plantation base: industrial concessions, outgrower schemes and rehabilitation of ex-mining land. Power plants also differ, with either private or public investments and support. However, they share one characteristic: all struggle to make the case for wood-based electricity. This shows that the road will be long for this sector to develop at scale, however appealing it might be and whatever policies are put in place.

Indeed, our research leads to one straightforward message that this source of energy is not going to represent a significant share of the energy mix for a long time. Despite all the arguments in favor of its expansion, major obstacles hinder development. These include the difficulty in establishing and managing large-scale tree plantations dedicated to energy production with recurrent claims and conflicts on the ground, the relative lack of financial attractiveness of the FiT that is insufficient to compensate investors for the risks of shifting to this relatively new type of energy, the absence of subsidies provided to the state-owned electricity company that sees little interest and may face losses in buying power at higher prices when based on biomass, and the lack of proof of concept so far in the absence of which it is difficult to expect a wave of investments in the sector.

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Annex

Annex 1. List of people interviewed

Name	Institution, position
Didik Suharjito	IPB
Eric Natanael	Speromora (biomass energy)
William Sabandar	Ministry of Energy and Mineral Resources (MoEMR), Tim of Acceleration of New and Renewable Energy Development
Tisnaldi	Director, New and Renewable Energy and Energy Conservation (EBTKE), MoEMR
Agus Saptono	Head Bioenergy Program Division, EBTKE, MoEMR
Agus Pranata Kusuma	Consultant, advisor, Chairman TIGFII
Basah Hernomo	Director, Directorate of Forestry and Water Conservation, Ministry of National Development Planning (Bappenas)
Nur Hygiawati Rahayu	Directorate of Forestry and Water Conservation, Bappenas
Bambang Widyantoro	Director, Inhutani III
Syah Darwin Siregar	Head, New and Renewable Energy Division, National Electricity Company (PLN)
Andrew Cahyo Adi	New and Renewable Energy Division, National Electricity Company (PLN)
Bambang Tri Hartono	Forestry Research, Development and Innovation Agency (FORDIA)
Paulus Tjakrawan	Association of Biodiesel Producer in Indonesia (APROBI)
Nanang Roffandi Ahmad	Indonesian Forest-Based Energy Society (MAPHEBI)
Seyong Jung	General Manager, Korintiga Hutani
Namhong Kim	Manager, Korintiga Hutani
Yasuhiro Maruyama	Director, Korintiga Hutani
Verania Andria	Programme Manager, Sustainable Development and Climate Change, United Nations Development Programme (UNDP)
Purwadi Soeprihanto	Executive Director, Association of Indonesian Timber Concession Holder (APHI)
Denny Sapulete	Directorate of Timber Plantation, Ministry of Environment and Forestry (MOEF)
Prof. Gustan Pari	FORDIA
Indra Sari Wardhani	Bioenergy Program, WWF Indonesia
Chrisandini	Bioenergy Program, WWF Indonesia
Andi Novianto	Asisten Deputi of Energy Productivity, Coordinating Ministry of Economic Affairs
Baderun Zainal	Sadhana (timber plantation company in Lombok)
Harly Bernady Wahyo	Dharma Hutani Makmur (timber plantation company in East Kalimantan)

Name	Institution, position
Jhon Pieter Rajagukguk	Sumber Graha Sejahtera (timber plantation company)
Ignatius Bambang Pepe	Nityasa Idola (timber plantation company)
Andy Budiman	PT SMI (timber plantation company)
Andianto Hidayat	Chief of renewable energy, Pertamina
Karel Sampe Pajung	Director, Indonesian Bioenergy Power Producers Association (APLIBI)
Sudjono Kosasih (Steve)	APLIBI / Energi Baru
Hanjaya Ekaputra	APLIBI
Koesnoto Partomihardjo	PT Hutan Mahligai, timber plantations in East Kalimantan
Djoko Josef	Sampoerna (integrated bamboo plantation power plant)
Symasu Rizal Arbi	Director PT. Biomass Andalan Energi
Rapolo Hutabarat	Manager, Musim Mas
Erwina Darmajanti	GIZ, EnDev, Advisor
Vegaswarasti Kumala	GIZ, LCORE-INDO, Advisor
Hendrik Segah	GGGI Central Kalimantan
Siti Maimunah	University Palangkaraya
Yuliana Wulan	LAMA-MORRE
Florian Vernaz	GGGI POME Kaltim
Hanjaya Ekaputra	Energi Baru, Project manager
Popi Komalasari	Manager, Forest governance, APHI
Japar Sidik	Forest Resource Management, Perhutani

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To achieve the target of 23% renewable energy by 2020, Indonesia has been actively exploring options to loosen its dependence on fossil fuels. While biofuels have been developing fast and remain a priority for the government, wood-based energy also holds great potential. This report is a first attempt to assess its state of development and feasibility.

Wood-based energy could be based on the high-profile large-scale industrial tree plantation program in Indonesia. This is one of the largest in the world with millions of hectares planted, but it has failed to achieve all of its public objectives. The government envisions its revival, with bioenergy as an alternative to the mature pulp and paper market. To do so, a flagship feed-in tariff policy has been put in place as an incentive for power plants to using biomass (or biogas material).

Our research – based on intensive interactions with stakeholders at all levels, secondary data and three case studies – leads to one straightforward message that this source of energy is not going to represent a significant share of the energy mix for a long time. Major obstacles include the difficulty in establishing and managing large-scale tree plantations dedicated to energy production with recurrent claims and conflicts on the ground, the inability of the feed-in tariff policy to compensate investors for the risks of shifting to a new type of energy, the absence of subsidies provided to the state-owned electricity company that sees little interest in buying relatively expensive power, and the lack of proof of concept that lowers the probability of significant investments in this field.

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